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Mechanical Option
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DEA Clandestine Laboratory Training Center
Quantico Marine Corps Base, Quantico, VA

Mechanical Technical Report 3

Mechanical Systems Existing Conditions Evaluation

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Executive Summary:

The DEA Clandestine Laboratory Training Center is located on the Quantico Marine Corps Base in Quantico, VA. It is a one-story building with a Mechanical Mezzanine Level that encompasses approximately 34,000 sq ft. The building spaces include multiple function types such as laboratories, classrooms, office space, and physical training areas.

The purpose of this report is to summarize and evaluate the existing mechanical system design of the DEA Clandestine Laboratory Training Center. First, the preliminary design objectives and requirements will be stated. These include ambient weather data, indoor design conditions, internal load generation assumptions, and several other factors. The sections that follow this will examine data which has been gathered from past Technical Reports using various calculation methods. This data will then be compared to the actual design values, and possible reasons for discrepancies will be discussed. Next, all major HVAC systems and their corresponding controls will be outlined and critiqued to determine the appropriateness and compatibility of their design with other systems and with the building as a whole.

Design Objectives and Requirements:

The following sections present the various criteria used in the design of the building's mechanical system. This data includes both assumptions of outdoor design conditions and intended interior space conditions. Estimates of interior thermal loads to be handled by the mechanical system and several other factors are also outlined here. The systems are then developed under these fundamental constraints.

Ambient Weather Criteria:

Outdoor design conditions used were those specified in ASHRAE Fundamentals 2005 as 0.4% occurrence in Richmond, VA.

Ambient Winter Conditions:

T_{DB}	%RH	V_{WIND}*
16°F	50	6 mph

*340° prevailing direction

Ambient Summer Conditions:

T_{DB}	T_{WB}*	V_{WIND}**
94°F	77°F	5 mph

*Mean coincident wet-bulb with design dry-bulb
**230° prevailing direction

Interior Space Temperature and Humidity Criteria:

Office and Support Area Conditions:

max T_{DB}*	min T_{DB}*	max %RH	min %RH	max T_{DB}**	min T_{DB}**
75°F	72°F	50	30	85	60

*Occupied condition **Unoccupied condition

Laboratory Areas:

max T_{DB}*	min T_{DB}*	max %RH	min %RH	max T_{DB}**	min T_{DB}**
72°F	70°F	50	30	75	72

*Occupied condition **Unoccupied condition

Thermostatic Zone Criteria:

This section outlines criteria that were used in the designation of thermostatic zones. Each of the following spaces was designated its own thermostatic zone: Break Room, Lobbies, Laundry Room, Physical Training, Chemical Clothing Try-on, Equipment Try-on, Lab Equipment Storage, Firearms Training System (F.A.T.S.) facility, and the Smokehouse. No more than one of the following types of spaces was allocated to a single thermostatic zone: Laboratories, Mock Lab, Raid Facility, Classrooms, and Conference Rooms. Open Interior Offices were limited to 3,000 ft^2 per zone, and Open Exterior Offices were limited to 1,500 ft^2 per zone of similar exposure. No more than four Closed Offices were permitted in a single zone.

Ventilation Criteria:

The design of the mechanical system was intended to meet the requirements of ASHRAE Standard 62. For an evaluation of the building's compliance with this standard, please see the Mechanical Technical Report 1. Listed below are the objective air change rates used in the design.

Minimum Air Changes Per Hour

Offices	Labs
2	6

The design and location of air intakes and discharges were required to be compliant with the Anti-Terrorism Force Protection (AT/FP) standards as mandated by Naval Facilities Engineering Command (NAVFAC).

Internal Thermal Load Criteria:

This section outlines estimates of internal loads used in the calculation of peak demand loads and in energy analyses. In offices and support spaces, equipment loads were assumed to be 2 W/ft^2, while the lighting load was calculated from the actual fixtures present. To account for diversity, the population density for office areas was estimated at 140 ft^2 per person. In the laboratory areas, equipment loads were estimated at 6 W/ft^2, and the lighting load was assumed to be roughly 3 W/ft^2. The population of the lab areas was set at 49 people.

Pressurization Criteria:

All spaces were designed to be positively pressured relative to the outside environment with the exception of lab areas. In order to ensure that no harmful substances present in the lab leak into adjacent spaces, the labs were designed for negative relative pressure. This was achieved by way of large exhaust fume hoods, as evident in the *Laboratory Airflow Table* in the appendices.

Filtration Criteria:

Supply air to offices and support areas is to pass through 30% ASHRAE efficient pre-filters and 85% ASHRAE final filters. Supply to mechanical and electrical rooms is to be through 30% ASHRAE efficient filters.

Building Operating Schedule:

Office spaces are intended to operate 12 hours per day for 5 days each week. Laboratory spaces are intended to operate 24 hours per day 7 days a week.

Acoustical Criteria:

The mechanical system has been designed to meet the following Noise Criteria levels, excluding occupant-generated noise and noise generated by equipment within the spaces in question:

Space	NC Rating
Enclosed Offices	35
Open Office Area	40
Conference Room	35
Classrooms	35
Laboratories	55
Support Spaces	55

Reliability of Systems:

One of the major intentions of the mechanical system design was to ensure reliability. In the event of a component failure or other type of emergency situation, the remaining components were designed to be capable of maintaining a certain capacity. These capacities are outlined below.

Reliability Requirements:*

Component	min % Capacity
Boiler	50
Heating HTW Pump	50
Chiller	75
CHW Pump	50
Lab Exhaust Fan	66

*In the event of a component failure, the remaining components must be capable of providing the % of design capacity listed here.

Fuel Requirements:

Both boilers and domestic water heaters were chosen with the objective of having dual-fuel capabilities. The boilers selected can be run on natural gas or #2 fuel oil. The design intent was to supply fuel via an existing storage tank located on the DEA Training Academy campus. The Clandestine Laboratory Training Center's generator was also intended to be fired by #2 fuel oil.

Miscellaneous Mechanical Criteria:

- The average face velocity of each fume hood shall be limited to 100 ft/min and the sash opening shall be 24 inches in height.
- The following mechanical equipment shall be connected to emergency/standby power:
  All direct digital controls (DDC) and control panels, lab AHU's, lab exhaust fans, boilers, heating hot water pumps, and fuel pumps.
- Design of the mechanical systems shall not make accommodations for future expansion.

Energy Sources and Utility Rates:

The major sources of energy utilized by the Training Center are natural gas for heating; #2 fuel oil for back-up heating as well as for the emergency generator; and electricity for cooling, illumination, and to drive many internal activities and pieces of equipment. As discussed in Mechanical Technical Report 2, actual electricity rates as consumed by the building were not able to be determined because construction has not been completed. Therefore, electric rates were estimated to be similar to those of Virginia Electric and

Power Company, a utility company which serves Prince William County, VA, where the DEA campus is located. The assumed rates were selected by comparison with rates charged to buildings having power usage and demand similar to the projected power use of the Training Center. For the entire electricity rate structure, see the *Virginia Electric and Power Company* appendix.

