

GLEN A. NEED LIBRARY

COASTAL UNIVERSITY

Wilmington, NC

Technical Assignment 2
Ventilation and Thermal Comfort Report
AE 481W - Thesis



Glen Library Entrance Rendering

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TABLE OF CONTENTS

Executive Summary 2

Project Background 3

Existing Mechanical Systems 3

 Air-Side Summary 4

 HVAC Controls 5

ASHRAE Standard 62.1 (2016): Ventilation Analysis

 Section 1 - Purpose 5

 Section 5 - Systems and Equipment 6

 Section 6 - Procedure 14

 Compliance Summary 16

ASHRAE Standard 55 (2017): Thermal Comfort Analysis

 Section 1 - Purpose 18

 Section 5 - Conditions that Provide Thermal Comfort 18

 Compliance Summary 22

Appendix I - References 22

Appendix II - List of Tables and Figures 23

Appendix III - Ventilation Calculations 24

EXECUTIVE SUMMARY

The Glen A. Weed Library located in Wilmington, North Carolina serves as a newly constructed building to supplement Coastal University's extensive library program. Glen Library includes open collaboration spaces, group study rooms, an auditorium, technology labs and creativity studios to enable learning, research and collaboration. High investments were made for this building and at a total area of 253,000 square feet, the cost per square foot is almost \$400.

The existing mechanical systems within Glen Library were designed to comply with the 2009 North Carolina State Building Code, applicable ASHRAE Standards and LEED Certification requirements. Ventilation rates for all spaces within Glen Library were determined based on ASHRAE 62.1 and LEED IEQc2. Three air handling units, AHU-1, AHU-2, and AHU-3, serve as ventilation and perimeter cooling for the North Area, South Area, and Auditorium 1103. An air recirculation unit, ARU-1, serves as space heating, cooling and humidification for the Automated Storage and Retrieval System (ASRS).

The goal of this technical report is to investigate mechanical system components, ventilation, and thermal comfort as demonstrated in the existing design. The first section of this report analyzes compliance with ASHRAE Standard 62.1 (2016). It was found that almost all the Section 5 – Systems and Equipment requirements were met with further review necessary on a few items. However, when using the ventilation rate procedure in Section 6, it was found that the existing design values for outdoor air flow into the spaces were less conservative, even with an additional 30% airflow to meet LEED IEQc2 credits. The difference was less than 15% and is likely due to discrepancies in engineering judgement with assigning occupancy category types to spaces during calculations.

The second section of this report analyzes the thermal comfort of occupants through compliance with ASHRAE Standard 55 (2017). Three different scenarios were tested using the CBE Thermal Comfort Tool with factors taken into consideration that include temperature, relative humidity, metabolic rate, and clothing insulation with values assumed and taken from building setpoints. The worst-case scenarios with high and low possible occupant metabolic rates and clothing insulation values did not achieve compliance. The scenario tested with most typical dress and clothing ensemble almost met the predicted mean vote (PMV) goal.

PROJECT BACKGROUND

After opening in January of 2013, the Glen A. Weed Library located in Wilmington, North Carolina serves as a newly constructed building to supplement Coastal University's extensive library program. Glen Library is an icon on campus that was designed not to mimic surrounding buildings but to compliment them with a futuristic look. Its main feature is the automated storage and retrieval system, also known as the ASRS or bookBot, which holds up to two-million volumes of books to reduce the building footprint size by almost 40%. Glen Library includes open collaboration spaces, group study rooms, an auditorium, technology labs and creativity studios to enable learning, research and collaboration.

At 253,000 square feet, the total project cost for this new library was \$93,750,000, leaving the cost per square foot to equal almost \$400. In comparison, most libraries in the past have cost less than \$200 per square foot to build. High investments were made towards sustainability efforts for this library including the incorporation of a solar thermal collector, active chilled beams and radiant panels, low-flow plumbing fixtures, a green roof and integral shading devices on the exterior facade. The building facade is comprised of metal panels and glass curtain walls that allow for an abundance of natural light into the study areas. These features along with others collectively contributed to a LEED Silver certification. Please note that a fictitious name and location were used for this project for owner confidentiality.

MECHANICAL SYSTEMS OVERVIEW

The existing mechanical systems within Glen Library were designed to comply with the 2009 North Carolina State Building Code, applicable ASHRAE Standards and LEED Certification requirements. Ventilation rates for all spaces within Glen Library were determined based on ASHRAE 62.1 and LEED IEQc2, although LEED IEQc2 differs from ASHRAE 62.1 because it requires 30% more outdoor air to be provided. The entire scope of the mechanical design includes campus delivered chilled water and steam converted to heating hot water and low pressure steam, three air handling units and one air recirculation unit, exhaust fans, active chilled beams, radiant panels, domestic hot water, solar heating, plumbing and fire protection. The first section of this report will focus on the air-side system to verify ventilation compliance with ASHRAE 62.1 (2016). Mechanical equipment and components are analyzed with respect to Section 5. An analysis on ventilation is then performed to ensure that an adequate amount of outdoor air is being provided within the building as specified by Section 6. The second section of this report investigates the thermal comfort of occupants by using ASHRAE 55 (2017) considering existing design setpoints and additional factors that contribute to thermal comfort.

Air-Side Summary

A conventional VAV reheat system is used within Glen Library. There are three air handling units, AHU-1, AHU-2, and AHU-3, that primarily serve for ventilation and perimeter cooling purposes. An equipment summary from the mechanical schedules is shown in Table 1. AHU-1 and AHU-2 are dedicated outdoor air systems (DOAS) providing 100% outdoor air to the spaces they serve. They both include dual wheel units with energy recovery and passive dehumidification. AHU-3 is an independent system bringing in approximately 50% outdoor air to the space it serves. AHU-1 serves floors one through five of the north section of the building, AHU-2 serves floors one through five of the south section, and AHU-3 serves Auditorium 1103.

ARU-1 is an air recirculation unit that serves as space heating, cooling and humidification for the Automated Storage and Retrieval System (ASRS) where air is distributed through a conventionally ducted system. Table 2 summarizes the important features of ARU-1 from the existing mechanical schedule. Figure 1 shows a schematic of these air handling units and the areas that they serve in plan view.

