University of Miami Interdisciplinary Laboratory

Mechanical Technical Report 3
Mechanical Systems Synopsis

Ben Burgoyne

November 21, 2006

Ben Burgoyne
University of Miami Interdisciplinary Laboratory
Miami, Florida
Mechanical Technical Report 3-Executive Summary
11/21/06

Executive Summary:

This report is an analysis of the University of Miami Interdisciplinary Laboratory mechanical system, including conditions leading up to the design, the systems included, their performance, components, and their effectiveness.

Many challenges need to be met for a functioning system. The University of Miami Interdisciplinary Laboratory is a laboratory and vivarium facility and requires 100% outdoor air to those spaces. The building is located in Miami, Florida, which is a very hot, humid climate. Additionally, direction from the owner requires a constant air volume system to the laboratories and vivaria. Additional considerations are a necessary steam plant for steam-using equipment and that chilled water is available from a separate chiller plant.

The mechanical scheme has two main air handling systems: constant air volume to laboratories and vivaria and variable air volume to the office spaces. Each part has associating exhaust systems to address specific spaces with the system. Additionally, a small air handling system serves mechanical spaces.

Through building simulation, code calculation, and posted energy rates, system performance data is available in Tables T.1-T.9 in the Appendix.

Insight and understanding are necessary when choosing appropriate methods to develop the different parts of the mechanical system from available choices. These principles were exercised for the University of Miami Interdisciplinary Laboratory, but there always exists possible energy saving alternatives that are worth exploring.

Ben Burgoyne
University of Miami Interdisciplinary Laboratory
Miami, Florida
Mechanical Technical Report 3
11/21/06

Design Considerations

The University of Miami Interdisciplinary Laboratory (hereafter referred to as the UMIL) is a ten floor laboratory building located at the University of Miami in Florida. The building contains seven floors of laboratory space, two floors of vivarium space, office spaces located on nine floors, and a penthouse mechanical space. Work has begun on construction in October 2006 and will continue until completion in April 2008. Much labor and care will be taken by scientists, students, and university to obtain successful results for the research they will conduct in the UMIL. Also, funds and effort are being contributed by the University of Miami to undertake this project, which include the destruction of an existing, functioning building on the site. This is why it is imperative that, in addition to all the other aspects of the building, the mechanical system have a high standard of efficiency, cost effectiveness, and functionality in order to meet the UMIL's needs.

In order to accomplish this standard, considerations must be made for many factors. Miami is located in one of the hottest, most humid climates in the United States. The mechanical system may have to work very hard to maintain satisfactory indoor conditions, so care must be taken to minimize cost to run it, as well as the pollution created, by saving as much energy as possible. Conditioning the building is an even greater feat because of the intended use of the UMIL. The precise nature of laboratories and the sensitivity of vivarium spaces require that 100% outdoor air be supplied. Without the help of return air to bring the supply air to design conditions, a lot of energy is required. For the same reasons, adequate ventilation is necessary. Proper dedicated exhaust fans need to be used to fulfill this need, some of them having the ability to propel the contaminated air high enough up from the building to avoid recirculation into the intake or traveling to pedestrian areas around the UMIL. Further, specific pressure differentials need to be maintained between certain spaces to ensure that some air doesn't infiltrate, or escape from them.

Owner requirements are also an important factor in the UMIL's design. The building belongs to the University of Miami, and final say in building decisions is theirs. In the case of the UMIL, the University desires a controlled air volume system for the laboratories and vivaria. Incorporation of this condition influences the approach to system design. It can be decided to run the whole building on a constant volume system, or to create a separate system for non-laboratory or vivarium spaces, such as the office spaces. That decision also depends on the arrangement of those spaces in the building. With the UMIL, the office spaces are massed on the west side of each floor, so a separate system for them is feasible.

Another consideration for the UMIL mechanical system is the decision whether to use a hot water heater plant or a steam boiler plant. In this case, steam is the advisable approach because of the presence of steam-using equipment. Certain spaces through the UMIL are used for cleaning glassware from the laboratories or cages from the vivaria, and the associated equipment requires steam. Instead of incorporating a separate steam system, it will be cost, space, and time effective to use a steam source for all the building heating needs.

On the chilled water side, a chiller plant is not necessary in the UMIL, as it derives its chilled water from a campus plant. A proper system must be designed for bringing in that chilled water and distributing it to the necessary equipment.

Operating System

The University of Miami Interdisciplinary Laboratory can be divided into three main conditioning sections: the Laboratory System, the Office System, and the Mechanical Spaces System. The descriptions of these systems in detail are given below, along with references to fluid flow schematics (labeled S.X) which can be found in the Appendix along with Equipment information tables.

Laboratory System

Supply (S.5)

The laboratory and vivarium spaces, located on the 1st through 9th floors, are served by four air handling units located on the penthouse floor. These air handling units are connected in parallel to a main 220x60 duct that descends a mechanical shaft to reheat terminal units in the served spaces. The airflow is constant volume 100% outdoor air, set at 171,710 cfm, and is powered by variable speed fans located in each air handling unit. A duct pressure sensor downstream controls the fans to maintain 1.0" w.g. in the supply duct.

Within the air handling unit, the air first passes through a filter, then through a runaround coil from energy recovery units (S.2). There is an energy recovery unit dedicated to each air handling unit, four in all. Each air handling unit receives 110 gpm, which is powered by two constant volume pumps. These pumps are rotated in use, only one running at a time. The energy recovery units turn on when the outside dry bulb temperature is greater than 80°F or less than 55°F.

Next, the air passes through a hot water coil, then a chilled water coil. The hot water (S.3) is heated by steam from the boiler plant (S.4) by means of a heat transfer package, which includes a shell and tube heat exchanger and two variable speed pumps. The heat exchanger, controlled by internal pressure controls to maintain hot water system pressure, modulates the low pressure steam through two control valves, 33% and 67%, to maintain the hot water temperature setpoint linearly from 200°F to 140°F for outside temperatures from 40°F to 80°F. This temperature is controlled by a temperature sensor downstream of the heat transfer package. The hot water flow rate passing through the air handling unit coils is maintained by control valves located downstream of the coil, which are in sequence with an air temperature sensor located downstream in the air stream. The boiler plant includes two 10,043 MBH, 80 psig boilers. The steam is also used for glass and cage washing equipment.

Chilled water (S.1) is supplied by an offsite campus chilled water plant, and recirculated through the UMIL by a secondary system powered by two variable speed pumps. These pumps work in rotation, one on at a time. They maintain system pressure based on both pressure sensor locations. The bypass control valve operates to keep the minimum chilled water return temperature at 56°F. Flow through the air handling unit coils is maintained by control valves downstream of the coils, which are in sequence with an air temperature sensor located in the air stream downstream of the air handling unit.

Chilled water is also used in this system to serve 1000 cfm, 10 gpm computer room units conditioning equipment hallways on the 3^{rd} through 9^{th} floors.

Finally the air is passed out of the air handling unit and down to the terminal units. These contain reheat coils, fed by the hot water system, which heat the supply air in response to temperature sensors in the conditioned spaces. The terminal units maintain constant air volume to the spaces.

Exhaust

There are multiple space air exhaust systems for the laboratories and vivaria. These are General Laboratory Exhaust, Fume Hood Exhaust, Vivarium Exhaust, and Cagewash Exhaust.

General Laboratory Exhaust (S.5):

Spaces exhausted by this system are the laboratory spaces located on the 3^{rd} through 9^{th} floors, which are typical. This air is pulled through the energy recovery system (S.2), and the fans (204,000 cfm total) are located in the energy recovery units on the penthouse floor. These fans maintain 1.0" w.g. in the return duct, controlled by the duct pressure sensor located there. Exhaust terminal units located in the spaces maintain constant air volume.