The cost of natural gas was estimated from the rates paid by a neighboring building on the DEA Training Academy campus, and was set at $13.79 million per Btu. When the demand for natural gas exceeds what the supplier is capable of producing, the supplier can "cut off" the supply of natural gas. In this case, the boilers will be fired by fuel oil purchased in bulk through the Marine Corps. When in need of emergency power, the generator will also run off of fuel oil. For simplicity, the energy simulation in Mechanical Technical Report 2 assumed no emergency situations and an unlimited supply of natural gas from the supplier, so #2 fuel oil was not included in the economic analysis. However, by looking at a fuel oil purchase made by the neighboring Justice Training Center building from October 2004 through September 2005 (7,500 gal for $8,626.15) and assuming no inflation from that period, the cost of fuel oil can be calculated to be roughly $ 1.15 per gallon.

Design Calculation Values:

This section outlines the design values obtained from several different calculation methods utilized in the previous technical reports and compares these values with those used in the actual design. Possible reasons for inconsistencies are then discussed. Included in this section are outdoor air ventilation requirements, peak heating and cooling loads, and an estimation of annual energy use.

Design Ventilation Requirements:

In Mechanical Technical Report 1, the building's ventilation requirements were evaluated using ASHRAE Standard 62.1-2004. The building energy simulation program TRACE 700 calculated the needed outdoor air in Mechanical Technical Report 2. The results from these two methods are compared with the actual design outdoor air flows below.

Outdoor Air Requirements (cfm)

	Standard 62	TRACE 700	Actual Design
AHU-1	-34,840	8,133	2,280
AHU-2	1,204	5,959	8,040
AHU-3	4,322	1,113	1,310
AHU-4	827	863	880
AHU-5	434	300	340

In Technical Report 1, assumptions regarding the minimum primary supply airflow to spaces served by AHU-1 proved to be pivotal to its compliance with the standard. Also regarding AHU-1, differences in occupant diversity assumptions could very well be responsible for discrepancies between the actual design airflow and that obtained from TRACE 700.

When considering AHU-2, the result obtained in Technical Report 1 is significantly lower than the other methods. Although 1,204 cfm may be sufficient OA for such a space, no recirculation of return air was permitted in the actual design due to potentially hazardous materials contained in the air. Because of this, the actual design called for all of the supply air to be OA, making that number significantly greater than the value achieved by Standard 62.

The values obtained from the different analyses for AHU's 3, 4, and 5 are quite similar compared to the vast discrepancies of AHU's 1 and 2. This is most likely due to the relatively smaller size of the spaces served by these units and a more accurate idea of population density of those areas.

Design Heating and Cooling Loads:

According to design documents, the estimated building heating load was 1,577 MBH and the domestic water heating load was 900 MBH. From the TRACE 700 analysis performed in Mechanical Technical Report 2, a peak building heating load of 1,226.7 MBH was estimated. The peak cooling load in the design documents was listed as 151 tons, while the peak load calculated in Mechanical Technical Report 2 was equal to 161.0 tons. Both the peak heating and cooling loads in the design documents are greater than those calculated in the previous technical report. This may be due to a conservative estimation or the use of a safety factor. Other possible causes for the disagreement are varying population density and diversity assumptions, as well as slight differences in the estimation of internal load generation of equipment and lighting.

Annual Energy Use:

In Mechanical Technical Report 2, TRACE 700 was used to simulate total building energy use throughout a typical year. Electricity and natural gas use were both considered. According to the analysis, the total building energy use equals 5.42 million kBtu/yr. Of that total, 29.3% was used by the lighting system and roughly 21.7% was from pumps and fans. Cooling and heating make up 20.2% and 19.4%, respectively, while receptacles round out the field at 9.3%. There was no annual energy analysis performed in the design process, therefore, a comparison cannot be made to design document values in this area. For a more in-depth analysis of the annual energy and economic simulation, please see Mechanical Technical Report 2.

<u>Mechanical System Summary</u>:

Primary Heating System:

Two 1,500 MBH water tube boilers located in the Boiler Room supply 180°F hot water for space heating as well as for heating of domestic and laboratory hot water via a plate and frame heat exchanger. "Water tube" means that the water being heated flows through small tubes which are surrounded by the hot combustion gases in the boiler. Due to the relatively small amount of water in the tubes, this type of system can respond rapidly to changes in load and can decrease the amount of time needed for start-up.

The heating hot water is distributed via two parallel inline centrifugal pumps to the AHU's for primary heating; to unit heaters (UH), cabinet unit heaters (CUH), and finned-tube radiators (FTR) for auxiliary heating; and also to VAV terminal units for reheat. This piping arrangement is called "variable primary flow" because it uses pumps with variable frequency drive to directly adjust the amount of flow to the system. Variable primary flow is thus different than primary-secondary flow, which generally uses constant-flow pumps to circulate the water in a loop around the boilers, and then makes use of valves to control the distribution out to the secondary system. This distribution arrangement is illustrated in the *Heating Hot Water Schematic*.

The majority of the heating load is to be handled by the heating coils located in the air handling units. There is only one heating coil in AHU's 1, 2, and 3. These coils must be capable of heating the air from its design low incoming condition to its intended supply temperature. AHU's 4 and 5 both contain two heating coils, allowing the heating load to be divided between the coils. For entering and leaving air temperatures of the coils, please see the *Air Handling Unit Schedule*. AHU-2 handles the largest load of the heating coils because of the large amount of outdoor air that it must condition at low ambient temperature. Also note that the water side of the system is based on a 20°F drop in temperature across the loads, meaning that a relatively constant temperature of 160°F is returning to the boilers.

With the exception of AHU-5, all air handling units utilize an ultrasonic humidifier to increase the relative humidity that was "lost" across the heating coil. In these humidifiers, a metal diaphragm vibrates at a very high frequency causing condensation to occur.

Auxiliary Heating Systems:

As mentioned above, heating hot water is also piped to unit heaters serving various spaces such as stairs, entry vestibules, corridors, shower areas, and mechanical spaces. These unit heaters range in size up to 50.8 MBH, and all require a supply of around 3 gpm of hot water at design capacity. Like the AHU heating coils, they are also based on a 20°F drop in water temperature. For more information on these components see the *Unit Heater and Cabinet Unit Heater – Hot Water – Schedule*.

Serving exterior zones on the north side of the building are finned-tube radiators. These FTR's provide sensible heating to counteract what would otherwise be a low mean radiant temperature due to the large expanses of glass on that façade. At a total active length of about 73 ft, they offer another 45.5 MBH of auxiliary heating and require roughly 4.5 gpm of hot water.

Many VAV terminal units in the system contain reheat coils which also require hot water. These are typically used when the air at the cooling coil was cooled to a lower temperature than is desired for supply to a space. This is done in order to achieve an acceptable humidity level by condensing some of the moisture out of the air. The reheat coil then adds sensible heat to bring the air back up to its desired supply temperature. The largest reheat coils utilized in this system are capable of over 30 MBH of sensible heat and require about 3.3 gpm of hot water.

Primary Cooling System:

The Training Center uses a chilled water system to meet the vast majority of its cooling needs. Chilled water containing 30% propylene glycol is cooled via two 105.5 ton chillers. The propylene glycol additive acts as an antifreeze. Propylene glycol was most likely selected because, in the event that it came in contact with potable water, it is generally non-toxic in small concentrations.