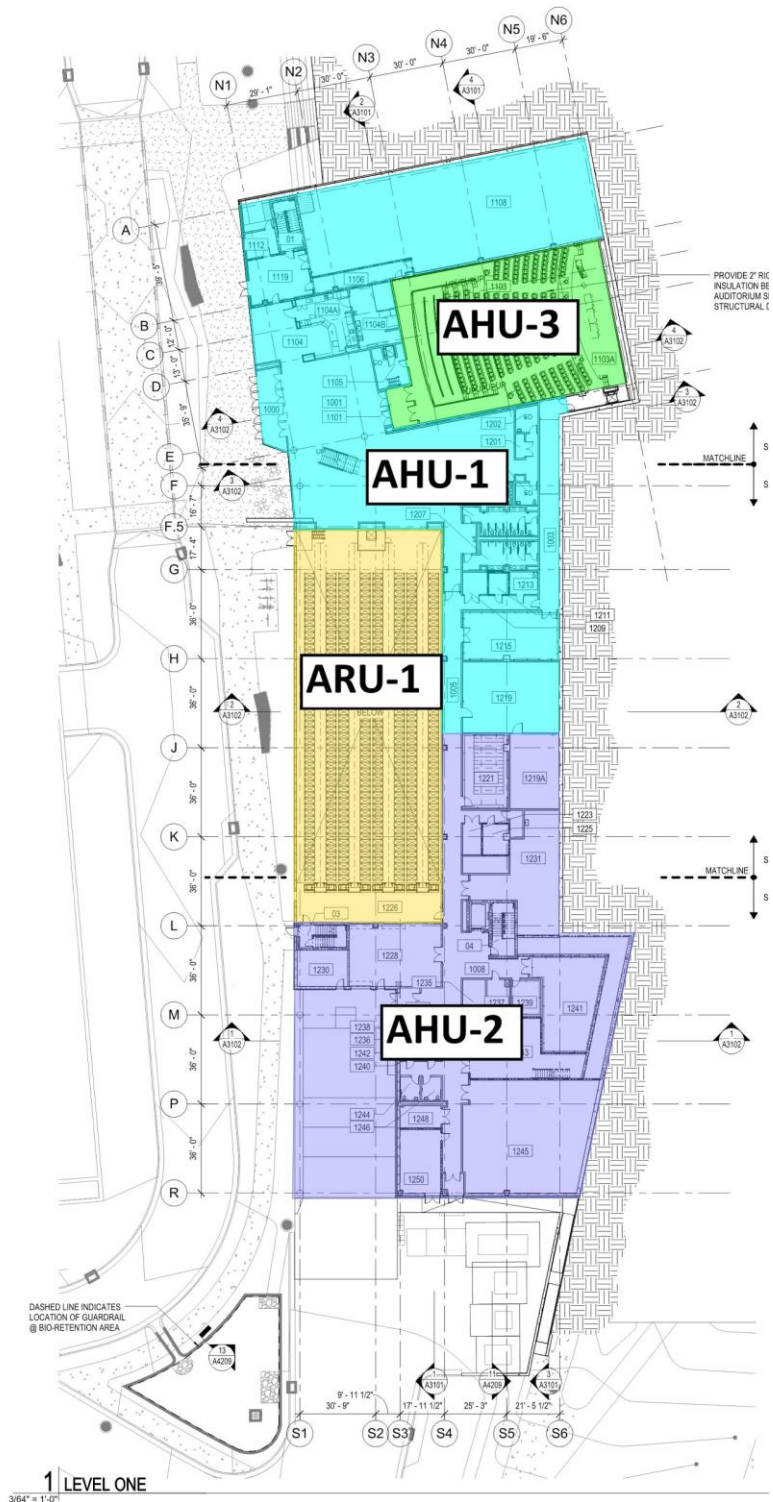


Figure 1: Air-Side System Zoning

Unit	Relief Fan	Location	Supply CFM	Minimum OA	Pre-Filter (MERV)	Final Filter (MERV)
AHU-1	EF-1	North	42175	42175	8	13
AHU-2	EF-2	South	42175	42175	8	13
AHU-3	RF-3	Auditorium	6500	3100	8	13

Table 1: Air Handling Units

Unit	Location	Supply CFM	Pre-Filter (MERV)
ARU-1	ASRS	4000	11

Table 2: Air Recirculation Unit

HVAC System Controls

Zone setpoints are predetermined by the building operator and include normal setback at 72°F, a heating setpoint at 65°F, and setback cooling 80°F each with a dead band of 2°F. Only cooling or heating mode can be entered at one time. Active chilled beams and radiant heating and cooling panels maintain setpoint temperatures. Chilled water and hot water valves open when the space temperatures are above or below setpoints. The chilled water supply for the active chilled beams modulates to maintain zone temperature setpoints. Terminal boxes provide air to the active chilled beams with constant airflow. Occupied setpoints within each terminal box are activated when at least one space served by a terminal box is in occupancy mode which is determined by occupancy sensors.

ASHRAE STANDARD 62.1 (2016)

VENTILATION FOR ACCEPTABLE INDOOR AIR QUALITY

SECTION 1 – PURPOSE

ASHRAE Standard 62.1 was established to provide recognized standards for ventilation system design and acceptable indoor air quality for the health and benefit of building occupants. According to Section 1, it specifies “minimum ventilation rates and other measures intended to provide indoor air quality... acceptable to human occupants and that minimizes adverse health effects.” This section of the report analyzes the existing mechanical design in regard to compliance with ASHRAE Standard 62.1.

SECTION 5 – SYSTEMS AND EQUIPMENT

Each subsection within Section 5 - Systems and Equipment was investigated to receive one of the following statuses: complies, noncompliance, not applicable, or further review necessary.

5.1 VENTILATION AND AIR DISTRIBUTION SYSTEM

5.1.1 DESIGNING FOR AIR BALANCING [COMPLIES]

The ventilation air distribution system is provided with the ability to adjust system controls to meet the minimum ventilation requirements under any load condition. This can be performed manually by an authorized building operator or through electronic controls integrated with the building automation system (BAS).