Vivarium Exhaust (S.6):

The vivaria located on the 1^{st} and 2^{nd} floors are exhausted by three constant speed high induction fans (36,400 cfm total). This system operates similar to the Fume Hood Exhaust system. Outside air is also drawn by the fans, and variable volume exhaust terminal units, instead of fume hoods, and automated dampers maintain 1.5" w.g. duct pressure through a duct pressure sensor. The exhaust terminal units adjust to alternate pressure differentials across specific vivarium rooms.

Specialty Exhaust (S.6):

Radio-isotope rooms located on the 3^{rd} through 9^{th} floors and necropsy rooms on the 1^{st} and 2^{nd} floors have each their own dedicated exhaust fan and riser. Radio-isotope fans are 500 cfm and necropsy are 755 cfm.

Cagewash Exhaust (S.7):

Special rooms located on the 1^{st} and 2^{nd} floors are dedicated to washing, sterilizing, and storing animal cages. These are served by two constant speed fans (12,000 cfm each). One of these is constantly running at a time, and they are rotated in use.

Fume Hood Exhaust (S.7):

Fume hoods located in the laboratories on the 3rd through 9th floors are exhausted by three constant volume high induction fans (38,220 cfm total) located on the roof. They also draw outside air along with exhaust air from the fume hoods. Automated dampers and the opening and closing of fume hoods maintain the exhaust duct pressure at 1.5” w.g. as controlled by the duct pressure sensor.

Office System

Supply/Return (S.8)

All the spaces on the 1st through 9th floors that are not supplied by the Laboratory System are supplied by the Office System. The spaces are offices, conference rooms, hallways and similar rooms.

This system is variable air volume, drawing outside air and mixing it with return air from the spaces for the supply air. This mixing occurs before the air handling unit. One air handling unit is used, with a 48,500 cfm variable speed fan moving outside air through a hot water coil, then a chilled water coil. These are fed by the hot water and chilled water systems as described in the Laboratory System section. Flow through these coils is varied by control valves on the return side that are linked to temperature sensors down the air stream. The fan maintains a 1.0” w.g. duct pressure, controlled by a downstream pressure sensor, and automated dampers in the return air duct maintain a minimum outside airflow of 23,000 cfm. This airflow is measured by the sensor located downstream of the intake louvre. Additionally, a smoke exhaust fan is attached to the return duct. If the fire alarm sounds, the damper linking the return air duct to the air handling unit closes, and the fan turns on. The air handling unit fan also runs at 100% then.

The system supply air is distributed to space variable volume terminal units. These adjust supply air quantity to maintain a space temperature of 75°F as measured by space temperature sensors. When the air valve in a terminal unit reaches its minimum position, hot water coils governed by a control valve are used to further maintain space conditions. Return air is taken from the spaces via a return air plenum.

Exhaust

Toilet Exhaust (S.9):

One variable volume, 10,200 cfm fan exhausts the toilets on all floors, as well as copy rooms, kitchenettes, and break rooms within the Office System.

Janitor’s Closet Exhaust (S.9):

One constant volume, 750 cfm fan exhausts the janitor’s closet located on all floors, including the penthouse floor.

Mechanical Spaces System

The mechanical spaces include the mechanical and electrical rooms on the 1st floor, the elevator rooms, and the penthouse floor.

Mechanical and Electrical Rooms/ Elevator Rooms

The spaces are conditioned by 1,200 cfm fan coil units, including 10 gpm chilled water coils. With the sensible heat gain from the equipment in these spaces, hot water coils will not be needed.

Penthouse Floor (S.10)

Two small air handling units condition the mechanical penthouse. These are constant volume (4000 cfm), and air is drawn 100% from the space. They only run when the outside dry bulb temperature is 70°F or higher. Chilled water coils shall be modulated to produce 55°F to 60°F to 65°F as the return air temperature drops from 85°F to 80°F to 75°F using the control valve and based on information from the return and supply duct temperature sensors.

Stairwell Pressurization (S.11)

One system not covered previously is the stairwell pressurization. A variable speed, 9,100 cfm fan supplying 100% outside air turns on upon sounding of the fire alarm. It maintains between a 0.05” and 0.35” w.g. pressure differential between the stairwell and surrounding spaces based on readings from three pressure sensors located on the 9th, 5th, and 2nd floors. A relief damper and louvre to the outside assists in the maintaining of the pressure.

System Conditions

Through building simulation, energy source information review, and calculation based on ASHRAE Standards, key mechanical system performance data can be determined for a building. This is beneficial for design, because this data can be obtained near the beginning of the project and not after completion and years of use. Important changes or additions can then be made to improve the system.

The performance data for the UMIL is listed in tables found in the Appendix, a summary of which is given below:

Energy Rates:

- -T.1 Florida Power & Light Energy Rates
- -T.2 Peak Periods

Design Conditions:

- -T.3 Conditions

Ventilation ASHRAE 62.1-2004:

- -T.4 Required Exhaust Rates
- -T.5 Required OA Rates

Design Data:

- -T.6 Peak Airflow Rates
- -T.7 Peak Cooling Loads
- -T.8 Annual Power Consumption
- -T.9 Power Cost

System Critique

The UMIL mechanical system can be viewed in two categories, the air system and the water system. These categories can be further divided up into subcategories. Within air: supply, return, ventilation, laboratory system, office system, and other systems. Within water: heating, cooling, steam, and energy recovery. When evaluating the overall system, these points should be taken into consideration. Certain aspects of interest from these points are discussed below.

The chilled water flows through a simple system in the UMIL. Because it is alright cooled at a campus plant offsite, the only running equipment in the building are the secondary pumps. It could be considered whether it would be worth it to create a dedicated chilled water system, but that would be a major addition to the system. This would impact initial cost, with all the additional equipment, as well as energy consumption. With an already up and running chiller plant, using that resource seems like the most convenient method.

Using steam to heat the hot water system for the UMIL has an immediately apparent purpose with the steam-using washing equipment being present. A possible alternative that still meets that need may be a direct hot water heater with a separate smaller water boiler dedicated to that other equipment. That boiler would be sized based on the needs of the building and may require less energy input. Again, such an avenue would require more space and equipment, so it’s hard to imagine it being a better method.