The chillers contain air-cooled condensers, so they are located in the utility yard in order to reject heat to the outside. Both chillers contain six hermetic scroll compressors that are electrically driven and handle one step of compression each. The refrigerant specified is R407C, a hydrofluorocarbon mixture that has minimal negative effects on the environment. Chilled water leaves the evaporator at 45°F, and is sent via two centrifugal pumps in parallel to the cooling coils in the air handling units.

Like the heating hot water system, the chilled water system also makes use of a variable primary pumping configuration as illustrated in the *Chilled Water Schematic* in the appendices. This means that the pumps must be capable of VFD operation to control the distribution of chilled water to the coils. One challenge of this type of configuration is to keep the chilled water flow rate through the evaporator within the limits specified in the *Air-Cooled Scroll Chiller Schedule*. This is achieved via a modulating control valve in the bypass line (see *Chilled Water Schematic*) that maintains the correct flow through the evaporator despite the varying load conditions.

All five air handling units contain cooling coils that remove both latent and sensible heat from the supply air. As with the heating coils, the cooling load on AHU-2 coil is the greatest due to the large amount of outdoor air being conditioned from high ambient temperature and humidity levels. The water side of the system is based on a 10°F rise in temperature through the coils, meaning that a near constant temperature of 55°F returns to the chiller. From the *Air Handling Unit Schedule* you'll notice the leaving air temperature of the coils is generally a few degrees cooler than typically supplied in these types of systems. However, this value is the temperature leaving the coil and has not yet accounted for heat gain from the AHU draw-through supply fans. This, in combination with the reheat capability at VAV terminal units, explains for the apparent low leaving air temperature.

Auxiliary Cooling System:

The lone component type that provides cooling but does not does not use chilled water is the Air Conditioning Unit (ACU). This equipment supplies specially conditioned transfer air to electric rooms and LAN closets. Instead of using chilled water, the ACU's use the refrigerant itself, R407C, to extract heat from the space. This is known as the direct expansion (DX) technique. Like the chillers, the ACU's compressors are electrical and the condensers are air-cooled. Having an air-cooled condenser mandates that the refrigerant must be piped to remote condensing units to reject the heat to the outdoors. These remote units are the Air-Cooled Condensing Units (ACCU), and this type of configuration is called a "split system." For more detailed information on ACU's and ACCU's see the *Air-Conditioning Unit Schedule* and the *Air-Cooled Condensing Unit Schedule*.

Air Handling Units:

Five air handling units located in the Mechanical Mezzanine Level supply the building with conditioned air. AHU's 1 through 5 serve Classrooms, the Analytical Lab, Offices, Raid Facility, and Smokehouse, respectively. AHU-2 is a 100% OA unit serving the labs. Outdoor air is ducted to the AHU's from an intake louver in the mechanical room. AHU's 1 and 3 are capable of economizer mode, in which outdoor air meeting temperature and humidity requirements is supplied directly to the space. Return air is routed back to the AHU's through the plenum using transfer ducts and some longer duct runs where necessary. The Mechanical Room is both ventilated and pressurized by relief air from AHU's 1 and 3 which then is forced out of relief louvers that are ducted from the Mechanical Room.

Fans:

All AHU's utilize draw-through centrifugal supply fans. Supply fans in AHU's 1, 2, and 3 are capable of VFD operation, while AHU's 4 and 5 are constant volume. Integral to AHU's 1 and 3 are centrifugal return fans, both capable of VFD, recirculating air from offices and classroom areas. A ducted, constant volume, inline centrifugal return fan recirculates air for AHU-5 or exhausts it depending on the operating mode of the Smokehouse. AHU-4 relies on the supply fan to draw sufficient return air back for recirculation. See the *Air Handling Unit Schematics* for a better illustration of flow to and from the spaces.

Mixed flow, induced dilution exhaust fans in the lab (EF-1,2,3) purge the space of contaminant-ridden air through large fume hoods. EF-4 exhausts air from toilet rooms and janitor closets. The Boiler Room is supplied OA for both ventilation and combustion air via a constant volume inline centrifugal fan. See the *Fan Schedule* for more detailed information.

Mechanical System Controls:

The following sections will discuss sequences of operations and control logic for the major mechanical systems in the building. Only simplified versions of the basic operating modes will be discussed. For all possible modes of operation and in-depth control logic, see the Instrumentation and Controls design documents.

AHU's 1 and 3:

When the supply fan is started at the beginning of day, the return fan shall also begin operating. The DDC will gradually increase the drive frequency until both fans have reached their static pressure setpoints. After a morning warm-up period, the outside air damper will open and modulate with the return damper until the minimum amount of OA is reached as determined by a flow measuring station upstream from the OA damper. The relief damper will modulate independently of the other dampers to maintain the static pressure setpoints as measured in the return fan plenum. Both fans will run continuously throughout the day during the scheduled "occupant mode," and be turned off during the unoccupied period.

In order to maintain the correct leaving air temperature from the heating coil, a sensor located downstream from the coil will modulate a valve controlling hot water flow through the coil. When the fans are stopped, the valve will usually close completely. However, the valve will open to allow circulation of hot water to prevent freezing in some circumstances. The cooling coil valve will close when in heating mode.

Similar to heating mode, when the AHU is in cooling mode, a sensor located downstream from the cooling coil will modulate a valve to control flow through the coil, maintaining correct leaving air temperature. When the fans are stopped, the valve will usually close completely. The heating coil valve will close when in cooling mode.

Both AHU's will go into economizer mode under these conditions:

- OA temperature is below 70°F
- OA enthalpy is lower than the return air enthalpy
- Dewpoint temperature is above 39°F

In economizer mode, the return and OA dampers shall modulate to provide the correct mixture of OA and return air to maintain the temperature setpoint.

AHU-1 utilizes CO_2-based demand controlled ventilation to limit the amount of OA delivered to unoccupied spaces. When CO_2 levels rise 700 ppm above the measured ambient condition, the OA damper shall modulate open to increase ventilation to the spaces. In the case that ambient CO_2 levels are above those measured indoors, the economizer mode will not be permitted.

AHU-4:

As with AHU's 1 and 3, the supply fan for AHU-4 will run continuously during the occupied mode and will be turned off during unoccupied periods.