5.1.2 PLENUM SYSTEMS [NOT APPLICABLE]

There are no above ceiling plenum spaces used to distribute supply air and recirculate return air. This section is not applicable because all spaces within Glen Library receive airflow through traditional ductwork or natural ventilation and transfer air between spaces.

5.1.3 DOCUMENTATION OF AIR BALANCE TESTING [COMPLIES]

The specifications for Glen Library state that National Standards must be met for measuring and balancing airflows. The Control Contractor must also work in association with the Test and Balance Contractor to determine actual required airflow offset in order to maintain a positive building pressure without creating door opening forces that exceed code values. The total exhaust fan setpoint on the DOAS air handling units were calculated by subtracting the total exhaust (3888 cfm) and offsets (850 cfm) from the total supply.

5.2 EXHAUST DUCT LOCATIONS [NOT APPLICABLE]

Air classes as defined by ASHRAE Standard 62.1 are described in Table 3 to the right. Section 5.2 requires that exhaust air of class 4 is negatively pressurized through ductwork and plenum spaces. There is no generation of Class 4 air within Glen Library, so this section does not apply. However, two exhaust fans EF-3 and EF-4 exhaust Class 3 air from restrooms. Their locations are shown in Figure 2 on the following page.

Air Class	Description
Class 1	Air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odor
Class 2	Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odors (Class 2 air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.)
Class 3	Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor
Class 4	Air with highly objectionable fumes or gases or with potentially dangerous particles, bioaerosols, or gases, at concentrations high enough to be considered as harmful

Table 3: Air Class Definitions by ASHRAE Standard 62.1

5.3 VENTILATION SYSTEM CONTROLS

5.3.1 **[COMPLIES]** This section states that all systems should be provided with manual or automatic controls to maintain no less than the minimum outdoor airflow (Vot). As stated in the mechanical system summary narrative, manual and automatic controls are provided to ensure minimum outdoor airflow is being provided.

5.3.2 **[COMPLIES]** Multiple zone VAV Systems with fans that provide variable primary air (Vps) are provided within Glen Library with the specified criteria in option (a) that includes a combination of outdoor air intakes and return air dampers that modulates to maintain no less than the outdoor air intake flow (Vot).

5.4 AIRSTREAM SURFACES

5.4.1 RESISTANCE TO MOLD GROWTH **[COMPLIES]**

All HVAC ductwork must be resistant to mold growth and erosion. The specifications of Glen Library state that “all penetrations of the Evolution™ [mechanical system insulation] and exposed ends of insulation shall be sealed with a mold resistant vapor barrier mastic.” In the supply and return ductwork, sound attenuating devices are to be made of material treated to actively inhibit the growth of mold, mildew, bacteria and fungi and comply with UL 181 and NFPA 90A. Air terminal devices also comply with insulation requirements of UL 181 and fungi resistance of ASTM C665.

5.5 OUTDOOR AIR INTAKES

5.5.1 LOCATION **[COMPLIES]**

This section requires that outdoor air intakes must be located such that the shortest distance from the intake to any specific potential outdoor contaminant source shall be equal to or greater than the separation distance listed in ASHRAE 62.1 Table 5.5.1 (or the calculation method in Normative Appendix B). For this section, Table 5.5.1 was used to analyze compliance. The only

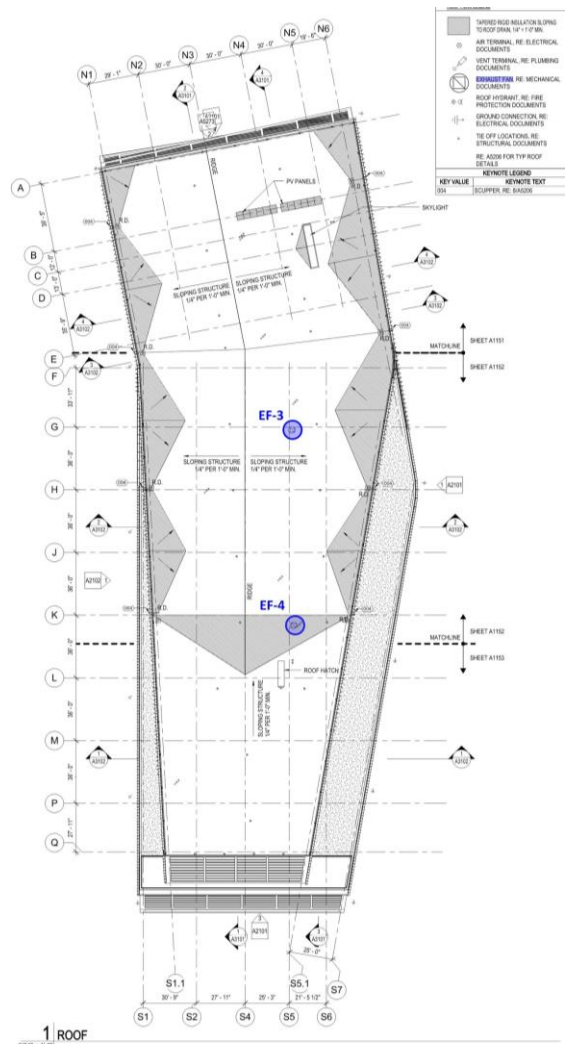
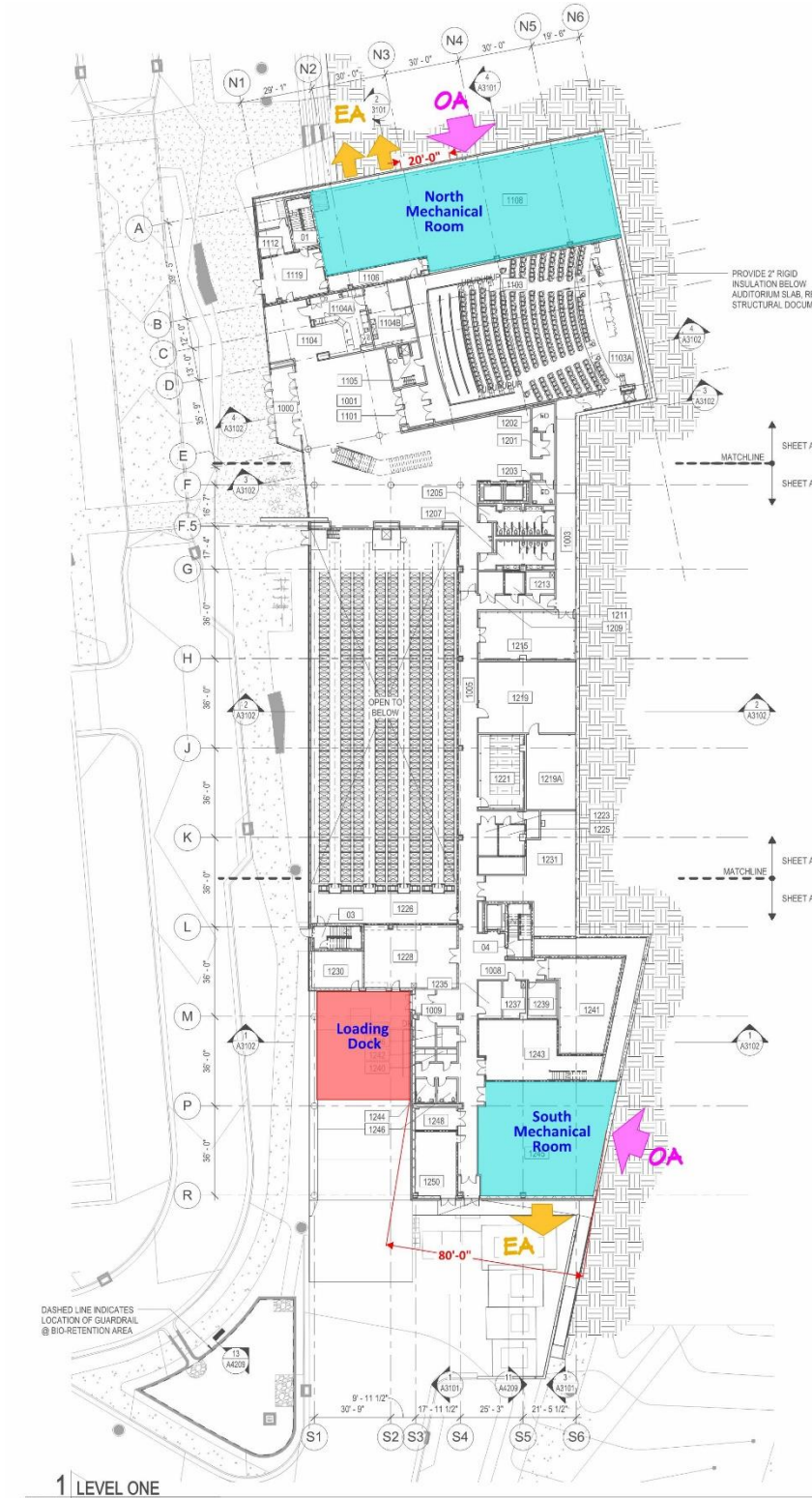