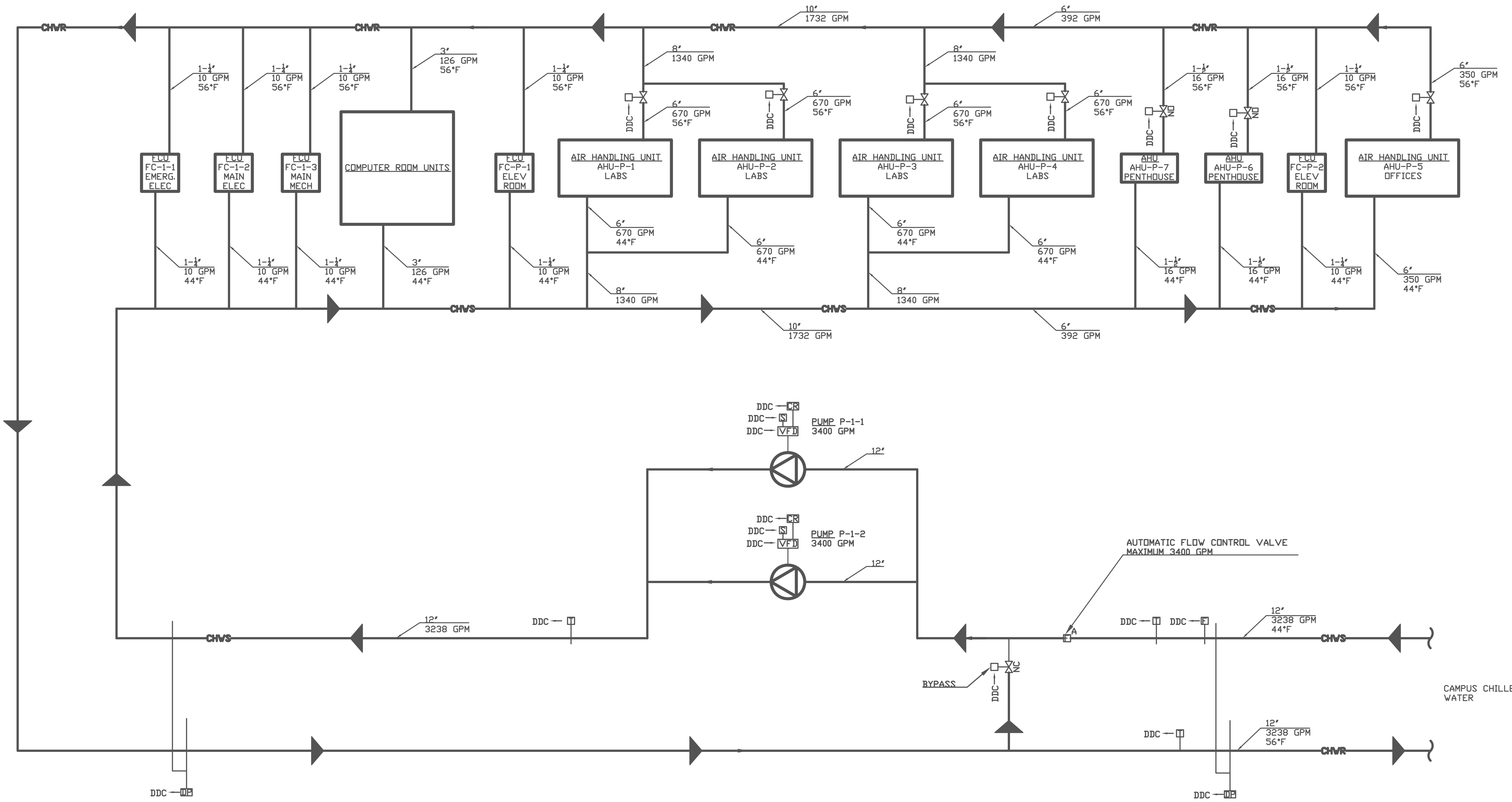
The energy recovery system is an obvious help to lab air handling units, lessening the load on them. However, they only decrease the sensible load by lowering the incoming air dry bulb temperature. Indeed, air is dehumidified in this system through condensation, which is done through lowering the dry bulb temperature. However, a more direct way to aid the latent load, which is large in southern Florida, may be a desiccant wheel instead of a runaround coil. Thereby, humidity can be lowered more effectively as well as the dry bulb temperature of the incoming air. Indoor air quality issues may, however, arise if the exhaust air blown through the energy recovery unit is contaminated to the point of affecting the wheel, and in turn the incoming air. Filters could reduce that contamination, but that would involve extra cost.

With the air system, it seems that a significant change could be undertaken with the laboratory supply. The present design involves 100% outdoor supply air through a constant volume system. Even with the aid of the energy recovery system, this method demands a large cooling load compared to the possibility of a variable volume system. The constant volume system was undertaken because of owner request, but an energy analysis between the two methods could reveal significant savings in energy. The office system and the ventilation systems are mostly variable air volume, and they no doubt will function as well as can be designed.

Conclusion

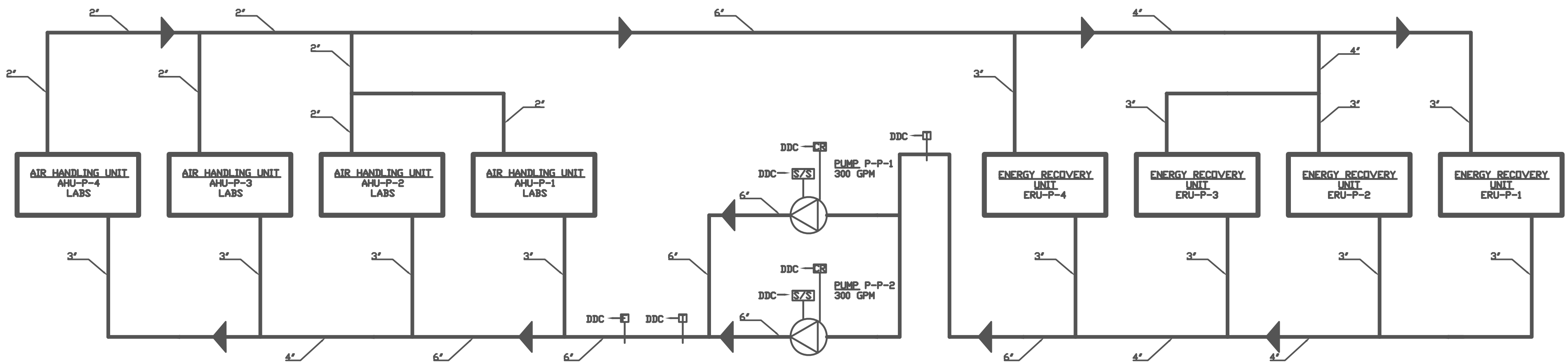
The University of Miami Interdisciplinary Laboratory mechanical system has been analyzed, including conditions leading up to the design, the systems included, their performance, components, and their effectiveness. Possibilities for change or improvement have also been explored. The building system design is sound and should serve the needs of the occupants, which, for its use as a laboratory building, it is essential to meet. Many methods were undertaken to keep the system as simple, accurate, and efficient as possible, but there are always ways to improve that efficiency. New methods are always worth considering.