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Air Handling Unit Schedule

		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5
General:	Service	Classrooms	Lab	Offices	Raid	Smokehouse
	Total CFM	9,420	8,040	10,880	2,090	560
	min OA CFM	2,280	8,040	1,310	880	340
Supply Fan:	Type	22" Airfoil Cent.	20" Airfoil Cent.	22" Airfoil Cent.	12" Airfoil Cent.	Airfoil Centrifugal
	Ext. S.P. (in w.g.)	2.28	2.54	2.20	1.56	0.75
	Total S.P. (in w.g.)	5.80	6.30	5.60	4.30	3.12
	max BHP	13.1	12.0	14.2	2.5	1.1
	max RPM	1,711	2,006	1,725	2,611	3,499
	Volume Control	VFD	VFD	VFD	Constant	Constant
Motor:	HP	15	15	20	3	1
	max RPM	1,800	1,800	1,800	1,800	1,800
	Volts/Phase/Hz	460/3/60	460/3/61	460/3/62	460/3/63	460/3/64
Sound Attenuator:		SA-1S	-	SA-3S	-	-
Return Fan:	Type	20" Airfoil Cent.	-	22" Airfoil Cent.	-	-
	max CFM	8,270	-	10,880	-	-
	Ext. S.P. (in w.g.)	1.0	-	1.0	-	-
	Total S.P. (in w.g.)	1.1	-	1.1	-	-
	max BHP	3.4	-	4.6	-	-
	max RPM	1,255	-	1,150	-	-
	Volume Control	VFD	-	VFD	-	-
Motor:	HP	5	-	7.5	-	-
	max RPM	1,800	-	1,800	-	-
	Volts/Phase/Hz	460/3/60	-	460/3/62	-	-
Cooling Coil:	CFM	9,420	8,040	10,880	2,090	560
	EAT DB/WB (°F)	82.0 / 67.6	92.0 / 79.0	80.9 / 65.9	82.7 / 69.7	86.7 / 63.1
	LAT DB/WB (°F)	52.1 / 51.1	52.1 / 52.0	52.1 / 52.0	52.1 / 52.0	53.1 / 53.0
	MBH Sensible/Total	310.5 / 446.5	358.3 / 760.4	344.8 / 450.9	70.7 / 115.4	21.3 / 36.7
	max Face Velocity (fpm)	475	500	475	450	450
	max Air ΔP (in w.g.)	0.9	1.3	0.7	0.6	1.0
	% Propylene Glycol	30	30	30	30	30
	EWT / LWT (°F)	45 / 55	45 / 55	45 / 55	45 / 55	45 / 55
	GPM	96.6	165.0	97.5	25.0	7.5
	max Water ΔP (in w.c.)	8.4	16.1	7.2	7.8	20
Pre-Heat Coil:	max CFM	4,940	8,040	4,350	2,090	560
	EAT / LAT Dry Bulb (°F)	44.5 / 69.0	16.0 / 74.2	52.9 / 75.6	48.4 / 63.6	16.0 / 55.0
	MBH	131.7	507.5	107.1	34.5	18.7
	max Face Velocity (fpm)	500	500	500	500	500
	max Air ΔP (in w.g.)	0.1	0.1	0.1	0.1	0.04
	EWT / LWT (°F)	180 / 160	180 / 160	180 / 160	180 / 160	180 / 160
	GPM	13.2	50.7	10.7	3.4	2.0
	max Water ΔP (in w.c.)	1	7	1	1	1
Re-Heat Coil:	max CFM	-	-	-	2,090	560
	EAT / LAT Dry Bulb (°F)	-	-	-	55 / 85	55 / 85
	MBH	-	-	-	68	20.6
	max Face Velocity (fpm)	-	-	-	500	500
	max Air ΔP (in w.g.)	-	-	-	0.1	0.04
	EWT / LWT (°F)	-	-	-	180 / 160	180 / 160
	GPM	-	-	-	6.8	2.2
	max Water ΔP (in w.c.)	-	-	-	4.4	1.0
Humidifier:	5 ft Section	H-1	H-2	H-3	H-4	-
Pre-Filters:	Type	Pleated	Pleated	Pleated	Pleated	Pleated
	Efficiency %	30	30	30	30	30
	ΔP Clean/Change (in w.g.)	0.25 / 0.75	0.25 / 0.75	0.25 / 0.75	0.25 / 0.75	0.25 / 0.75
Final Filters:	Type	Cartridge	Cartridge	Cartridge	Cartridge	Cartridge
	Efficiency %	85	85	85	85	85
	ΔP Clean/Dirty (in w.g.)	0.75 / 1.25	0.75 / 1.25	0.75 / 1.25	0.75 / 1.25	0.75 / 1.25

Fan Schedule

Fan										Motor		
Equip. No.	**Location**	**Service**	**Design CFM**	**S.P. (in w.g.)**	**Type**	**max RPM**	**Volume Control**	**Drive**	**max BHP**	**HP**	**RPM**	**V/PH/Hz**
SF-1	Boiler Room	Ventilation/ Combustion	1,500	1	Inline Centrifugal	1,214	Constant	Belt	0.44	1/2	1,725	120/1/60
EF-1,2,3	Roof	Lab	2,465	2.65	Mixed Flow Induced Dilution	1,770	VFD	Direct	2.68	3	1,725	460/3/60
EF-4	Mech Room	Toilets/ Janitor Closets	1,185	0.75	Inline Centrifugal	1,125	Constant	Belt	0.28	1/3	1,725	120/1/60
R-5	Mech Room	AHU-5	560	0.75	Inline Centrifugal	1,644	Constant	Belt	0.23	1/2	1,725	460/3/60

Boiler Schedule

		B-1	B-2
Design:			
	LWT (°F)	180	180
	Boiler HP	44	44
	MBH	1467	1500
	EWT (°F)	160	160
	Operating Pressure (psig)	18	18
	min Efficiency at Rated Output	80%	80%
Burners:			
	Type	Natural Gas	Natural Gas
	Supply Pressure (psig)	7	7
	Type	#2 Fuel Oil	#2 Fuel Oil
	gal/hr	10.7	10.7
	Supply Pressure (psig) max	3	3
Blower:			
	HP*	3/4	3/4
	Combustion CFM	750	750
	V/PH/Hz	460/3/60	460/3/60
Oil Pump:			
	gal/hr	35	35

*Includes oil pump horsepower

Air-Cooled Scroll Chiller Schedule

	CH-1	CH-2
Location	Outside	Outside
Service	AHUs	AHUs
Refrigerant	R407C	R407C
Capcity in Tons	105.5	105.5
max kW/Ton	1.3	1.3
Evaporator:		
max GPM	267.6	267.6
min GPM	165	165
EWT (°F)	55	55
LWT (°F)	45	45
∆P (ft w.c.)	16.9	16.9
No. of Passes	2	2
Fouling Factor	0.0001	0.0001
Condenser:		
Fan Type	Prop	Prop
No. of Fans	8	8
Drive	Direct	Direct
Design EAT (°F)	95	95
Total kW	14.4	14.4
Compressors:		
No. of Compressors	6	6
Steps per Compressor	1	1
Full Load Amps	215.6	215.6
max Inrush	225.0	225.0
V/PH/Hz	460/3/60	460/3/60

30% Propylene Glycol

Expansion Tank Schedule

Equip. No.	Location	Service	Nominal Tank Size (gal)	min Tank Accept. Vol. (gal)	min Operating Temp (°F)	max Operating Temp (°F)	max Operating Pressure (psig)	Remarks
ET-1	Mech Room	Heating Hot Water	45	22	160	180	40	Vertical Tank
ET-2	Mech Room	Chilled Water	10	2.5	40	75	45	Vertical Tank

<u>**Supply Air Terminal Unit Schedule (SB)**</u>

VAV Box					Reheat Coil***		
Equip. No.	**max CFM**	**min CFM***	**ΔP (in w.g.)****	**Nominal Inlet Size (in)**	**min MBH**	**GPM**	**max ΔP (ft w.c.)**
SB5	200	80	0.5	5	4.3	0.4	1.6
SB6	400	125	0.5	6	7.1	0.7	1.6
SB8	700	210	0.5	8	12.9	1.3	1.6
SB10	1,205	360	0.5	10	22.3	2.2	1.6
SB12	1,800	510	0.5	13x10 oval	33.2	3.3	1.6
SB14	2,300	690	0.5	16x10 oval	30.0	3.0	1.6

*Actual minimum airflows are to be set at 40% of the box maximum
**Discharge static pressure at max CFM
***Only where shown on drawings. Based on 180F EWT and 160F LWT.
Coil capacity and flow on drawings override schedule.