Figure 2: Roof Exhaust Fan Locations

potential contaminant source located around Glen Library is the loading dock which is plan west of the building, as seen highlighted in red in Figure 3. This was measured to be 80 feet from the nearest outdoor air intake at the South Mechanical Room, which complies with the distance required in Table 4 shown on the following page.



The exhaust air relief at the North Mechanical Room is 20 feet from the nearest outdoor air intake. This complies with the Class 3 air relief requirement which at a minimum location of 15 feet away. This does not comply with Class 4 air which must be located at 30 feet away from the nearest outdoor air intake, but it is assumed that no Class 4 air is being generated within the building.

Figure 3: Outdoor Air Intakes and Exhaust Air Reliefs

Object	Minimum Distance, ft (m)
Class 2 air exhaust/relief outlet ^a	10 (3)
Class 3 air exhaust/relief outlet ^a	15 (5)
Class 4 air exhaust/relief outlet ^b	30 (10)
Plumbing vents terminating less than 3 ft (1 m) above the level of the outdoor air intake	10 (3)
Plumbing vents terminating at least 3 ft (1 m) above the level of the outdoor air intake	3 (1)
Vents, chimneys, and flues from combustion appliances and equipment ^c	15 (5)
Garage entry, automobile loading area, or drive-in queue ^d	15 (5)
Truck loading area or dock, bus parking/idling area ^d	25 (7.5)
Driveway, street, or parking place ^d	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake ^{e,f}	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Table 4: Air Intake Minimum Separation Distance (ASHRAE Standard 62.1)

5.5.2 RAIN ENTRAINMENT, 5.5.3 RAIN INTRUSION, AND 5.5.4 SNOW ENTRAINMENT

[FURTHER REVIEW NECESSARY]

These sections state that outdoor air intakes must be designed to manage rain and snow entrainment. Rain and snow should not intrude at the air handling units and any other outdoor mounted equipment. The specifications do not specifically call out rain or snow entrainment, so further review is necessary at this time. It is assumed that the equipment manufacturer would produce a design that meets this criteria. Furthermore, Wilmington, NC does not experience a significant amount of snow because it is located in ASHRAE Climate Zone 3A however the specifications require that library exterior book return units must be strong enough to not pull apart under the weight of snow. They should also be constructed of weather resistant materials with no corner seams to allow leakage or snow to enter.

5.5.5 BIRD SCREENING **[COMPLIES]**

Bird screening devices are required at outdoor air intakes. The specifications explain that bird and insect screens shall be placed at louvers of intake and exhaust openings of fans, the emergency generator, and any other unit that feeds to supply or exhaust ductwork.

5.6 LOCAL CAPTURE OF CONTAMINATES **[FURTHER REVIEW NECESSARY]**

Discharge from non-combustion equipment that captures the contaminants generated must be ducted directly to the outdoors. Further review is necessary at this time to determine if any contaminants are produced by the mechanical ASRS bookBot and how the air is exhausted within the book storage space.

5.7 COMBUSTION AIR [COMPLIES]

The emergency diesel generator that provides backup power to Glen Library must follow NFPA 37 - Standard for Installation and Use of Stationary Combustion Engines and Gas Turbines and NSPS - Combustion Ignition for Internal Combustion Engines. Included in Section 263213 of the specifications, a safety automatic control system shall also be furnished with the generator.