Appendix

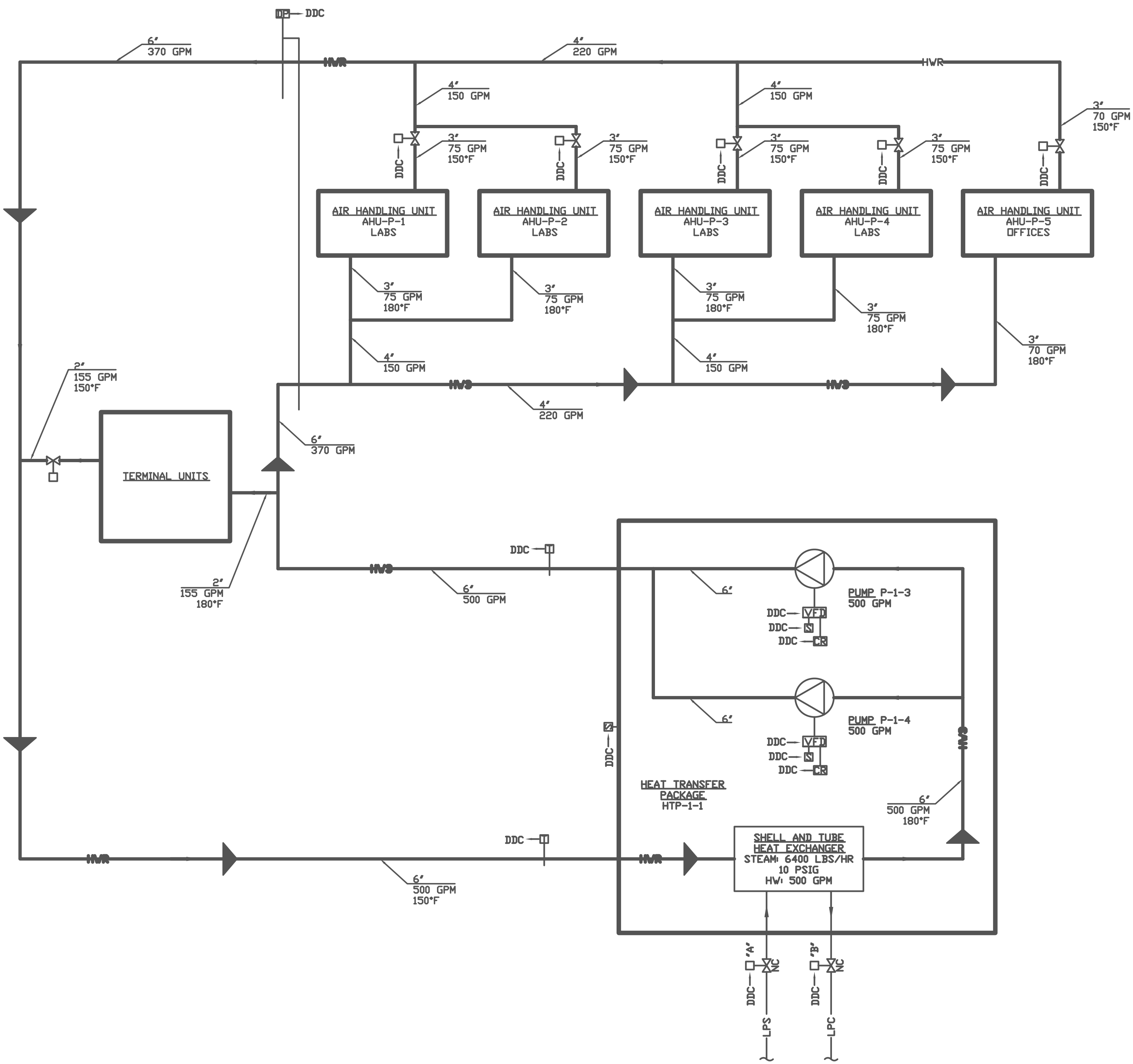


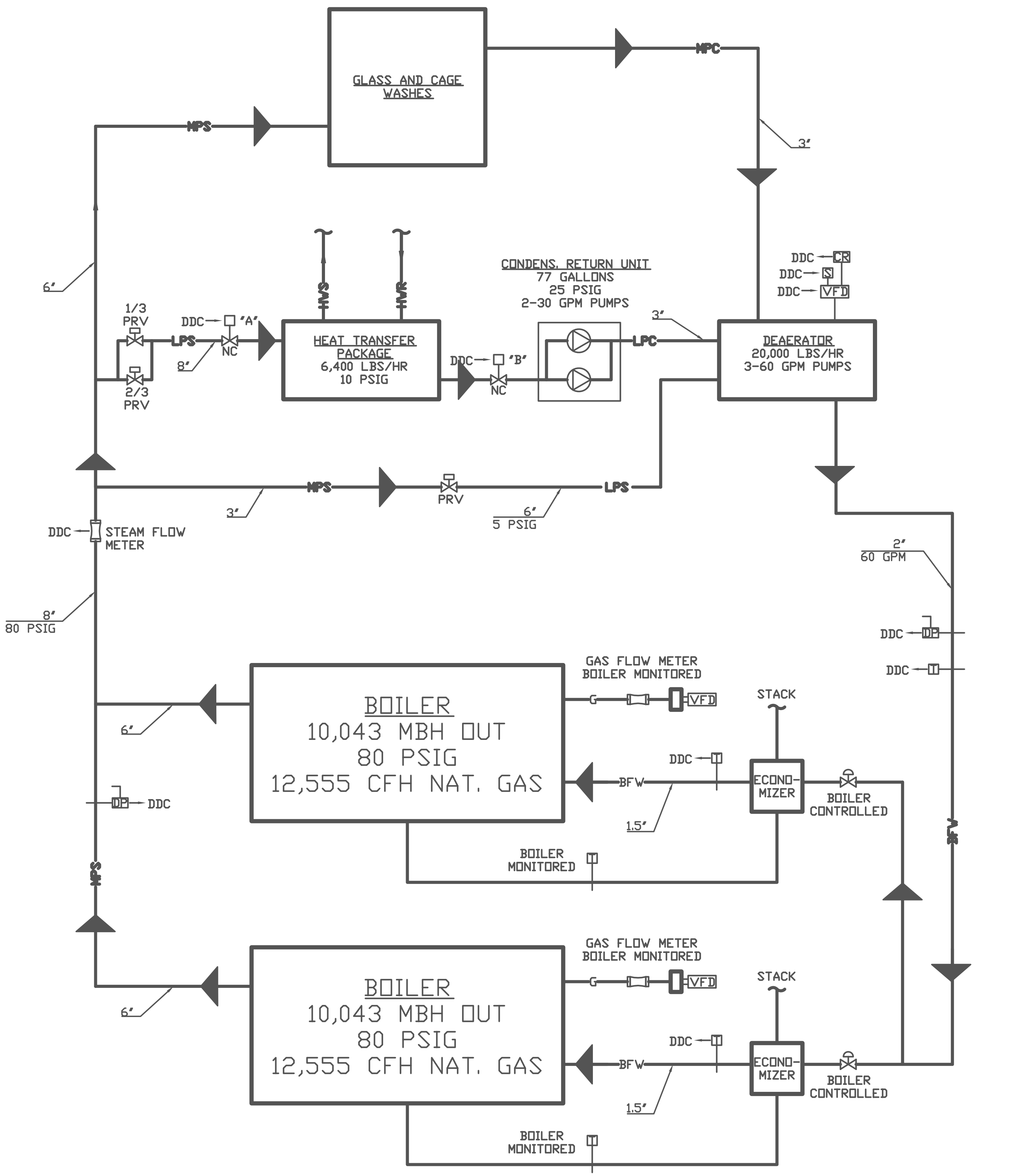
S.1 CHILLED WATER SCHEMATIC

S.2 ENERGY RECOVERY SCHEMATIC