<u>**Supply Air Terminal Unit Schedule (SB)**</u> (continued)

External Sound Attenuator									
Equip. No.	**max Face Velocity (fpm)**	**max ΔP (in w.g.)**	**WxHxL (in)**	**125* Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
SB5	700	0.06	10x10x36	6	10	17	23	18	13
SB6	700	0.06	10x10x37	6	10	17	23	18	13
SB8	700	0.06	12x12x36	6	11	17	18	14	11
SB10	700	0.06	21x12x36	6	11	17	21	16	12
SB12	700	0.06	12x31x36	6	11	17	18	14	11
SB14	700	0.06	40x12x36	6	10	17	23	18	13

*Minimum Insertion Loss (dB)

<u>**Laboratory Air Valve Schedule**</u>

VAV Valve*				
Equip. No.	**max CFM**	**min CFM**	**ΔP (in w.g.)**	**Nominal Inlet/Outlet Size (in)**
SV8	550	35	0.6	8
SV12	3,600	90	0.6	12
SV312	1,200	270	0.6	36x12
EV8	550	35	0.6	8
EV12	1,200	90	0.6	12
EV212	2,400	180	0.6	24x12

*Reheat coils as shown on drawings.
Based on 180F EWT and 160F LWT.
Max water ΔP=2ft, max air ΔP=2in

Laboratory Air Valve (VAV) Schedule (continued)

External Sound Attenuator

Equip. No.	max CFM	max Face Velocity (fpm)	max ΔP (in w.g.)	Inlet/Outlet (in)	125* Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Service
SV8	550	900	0.1	12x12	5	11	18	17	16	12	Supply
SV12	1,200	900	0.1	24x12	5	11	18	17	16	12	Supply
SV312	3,600	900	0.1	46x12	5	11	18	17	16	12	Supply
EV8	550	-900	0.1	12x12	6	12	19	17	16	11	General Exhaust
EV12	1,200	-1,200	0.07	12x12	5	10	14	9	8	6	Fume Hood Exhaust
EV12	1,200	-900	0.1	24x12	6	12	19	17	16	11	General Exhaust
EV212	2,000	-1,000	0.07	24x12	5	10	14	9	8	6	Fume Hood Exhaust
EV212	2,000	-1,000	0.1	24x12	6	12	19	17	16	11	General Exhaust

*Minimum Insertion Loss (dB)

Sound Attenuator Schedule

Equip. No.	Location	WxHxL (in)	Face Vel (fpm)	max ΔP (in w.g.)	Insertion Loss (dB) 63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
SA-1S	AHU-1	64x46x36	500	0.12	7	14	19	18	25	23	18	16
SA-1R	AHU-1 Return Duct	26x38x36	1250	0.17	4	8	13	18	18	14	11	9
SA-2S	AHU-2 Supply Duct	26x24x60	2000	0.21	3	6	13	22	20	16	12	9
SA-2E	EF-1,2,3 Inlet Exhaust	50x18x60	1250	0.21	11	8	17	18	12	11	9	8
SA-2B	EF-1,2,3 Inlet Bypass	24x18x36	1053	0.60	8	12	20	24	29	23	14	11
SA-3S	AHU-3	64x50x36	500	0.12	7	14	19	18	25	23	18	16
SA-3R	AHU-3 Return Duct	50x26x36	1250	0.17	4	8	13	18	18	14	11	9
SA-4S	AHU-4 Supply Duct	16x20x36	1250	0.17	4	8	12	14	17	15	13	11
SA-4R	AHU-4 Return Duct	16x20x36	1250	0.17	5	10	14	15	18	14	13	11

Laboratory Airflow Table

Condition	Supply		Fume Hood Exhaust					General Exhaust		Transfer	Pressurization
	SV312	SV312	EV212	EV12	EV12	EV12	EV12	EV212	EV12		
min cool / min exh	920	830	-560	-315	-315	-315	-315	-180	-90	280	-60
max cool/ min exh	2460	2060	-560	-315	-315	-315	-315	-1950	-1090	280	-60
max cool/ max exh	3260	2745	-1855	-1055	-1055	-1055	-1055	-180	-90	280	-60
min cool/ max exh	3260	2745	-1855	-1055	-1055	-1055	-1055	-180	-90	280	-60

Notes: All values in CFM. (+) indicates flow into the space. (-) indicates flow out of the space.

Pump Schedule

Equip. No.	Pump: Service	Type	Liquid	GPM	Total Head (ft w.c.)	min. % Efficiency	max BHP	Suction (in)	Discharge (in)	Motor: HP	RPM	V/PH/Hz	Remarks
CHWP-1	CHW Primary	Base Mounted Centrifugal	30% Propylene Glycol	201	129	57	11.8	3	2	15	1750	460/3/60	VFD
CHWP-2	CHW Primary	Base Mounted Centrifugal	30% Propylene Glycol	201	129	57	11.8	3	2	15	1750	460/3/61	VFD
HWP-1	Heating HW	Inline Centrifugal	Water	147	65	65	3.7	2.5	2	5	1750	460/3/62	VFD
HWP-2	Heating HW	Inline Centrifugal	Water	147	65	65	3.7	2.5	2.5	5	1750	460/3/63	VFD
P-1	AHU-1 Recirculating	Inline Centrifugal	Water	13.2	2.0	-	-	-	2.5	FRAC	1750	120/1/60	-
P-2	AHU-2 Recirculating	Inline Centrifugal	Water	50.7	10	53	0.24	-	-	0.33	1750	120/1/61	-
P-3	AHU-5 Recirculating	Inline Centrifugal	Water	2.0	2.0	-	-	-	-	FRAC	1750	120/1/62	-
FOP-1	Duplex Fuel Oil Pump	Direct Drive Positive Displacement	#2 Fuel Oil	2.58	115	-	-	0.5	0.5	0.5	1725	460/3/60	-
FOP-2	Fuel Oil Pump	Direct Drive Positive Displacement	#2 Fuel Oil	4.7	115	-	-	-	-	0.75	1725	208/3/60	-

Air Conditioning Unit Schedule

Equip. No.	Fan CFM	Drive	External S.P.	Motor HP	Motor RPM	Cooling Refrig.	Cooling Sens. MBH	Cooling Total MBH	Cooling EAT (°F) DB/WB	Heating Capacity kW	Heating EAT (°F) DB/WB	Electric MCA	Electric V/PH/Hz
ACU-1	2,200	Direct	0.5	1	1750	R407C	34.9	-	80/67	5.1	80/67	18.4	460/3/60
ACU-2	900	Direct	0.4	1/4	1750	R407C	19.4	-	75/63	5.1	75/63	9.8	460/3/60
ACU-3	1,000	Direct	0.4	1/3	1750	R407C	20.3	-	80/67	-	-	2	460/3/60