5.8 PARTICULATE MATTER REMOVAL [COMPLIES]

All filters within mechanical system must be at least a MERV 8 rating according to this section. The three air handling units within Glen Library all include MERV 8 pre-filters and MERV 13 final filters. The air recirculation unit includes a MERV 11 filter. In the specifications, Section 233114 on Ductwork states that all return air inlets must be covered with minimum of MERV 8 filters prior to operation of return and exhaust fans. Additional research shows compliance with ASHRAE Handbook of Fundamentals as shown in Table 5 below.

Std. 52.2 Minimum Efficiency Reporting Value (MERV)	Approx. Std. 52.1 Results		Application Guidelines		
	Dust-Spot Efficiency	Arrestance	Typical Controlled Contaminant	Typical Applications and Limitations	Typical Air Filter/Cleaner Type
20	n/a	n/a	5.0-30 µm Particles Virus (unattached)	Cleanrooms Radioactive materials	HEPA/ULPA Filters ≥99.999% efficiency on 0.1 to 0.2 µm particles, IEST Type F
19	n/a	n/a	Carbon dust Sea salt	Pharmaceutical manufacturing Carcinogenic materials	≥99.999% efficiency on 0.3 µm particles, IEST Type D
18	n/a	n/a	All combustion smoke Radon progeny	Orthopedic surgery	≥99.99% efficiency on 0.3 µm particles, IEST Type C
17	n/a	n/a			≥99.97% efficiency on 0.3 µm particles, IEST Type A
16	n/a	n/a	0.3 to 1.0 µm Particles All bacteria	Hospital inpatient care General surgery	Bag Filters Nonsupported (flexible) microfine fiberglass or synthetic media. 12 to 36 in. deep, 6 to 12 pockets.
15	>95%	n/a	Most tobacco smoke Droplet nuclei (sneeze)	Smoking lounges Superior commercial buildings	Box Filters Rigid style cartridge filters 6 to 12 in. deep may use lofted (air-laid) or paper (wet-laid) media.
14	90 to 95%	>98%	Cooking oil Most smoke		
13	80 to 90%	>98%	Insecticide dust Copier toner Most face powder Most paint pigments		
12	70 to 75%	>95%	1.0 to 3.0 µm Particles Legionella	Superior residential Better commercial buildings	Bag Filters Nonsupported (flexible) microfine fiberglass or synthetic media. 12 to 36 in. deep, 6 to 12 pockets.
11	60 to 65%	>95%	Humidifier dust Lead dust	Hospital laboratories	Box Filters Rigid style cartridge filters 6 to 12 in. deep may use lofted (air-laid) or paper (wet-laid) media.
10	50 to 55%	>95%	Milled flour Coal dust		
9	40 to 45%	>90%	Auto emissions Nebulizer drops Welding fumes		
8	30 to 35%	>90%	3.0 to 10.0 µm Particles Mold	Commercial buildings Better residential buildings	Pleated Filters Disposable, extended-surface, 1 to 5 in. thick with cotton/polyester blend media, cardboard frame.
7	25 to 30%	>90%	Spores Hair spray	Industrial workplaces Paint booth inlet air	Cartridge Filters Graded-density viscous-coated cube or pocket filters, synthetic media.
6	<20%	85 to 90%	Fabric protector Dusting aids		Throwaway Disposable synthetic media panel filters
5	<20%	80 to 85%	Cement dust Pudding mix Snuff Powdered milk		
4	<20%	75 to 80%	>10.0 µm Particles Pollen	Minimum filtration Residential	Throwaway Disposable fiberglass or synthetic panel filters
3	<20%	70 to 75%	Spanish moss Dust mites	Window air conditioners	Washable Aluminum mesh, latex coated animal hair, or foam rubber panel filters
2	<20%	65 to 70%	Sanding dust Spray paint dust		Electrostatic Self-charging (passive) woven polycarbonate panel filter
1	<20%	<65%	Textile fibers Carpet fibers		

Note: MERV for non-HEPA/ULPA filters also includes test airflow rate, but it is not shown here because it is of no significance for the purposes of this table.

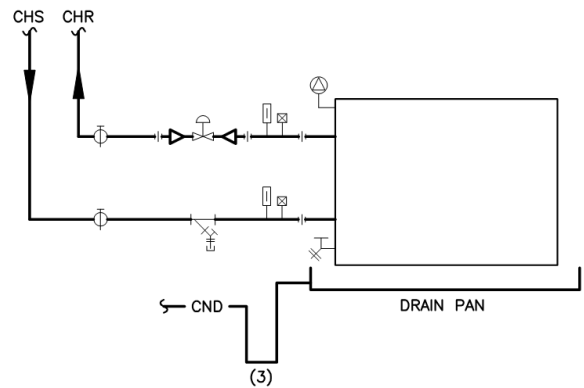
Table 5: Filter Ratings (ASHRAE Handbook of Fundamentals Chapter 28.11)

5.9 DEHUMIDIFICATION SYSTEMS [COMPLIES]

Four humidifiers are located within AHU-1, AHU-2, AHU-3, and ARU-1 with controls set at 35% RH at 72°F. There is a high limit humidity sensor located in the supply ductwork downstream in each one of the humidifiers. This complies with the relative humidity requirements of an occupied space having an RH value of 65% or less.

5.10 DRAIN PANS [COMPLIES]

This section discusses drain pan slope, outlet, and seal details. Drain pans are provided for all equipment that potentially produces condensation or water dripping. The drain pans are assumed to be sloped at least 0.125 in/ft toward the drain outlet with drain connections at the lowest part of the pan. The outlet must be at the lowest point and sized to handle flow under normally operating conditions, and a P trap must be included in the drain line. Specification sections 232116, 232118, and the mechanical details all show compliance with these requirements. Figure 4 on the left shows a typical drain pan and piping detail.



NOTES:

- (1) REFER TO SPECIFICATION SECTION 23 2116 FOR UNIONS AND REDUCING FITTINGS REQUIREMENTS.
- (2) REFER TO SPECIFICATION SECTION 23 2118 FOR BALANCING VALVE SIZING AND STRAIGHT INLET AND OULET PIPING REQUIREMENTS.
- (3) REFER TO COOLING COIL CONDENSATE DRAIN TRAP PIPING DETAIL.