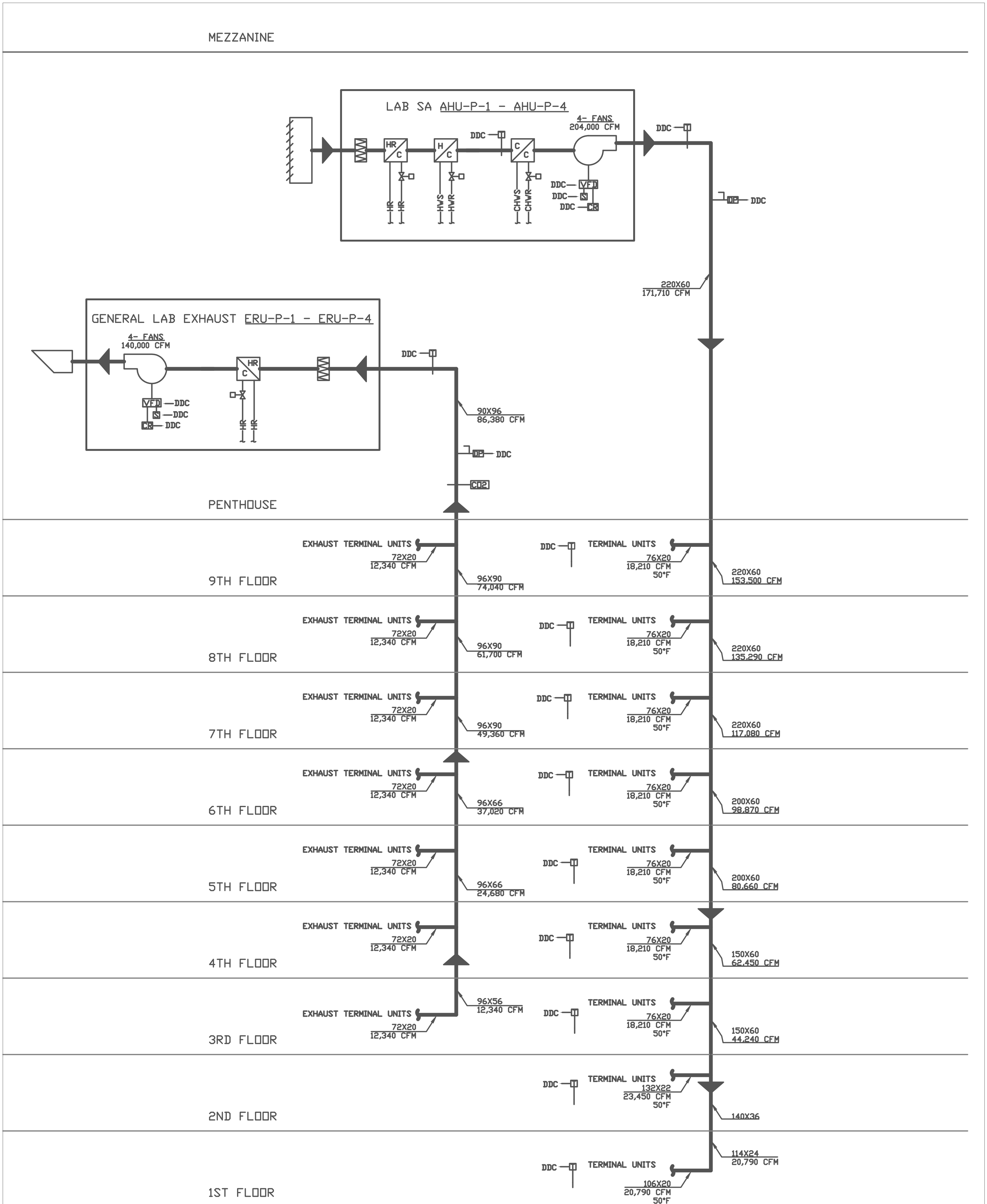


S.3 HOT WATER SCHEMATIC

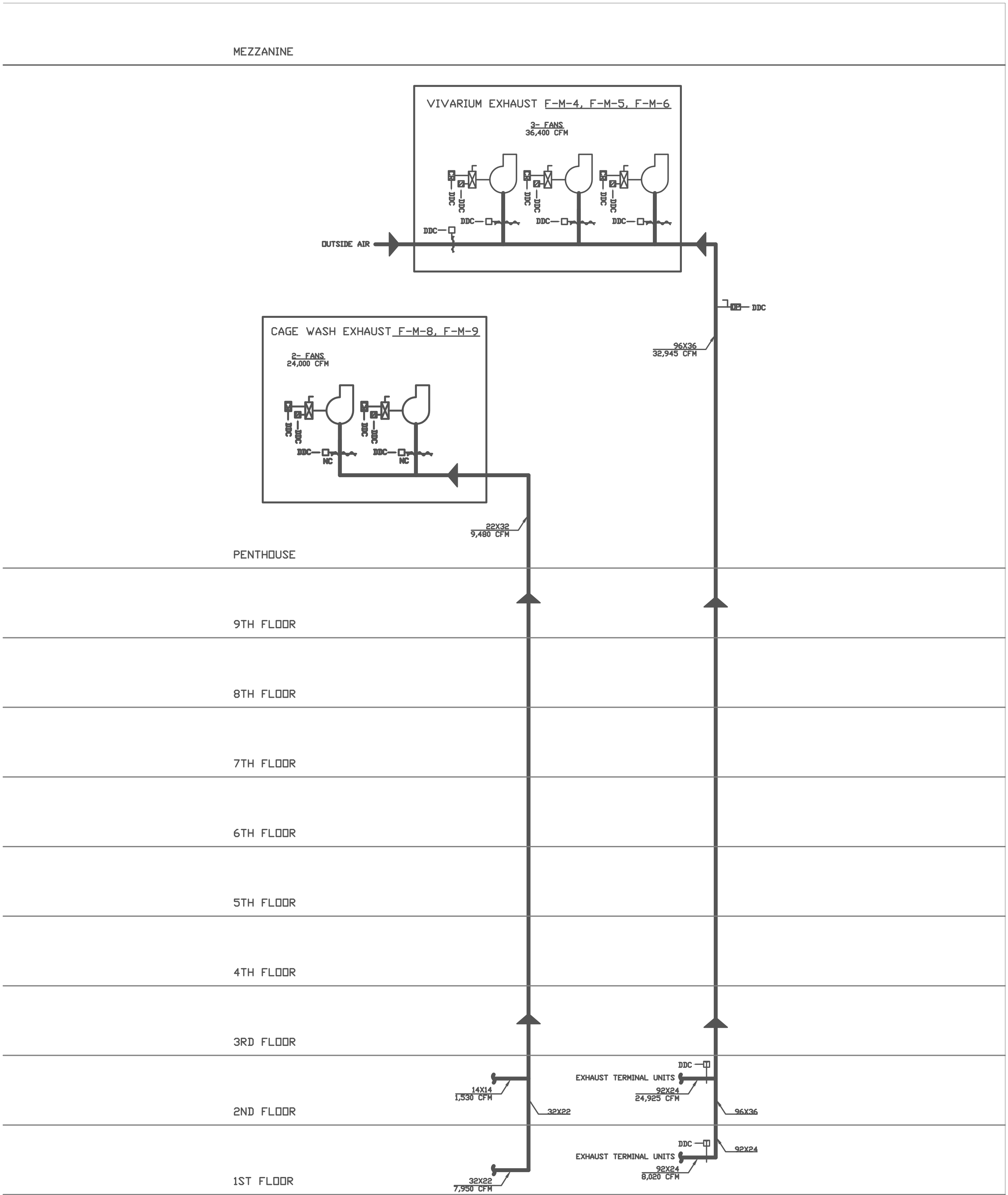