Air-Cooled Condensing Unit Schedule

Equip. No.	Location	Service	MBH	Design OA (°F)	Refrig.	Electric MCA	Electric V/PH/Hz
ACCU-1	Outside	ACU-1	70	95	R407C	18.4	460/3/60
ACCU-2	Outside	ACU-2	31.5	95	R407C	9.8	460/3/60
ACCU-3	Outside	ACU-3	40.5	95	R407C	2	460/3/60

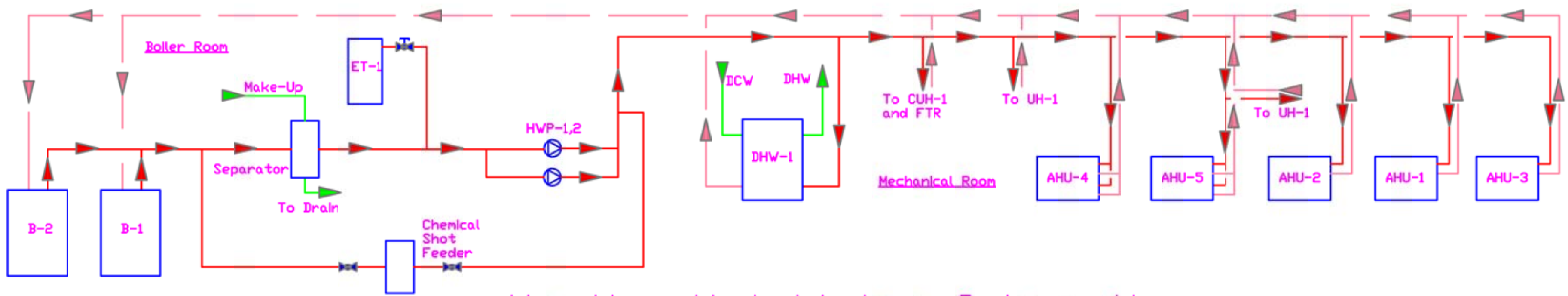
Ultrasonic Humidifier Schedule

Equip. No.	Service AHU-#	Supply CFM	OA CFM	Capacity (lbs/hr)	max air ΔP (in w.g.)	Electric A	Electric V/PH/Hz
H-1	1	4,940	2,280	61.2	0.1	8	460/1/60
H-2	2	8,040	8,040	171.6	0.1	13	460/1/60
H-3	3	4,350	1,310	30.8	0.1	4	460/1/60
H-4	4	2,090	880	21.1	0.1	4	460/1/60

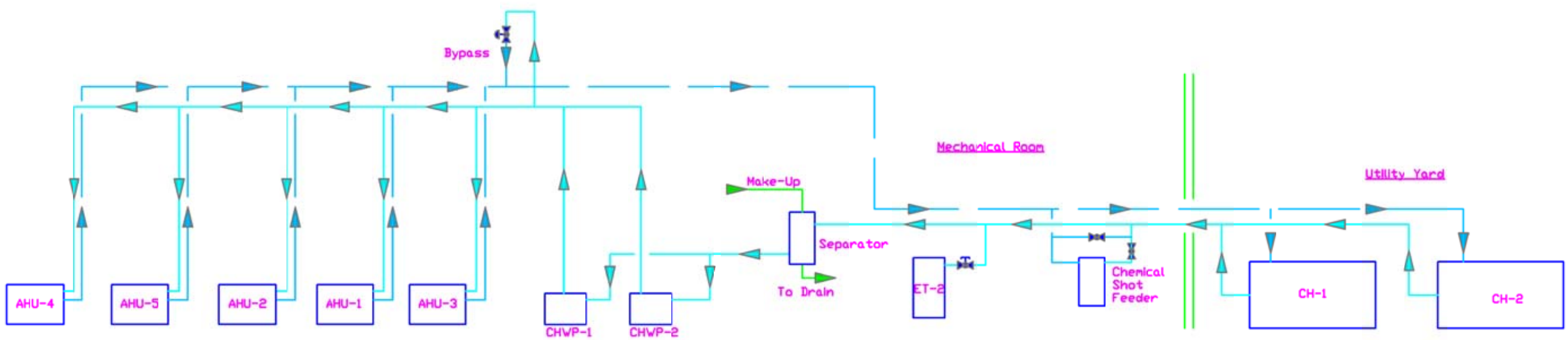
Notes: All humidifiers have a maximum absorption distance of 30".

Unit Heater and Cabinet Unit Heater - Hot Water - Schedule

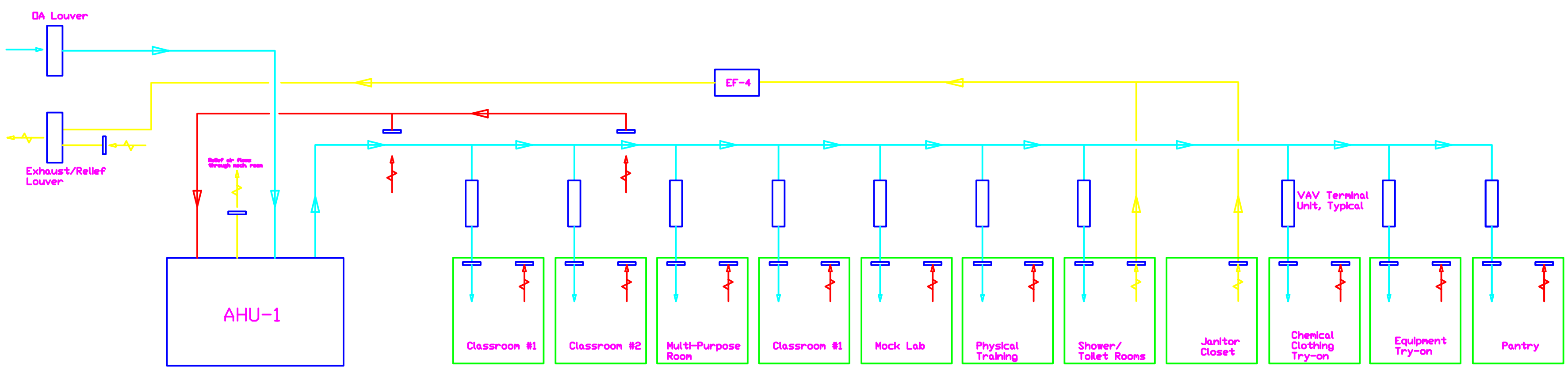
Equip. No.	Location	Type	Fan CFM	Throw (ft)	Motor			Coil					
					HP	V/PH/Hz	RPM	MBH	EAT (°F)	LAT (°F)	EWT (°F)	GPM	max Water ∆P (ft w.c.)
CUH-1	Corridor	Ceiling Recessed	420	-	FRAC	120/1/60	1050	33.0	60	141	180	3.3	2
CUH-2	Entry Vestibule	Wall Mounted	420	-	FRAC	120/1/60	1050	33.0	60	141	180	3.3	2
CUH-3	Main Vestibule	Wall Recessed	420	-	FRAC	120/1/60	1050	50.8	60	141	180	3.3	2
CUH-4	Stair	Wall Mounted	230	-	FRAC	120/1/60	1050	24.1	60	141	180	2.5	2
CUH-5,6	Shower	Wall Mounted	170	-	FRAC	120/1/60	1050	11.1	60	141	180	3.0	2
UH-1	Various	Horizontal	630	25	FRAC	120/1/60	-	30.0	65	120	180	3.75	5