Figure 4: Typical Drain Pan and Piping Detail

5.11 FINNED-TUBE COILS AND HEAT EXCHANGERS [COMPLIES]

Drain pans are in accordance with Section 5.10 as discussed above and are provided under all dehumidifying cooling coil assemblies and condensate producing heat exchangers. Access spaces are provided for fin tubes of at least 18” for individual or multiple tubes.

5.12 HUMIDIFIERS AND WATER-SPRAY SYSTEMS [COMPLIES]

Glen Library includes steam humidifying equipment that should comply with requirements in this section. The specifications require that manufacturer installation instructions for placing mechanical devices downstream from humidifying equipment must be followed.

5.12.1 WATER QUALITY [COMPLIES]

The water purity must meet or exceed potable water standards when entering the ventilation system, space, or water-vapor generator. The water vapor must also contain no chemical additives. The chemical treatment section in the specifications calls out these minimum water quality requirements in the building (specifically for the heating hot water system).

Minimum water quality requirements for closed heating hot water systems shall be as follows:

1. pH	7.0 - 9.5
2. TDS	<500 ppm
3. Hardness as CaCO ₃	<120 ppm
4. Iron	<0.1 ppm
5. Dissolved Oxygen	<0.04 ppm
6. Ryznar Index	>6.0
7. Suspended Solids	>10 micron

Table 6: Minimum Water Quality Requirements

5.13 ACCESS FOR INSPECTION, CLEANING, AND MAINTENANCE

5.13.1 EQUIPMENT CLEARANCE [COMPLIES]

Equipment must be installed with enough working space to allow for inspection, maintenance, adjustments and replacements. There are multiple sections within the specifications for access doors and minimum clearances of different pieces of equipment both on the air-side and water-side of the HVAC systems.

5.13.2 VENTILATION EQUIPMENT ACCESS [COMPLIES]

This section requires means of access to ventilation system components which include air handling units, fan coil units, other terminal units, controllers and sensors. All three air handling units and the air circulation unit have adequate equipment access. The following figures illustrate location and clearance dimensions of the units within the mechanical rooms. ARU-1 is located inside the ASRS and has a ladder and platforms for access.

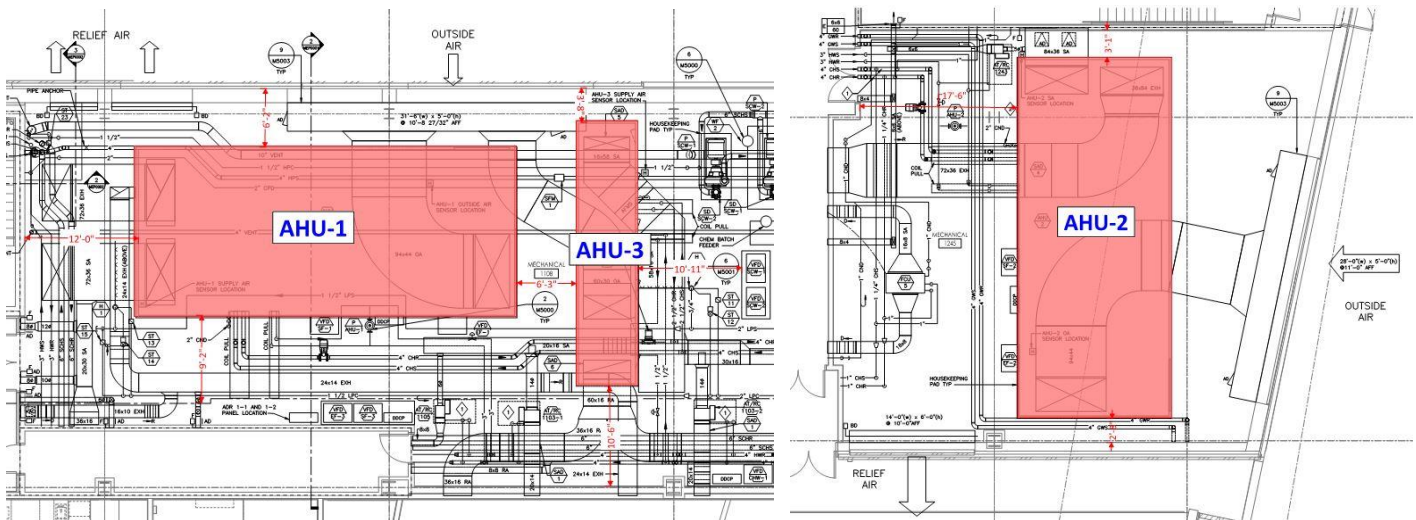


Figure 5: Air Handling Units Equipment Access

5.13.3 AIR DISTRIBUTION SYSTEM [COMPLIES]

Means of access shall be provided in ventilation equipment, ductwork, and plenums to allow for inspections, cleaning, and maintenance purposes. The specifications call for ductwork to be installed not to create obstructions and to allow adequate access and service space for equipment. Flexible ductwork is not allowed above non-accessible ceilings. Access doors should be provided as indicated on the drawings and for all air terminal devices with reheat coils at the inlet side of coils.

5.14 BUILDING ENVELOPE AND INTERIOR SURFACES

5.14.1 BUILDING ENVELOPE [**COMPLIES**]

Uncontrolled entry of outdoor air moisture and pollutants is managed by a carefully designed exterior facade comprised of glass curtain wall and metal panels and EPDM rubber roof along with a green roof section. Weather barriers were used including vapor retarder, caulking, and weather stripping to meet compliance of this section. There are also vestibules at the main entrances of the buildings to prevent undesired air from entering the building.

5.14.2 CONDENSATION ON INTERIOR SURFACES [**COMPLIES**]

This section explains that surfaces must be insulated if they will fall below dew point temperature. This includes components such as pipes and ductwork to prevent condensation from forming. The building specifications call out insulation locations and material types for necessary locations. Dew point temperature sensors are also located throughout the building.

5.15 BUILDINGS WITH ATTACHED PARKING GARAGES [**NOT APPLICABLE**]

This section does not apply to Glen Library because there are no parking structures attached to the building.