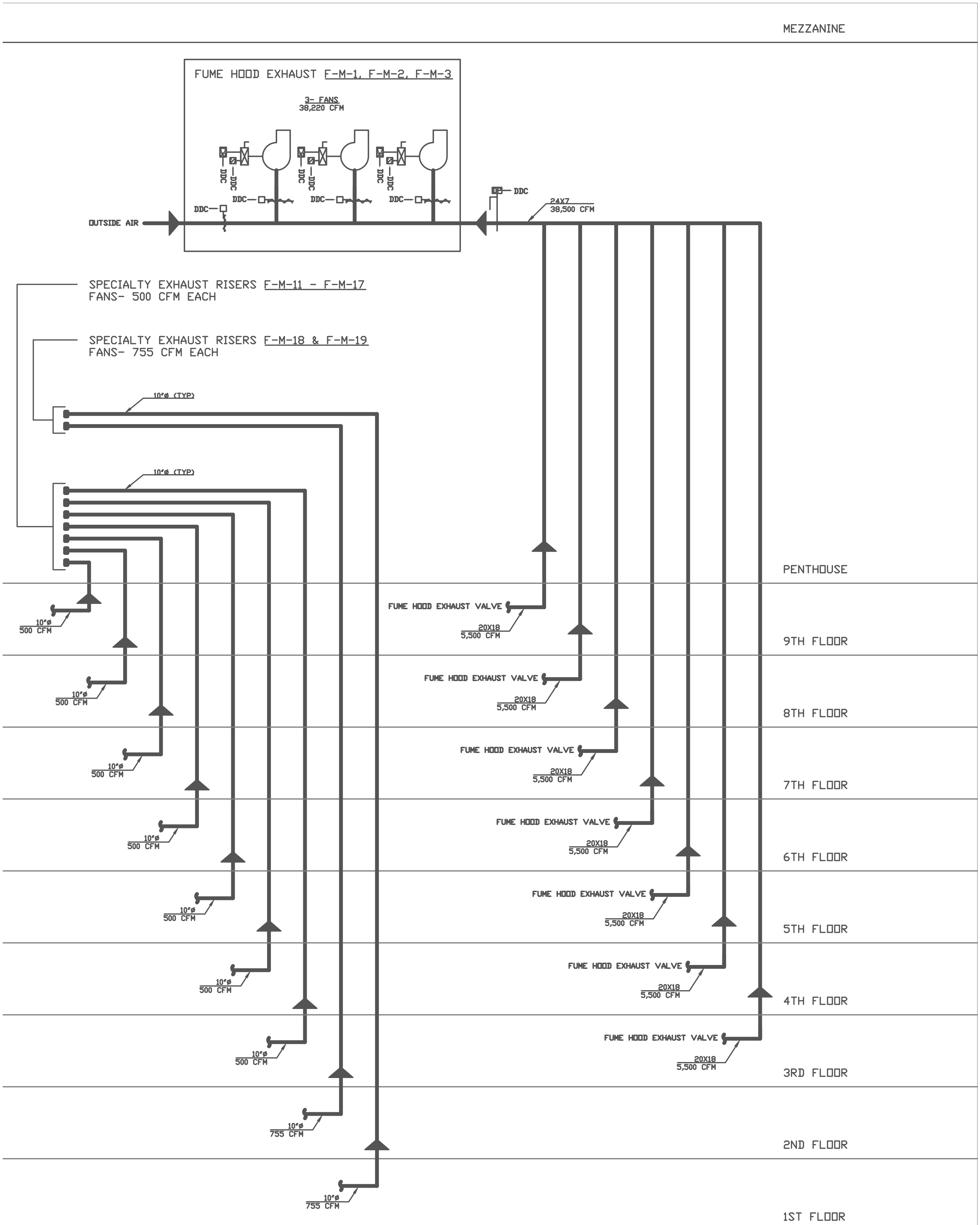
S.4 BOILER PLANT SCHEMATIC



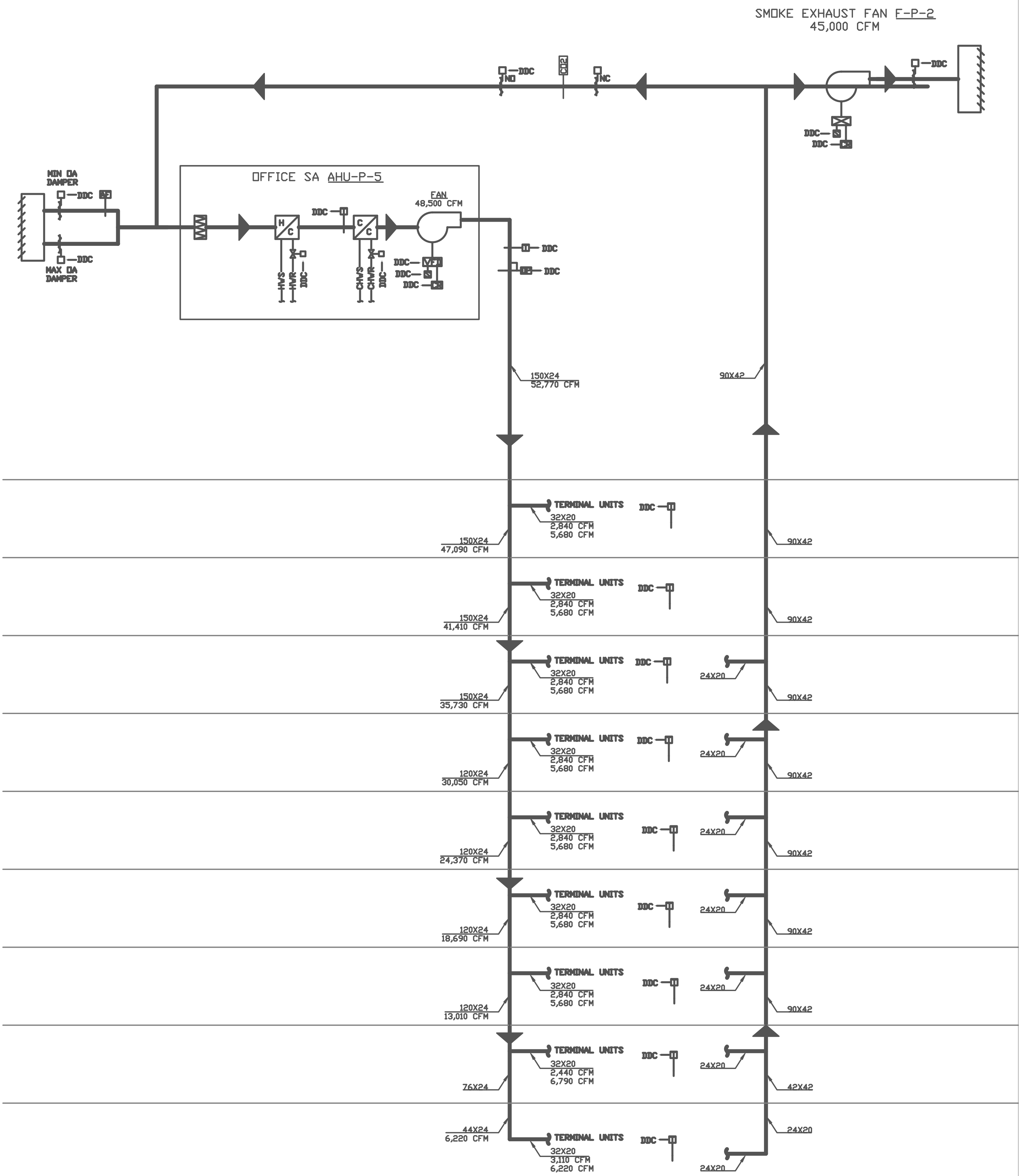
S.5 LAB SUPPLY, GENERAL LAB EXHAUST SCHEMATIC