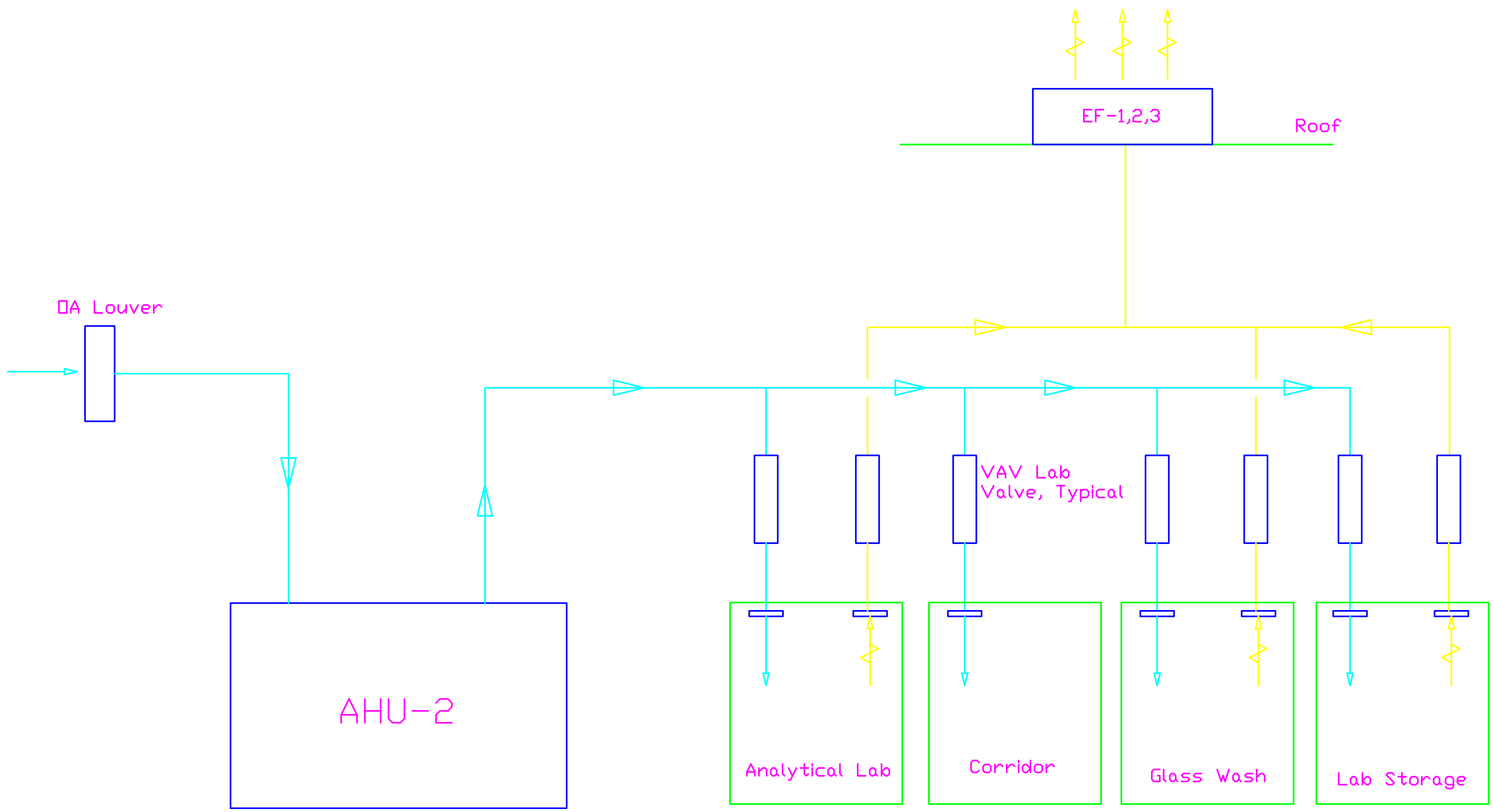
Heating Hot Water Schematic



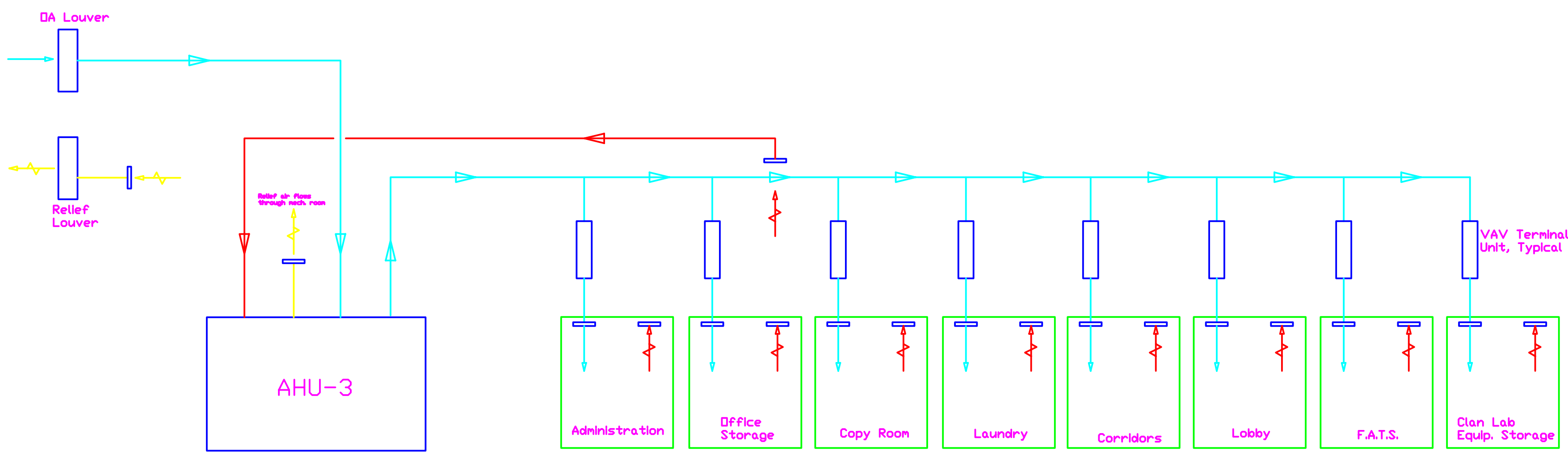
Chilled Water Schematic