5.16 AIR CLASSIFICATION AND RECIRCULATION

5.16.1 CLASSIFICATION [**COMPLIES**]

Recirculation of air within spaces is limited depending on the space air classes as defined earlier in this report. Re-designation of air is permitted to be transferred to a new space if it passes an air-cleaning system, but otherwise must be transferred to less clean spaces.

5.17 REQUIREMENTS FOR BUILDINGS CONTAINING ETS AREAS [**NOT APPLICABLE**]

There are no Environmental Tobacco Smoke (ETS) areas within Glen Library, so this section does not apply.

SECTION 6 – VENTILATION RATE PROCEDURE

6.1 GENERAL

ASHRAE 62.1 states that “The Ventilation Rate Procedure, IAQ Procedure, the Natural Ventilation Procedure or a combination should be used to meet the requirements of outdoor airflow rates.” For the design of Glen Library, the Ventilation Rate Procedure was used to determine outdoor airflow rates to individual spaces for mechanical system ventilation based on space type or application, occupancy levels, and floor area. The following sections describe the procedure calculation and results from analysis of this building.

6.2 VENTILATION RATE PROCEDURE

6.2.1 OUTDOOR AIR TREATMENT

Acceptable indoor air quality is defined as air with no known contaminants at harmful concentrations and where 80% or more of people exposed do not express dissatisfaction. Wilmington, NC has an above average air quality compared to many other urban areas, however the ozone and PM 2.5 levels may be unhealthy for sensitive groups. Ventilation systems that provide outdoor air through a supply fan must comply with subsections including Section 6.2.1.1 Particulate Matter Smaller than 10 Micrometers PM10, Section 6.2.1.2 Particulate Matter Smaller than 2.5 Micrometers (PM2.5), and Section 6.2.1.3 Ozone. It is assumed for this analysis that the outdoor air quality is treated accordingly to these sections.

6.2.2 ZONE CALCULATIONS

6.2.2.1 BREATHING ZONE OUTDOOR AIRFLOW

The outdoor airflow required in the breathing zone, (V_{bz}), can be calculated by:

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

where

R_p = outdoor airflow rate required per person as determined from Table 6.2.2.1

P_z = zone population, the peak number of people in the ventilation zone during use

R_a = outdoor airflow rate required per unit area as determined from Table 6.2.2.1

A_z = zone floor area, the net occupiable floor area of the ventilation zone, ft² (m²)

Table 7 below summarizes the ventilation rate and occupancy density values used from ASHRAE Standard 62.1 Table 6.2.2.1 for calculations performed on Glen Library.

Occupancy Category	Occupant Density (#/1000)	People Outdoor Air Rate, R_p (cfm/person)	Area Outdoor Air Rate, R_a (cfm/sf)
Café Dining	70	7.5	0.18
Lecture Classroom	65	7.5	0.06
University Laboratory	25	10	0.18
Computer Lab	25	10	0.12
Media Center	25	10	0.12
Multiuse Assembly	100	7.5	0.06
Auditorium Seating	150	5	0.06
Office Space	5	5	0.06
Main Entry Lobby	10	5	0.06
Storage	2	5	0.06
Conference/ Meeting	50	5	0.06
Corridors	-	-	0.06
Break Rooms	25	5	0.06
Libraries	10	5	0.12
Electrical Equipment	-	-	0.06
Elevator Machine	-	-	0.12
Reception Area	30	5	0.06

Table 7: Minimum Ventilation Rates in Breathing Zone (Table 6.2.2.1 Summary)

6.2.2.2 ZONE AIR DISTRIBUTION EFFECTIVENESS

Zone air distribution effectiveness (E_z) is determined from Table 6.2.2.2 in ASHRAE Standard 62.1. $E_z=1$ was used for calculations on Glen Library.

6.2.2.3 ZONE OUTDOOR AIRFLOW

Zone outdoor airflow (V_{oz}) provided to ventilation zone can be calculated by the following equation.

$$V_{oz} = V_{bz} / E_z$$

6.2.3 SINGLE ZONE SYSTEMS

Where one or more air handlers supply a mixture of outdoor air and recirculated air to only one ventilation zone, the following equation applies. This was used for the ASRS, or bookBot, space within Glen Library.

$$V_{ot} = V_{oz}$$

6.2.4 100% OUTDOOR AIR SYSTEMS

This section is used where the air handler supplies only outdoor air to one or more ventilation zones. AHU-1 and AHU-2 are both DOAS units serving the North and South halves of Glen Library for all levels.

$$V_{ot} = \sum_{\text{all zones}} V_{oz}$$

6.5 EXHAUST VENTILATION

The Prescriptive Compliance Path or Performance Compliance Path can be used to determine exhaust makeup air requirements based on a combination of OA, RA, and TA. For this project, the Prescriptive Compliance Path was used.

6.5.1 PRESCRIPTIVE COMPLIANCE PATH

Exhaust airflows were calculated in accordance with requirements shown in Table 8 below as summarized from ASHRAE Standard 62.1 Table 6.5.

Occupancy Category	Exhaust Rate (cfm/unit)	Exhaust Rate (cfm/sf)	Air Class
Toilets – private	25/50	-	2
Toilets – public	50/70	-	2
Copy/ Printing	-	0.5	2
Janitor Closet, Trash Rooms	-	1.0	3
Locker Rooms	-	0.25	2
Shower Room	20/50	-	2
Workshop	-	0.50	2

Table 8: Minimum Exhaust Airflow Rates (Table 6.5 Summary)

There are four exhaust fans in the existing mechanical design. Two serve the 100% outdoor air handling units and two serve to exhaust Class 3 air out of the restrooms. This is summarized in Table 9 below.