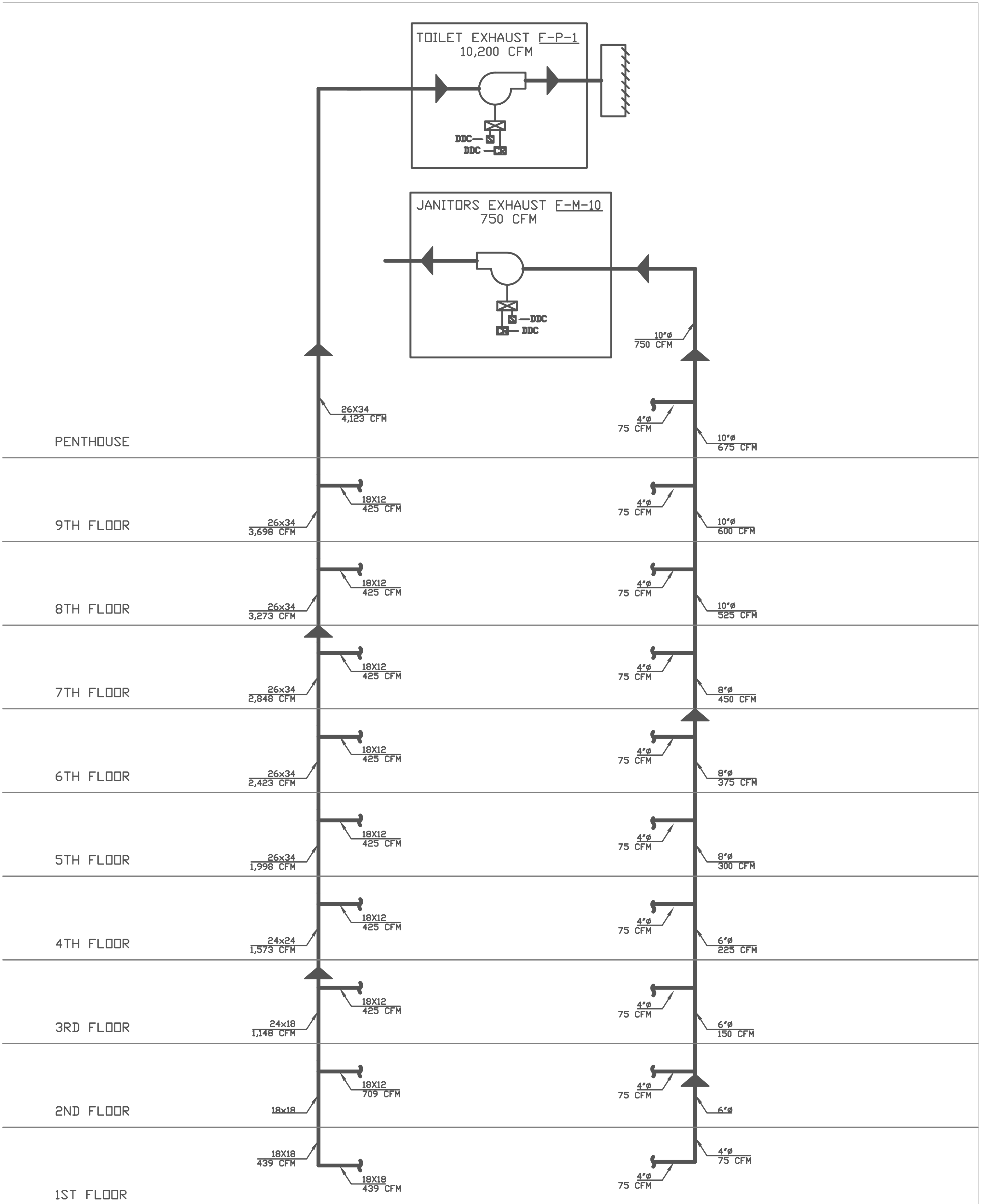
S.6 VIVARIUM, CAGEWASH EXHAUST SCHEMATIC