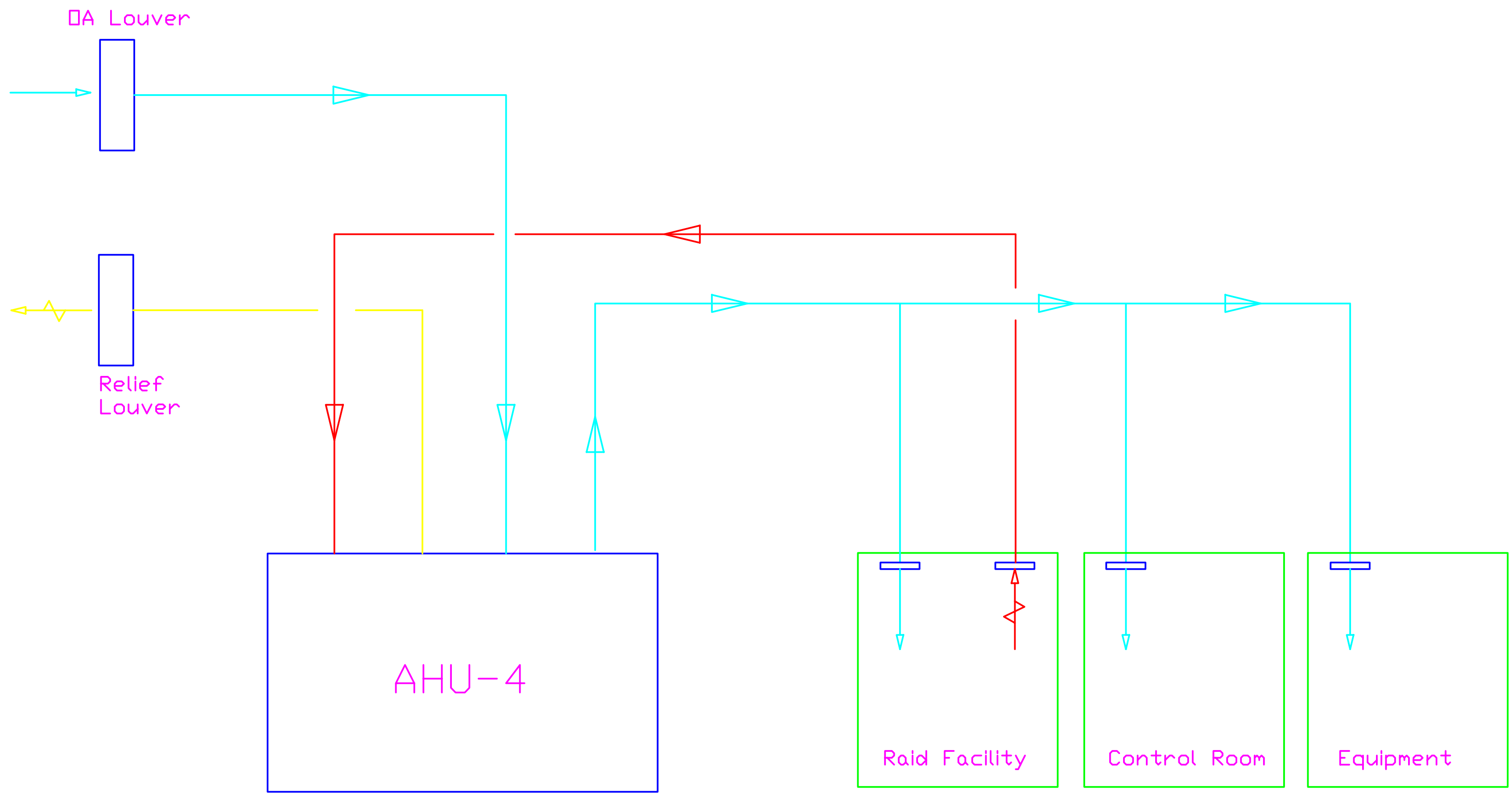
AHU-1 Schematic



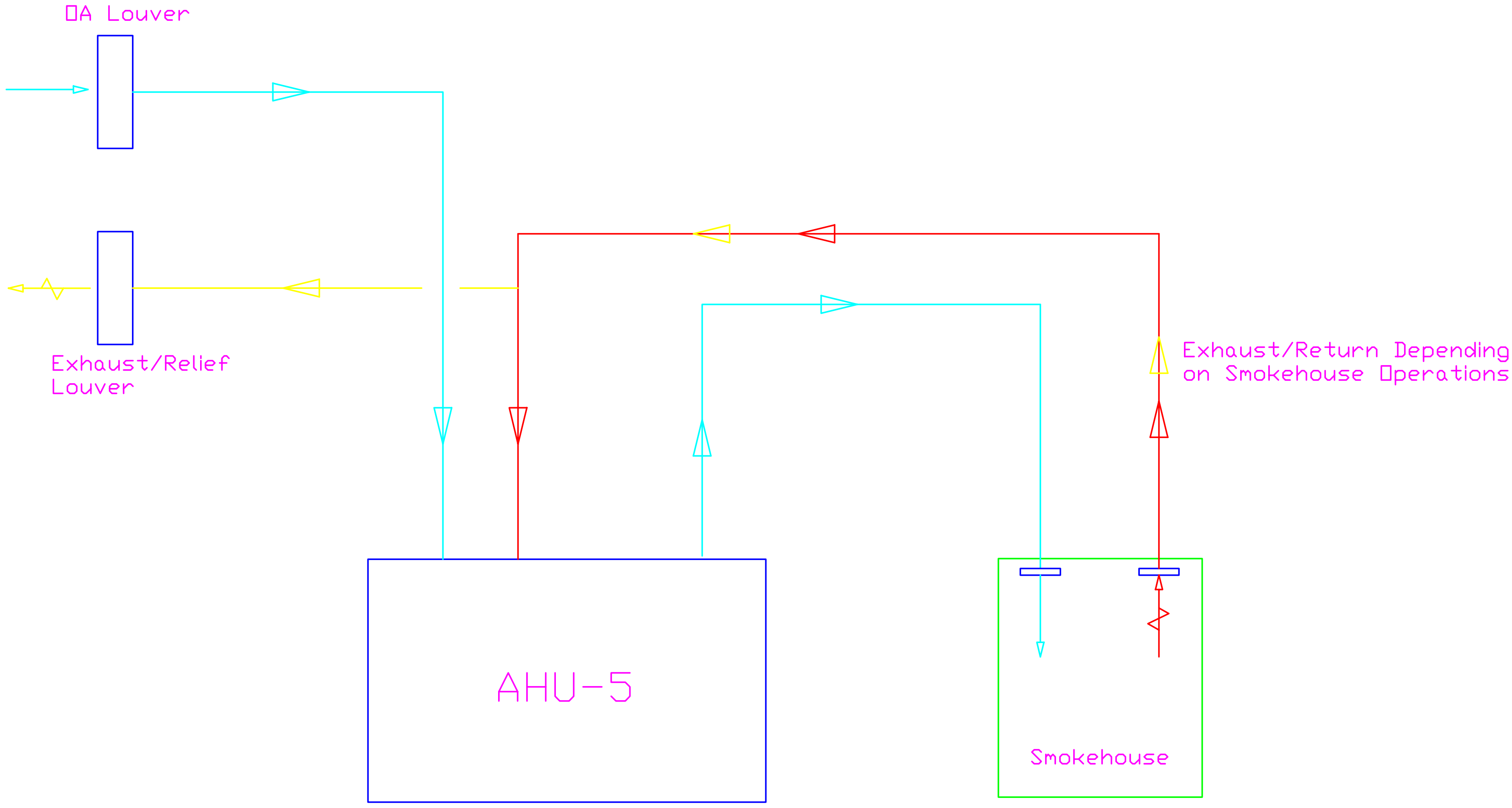
AHU-2 Schematic



AHU-3 Schematic



AHU-4 Schematic



AHU-5 Schematic