S.7 FUME HOOD, SPECIALTY EXHAUST SCHEMATIC

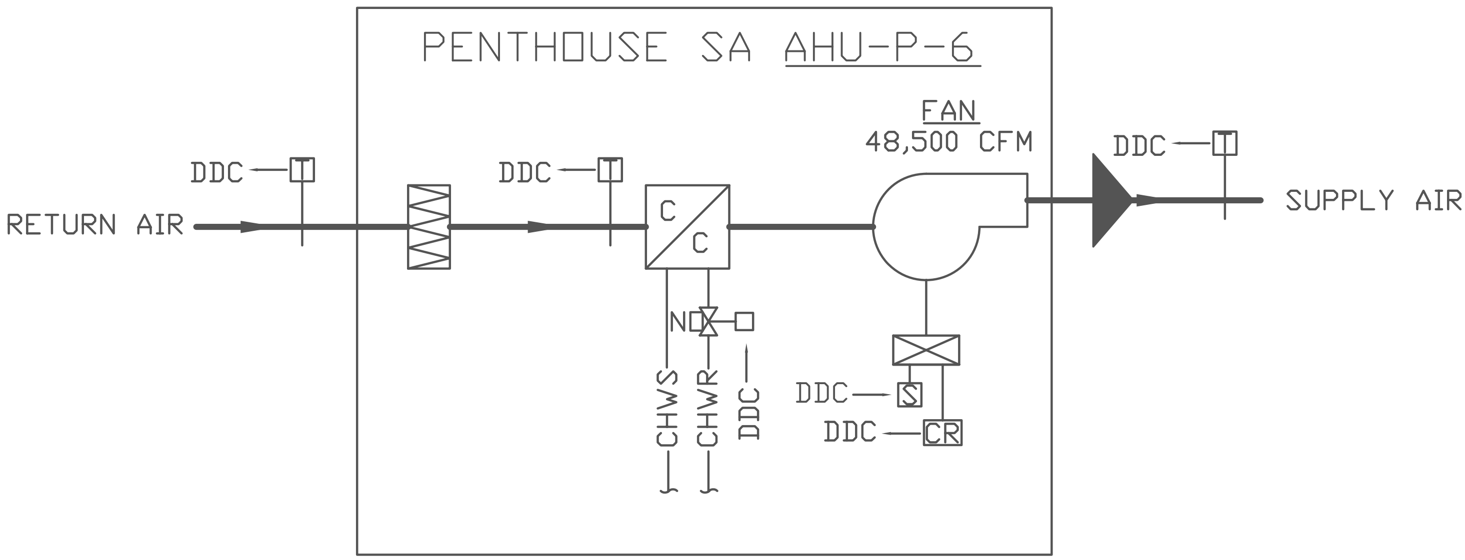


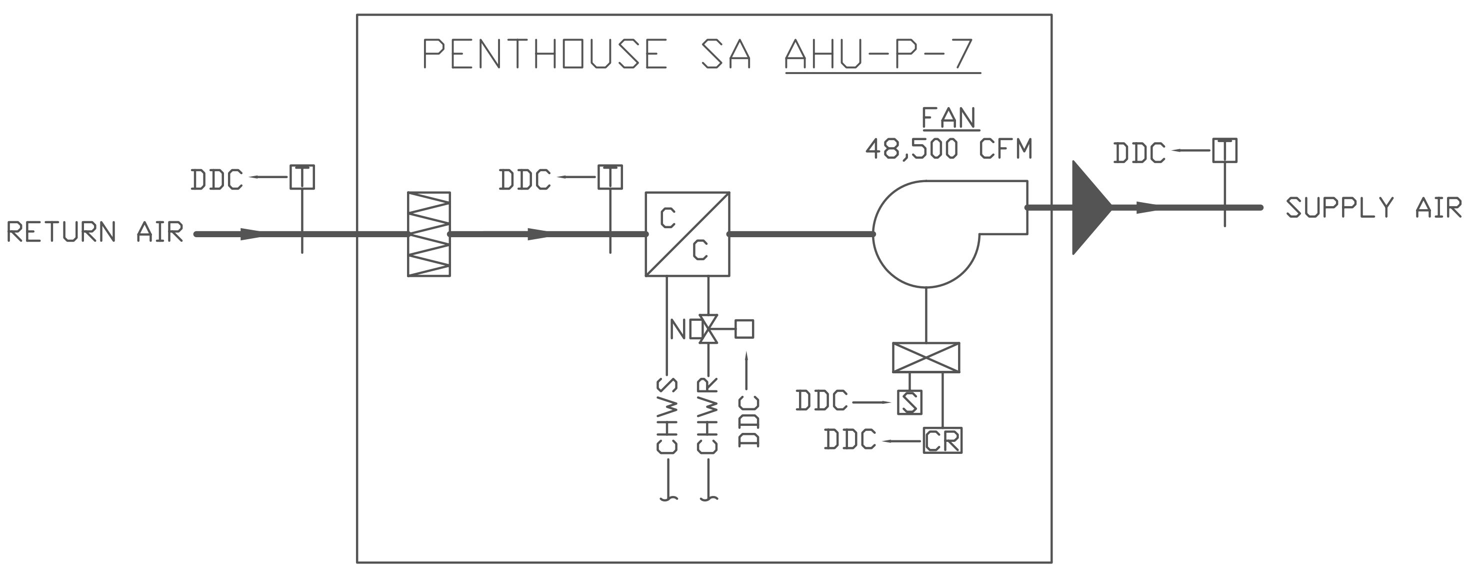
S.8 OFFICE SUPPLY, RETURN SCHEMATIC



S.9 TOILET, JANITORS EXHAUST SCHEMATIC

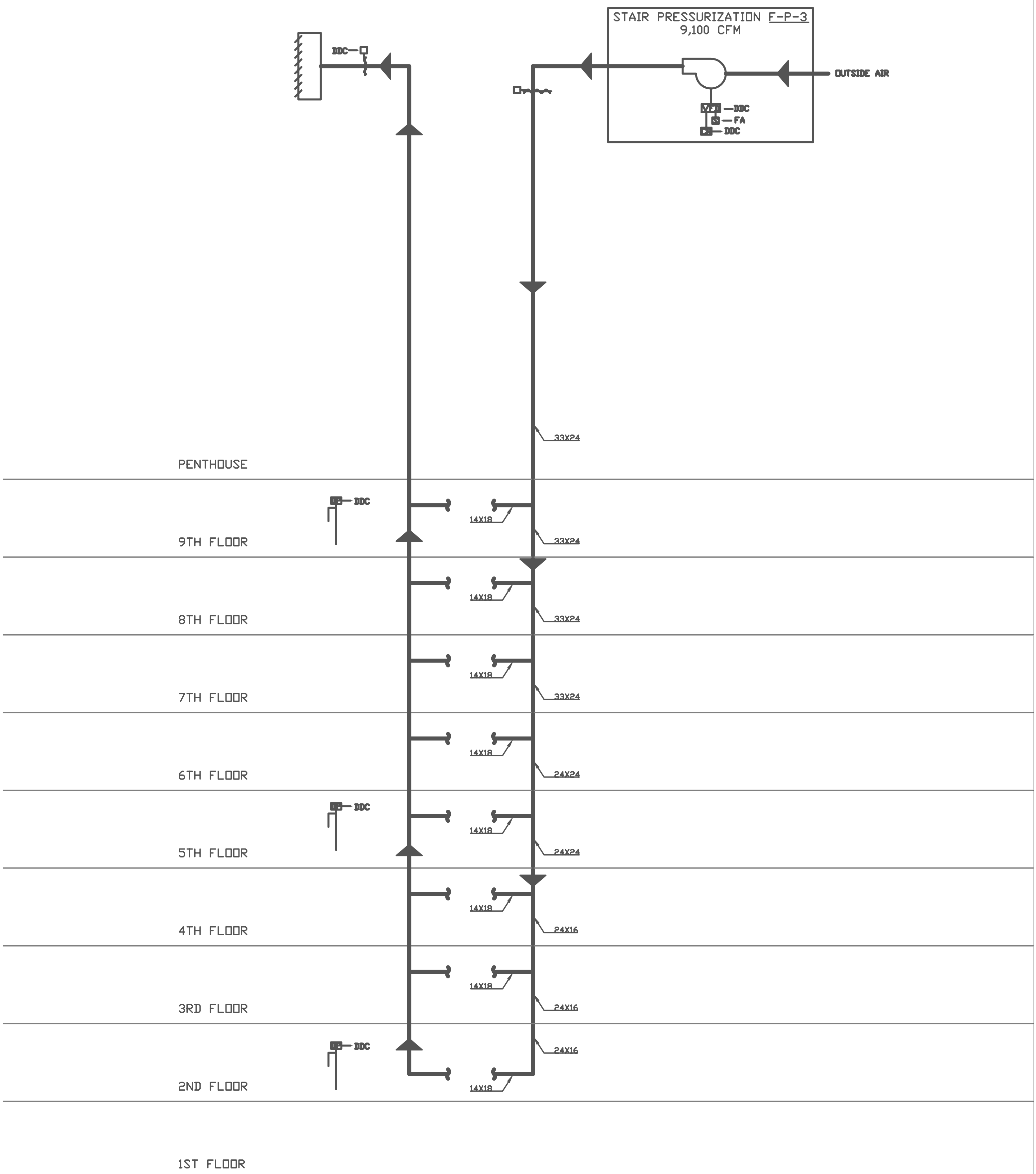
MEZZANINE





PENTHOUSE

S.10 PENTHOUSE SUPPLY, RETURN SCHEMATIC



S.11 STAIR PRESSURIZATION SCHEMATIC

Energy Rates:

T.1 Florida Power & Light Energy Rates

General Service Large Demand- TOU (GSLDT-1)	
Monthly Customer Charge	$38.12
Demand Charges per On-Peak kW	$5.81
Total Demand Charges per On-Peak kW	$8.15
Energy Charges per On-Peak kWh	2.279 cents
Energy Charges per Off-Peak kWh	0.788 cents

Fuel Charge per On-Peak kWh	4.085 cents
Fuel Charge per Off-Peak kWh	3.595 cents

T.2 Peak Periods

On-Peak	
Nov.1- March 31	**April 1- Oct. 31**
6:00 a.m. to 10:00 a.m.	Noon to 9:00 p.m.
6:00 p.m. to 10:00 p.m.	
Off-Peak	
All other hours	
Saturdays and Sundays	
Holidays	

Design Conditions:

T.3 Conditions

	Summer			Winter
	DB F	WB F	RH %	DB F
Outside	91	77		45
Labs	75		50	70
Offices	75		50	70
Mech Rms	80		50	50
Elec Rms	80		50	50

Ventilation ASHRAE 62.1-2004:

T.4 Required Exhaust Rates

Space	CFM
Labs	63,914
Vivaria	9,529
Toilet/Kitchen/Break	4,121
Janitor	605
Radioisotope	105
Cage Wash	4,036
Necropsy	168

T.5 Required OA Rates

Space	CFM
Labs	23,905
Offices	6,660

Design Data:

T.6 Peak Airflow Rates

	Cooling	Heating	Exhaust
Labs	169,481	180,437	169,481
Office	32,980	16,062	9,550
Penthous	15,916		

T.7 Peak Cooling Loads

	Tons
Labs	1,455
Office	299
Penthouse	39

T.8 Annual Power Consumption

	kBtu/yr	kWh/yr
Natural Gas	22,301,580	
Cooling	1,676,555	
Fans	14,546,066	4,261,959
Pumps	52,215	45,299
Lighting	50,471,174	857,511
Total	**89,047,590**	

T.9 Power Cost

		per year
Elec.	On Peak Cons.	$116,474.00
	On Peak Demand	$76,366.00
Gas	On Peak Cons.	$29,401.00
		$222,241.00
		/174,000 sf
		1.28 $/sf-yr