Unit	Serves	Location	CFM
EF-1	AHU-1	North	20890
EF-2	AHU-2	South	20890
EF-3	Toilets	Roof	5175
EF-4	Toilets	Roof	2990

Table 9: Existing Exhaust Fan Summary

Compliance Summary

Area takeoffs were performed for over 350 spaces within Glen Library. They were organized by level (1, 2, 2M, 3, and 4) and area (North, South, Auditorium, and ASRS) to determine which spaces the air handling units were serving. The spaces were then assigned ASHRAE Standard 62.1 occupancy categories and given values for occupancy density, people outdoor air rate, area outdoor air rate, and exhaust rates. The values were summed together to reach a total breathing zone outdoor airflow (V_{bz}) and then the zone outdoor airflow (V_{oz}) assuming a primary outdoor

air fraction (Z_p) value of 1. Additional airflow was added by 30% to meet the LEED IEQc2 requirements. Table 10 shows a summary of the calculated outdoor airflow and the design outdoor airflow that was used for the existing mechanical system. The calculated outdoor airflows were slightly higher than the design. This could be caused by discrepancies in area takeoffs and variances when assigning occupancy categories to spaces due to differing engineering judgement. The differences between values were all within 15% or less. The design outdoor airflows were overall less conservative. Based on the calculations made in this report, the design values do not meet minimum ventilation requirements. However, without including the additional 30% to meet LEED requirements, the calculated outdoor airflow at 30,800 CFM is within 1,000 CFM to the design outdoor airflow shown below.

	Design Outdoor Airflow (CFM)	Calculated Outdoor Airflow (CFM)
Vbz	29,570	35,000
Voz	29,570	35,000
Voz + 30%	42,654	45,500

Table 10: Ventilation Calculations Summary

The outdoor airflow and exhaust rates were totaled for each of the four air handling units. Table 11 below summarizes the calculated values for each of the units. When totaling the outdoor airflows for AHU-1 and AHU-2, the building was split into North and South areas. Assumptions were made because it is unsure exactly what rooms the designers assigned to each DOAS unit. In comparison, the design team found that AHU-1 and AHU-2 should have an outdoor airflow rate of 21,325 CFM per unit when split evenly.

	Voz + 30% (CFM)	Exhaust Rate (CFM per unit)	Exhaust Rate (CFM per sf)
AHU-1	710	0	0
AHU-2	25890	3875	745
AHU-3	14192	2150	11
ARU-1	5425	0	0

Table 11: Calculated Equipment Outdoor and Exhaust Airflow Summary

ASHRAE STANDARD 55 (2017)

THERMAL ENVIRONMENTAL CONDITIONS FOR HUMAN OCCUPANCY

SECTION 1 - PURPOSE

The purpose of ASHRAE Standard 55 is to “specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to the majority of occupants within the space.” This section of the report analyzes existing setpoints within the building to determine if a majority, or at least 80%, of the occupants will be satisfied given conditions explained in Section 5.

SECTION 5 – CONDITIONS THAT PROVIDE THERMAL COMFORT

5.1 GENERAL REQUIREMENTS

According to Section 5.1, the following factors should be addressed when considering acceptable thermal comfort.

1. Metabolic rate
2. Clothing insulation
3. Air temperature
4. Radiant temperature
5. Air speed
6. Humidity

5.2.1 METABOLIC RATE

According to this section, metabolic rates should not be averaged to represent multiple occupants if they vary by greater than 0.1 met, and activities should be chosen closest to what the occupants will be doing in the space. Table 12 highlights typical activities that would occur within a library. For each representative occupant, an overall metabolic rate was determined with the lowest at 1.0 met and the highest at 2.6 met.

Activity	Metabolic Rate		
	Met Units	W/m ²	Btu/h-ft ²
Resting			
Sleeping	0.7	40	13
Reclining	0.8	45	15
Seated, quiet	1.0	60	18
Standing, relaxed	1.2	70	22
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	37
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	48
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	70
Office Activities			
Reading, seated	1.0	55	18
Writing	1.0	60	18
Typing	1.1	65	20
Filing, seated	1.2	70	22
Filing, standing	1.4	80	26
Walking about	1.7	100	31
Lifting/packing	2.1	120	39

Table 12: Metabolic Rates for Typical Tasks (Table 5.2.1.2)

5.2.2 CLOTHING INSULATION

For each representative occupant, typical clothing insulation values were determined based on weather and time of year in Wilmington, NC. The heaviest ensemble of clothing was in the winter where $I_{cl} = 1.01$ clo. The lightest ensemble of clothing was during the summer where $I_{cl} = 0.36$ clo. The garments included in these ensembles is shown in Table 13 below.

Clothing Description	Garments Included ^a	I_{cl} , clo
Trousers	(1) Trousers, short-sleeve shirt	0.57
	(2) Trousers, long-sleeve shirt	0.61
	(3) #2 plus suit jacket	0.96
	(4) #2 plus suit jacket, vest, t-shirt	1.14
	(5) #2 plus long-sleeve sweater, t-shirt	1.01
	(6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/dresses	(7) Knee-length skirt, short-sleeve shirt (sandals)	0.54
	(8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	(9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	(10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	1.04
	(11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10
Shorts	(12) Walking shorts, short-sleeve shirt	0.36
Overalls/coveralls	(13) Long-sleeve coveralls, t-shirt	0.72
	(14) Overalls, long-sleeve shirt, t-shirt	0.89
	(15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	1.37
Athletic	(16) Sweat pants, long-sleeve sweatshirt	0.74
Sleepwear	(17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	0.96

Table 13: Clothing Insulation I_{cl} Values for Typical Ensembles (Table 5.2.2.2A)

5.3 METHODS FOR DETERMINING ACCEPTABLE THERMAL ENVIRONMENT IN OCCUPIED SPACES

The CBE Thermal Comfort Tool by UC-Berkeley Center for the Built Environment was used for the analysis of thermal comfort given the metabolic rates and clothing insulation values chosen above. The CBE Thermal Comfort Tool is a graphical method that uses the psychrometric chart and predicted mean vote (PMV) to determine compliance within a predetermined thermal comfort region. Assumptions were made when using this software that include an indoor air setpoint at 70 °F (21.1 °C), an air temperature equal to the mean radiant temperature, an airspeed at 0.1 m/s, and relative humidity at 50%.

Three scenarios were tested. Scenario 1 was a worst-case scenario for being uncomfortably cold where an occupant would wear light clothing while seated at rest. Scenario 2 was another worst-case scenario where an occupant would be heavily dressed while walking. Lastly, Scenario 3 was an ideal scenario where an occupant would wear medium clothing while studying (what a typical student would be doing while in Glen Library).

SCENARIO 1 - LIGHT CLOTHING, SEATED AT REST [NONCOMPLIANCE]

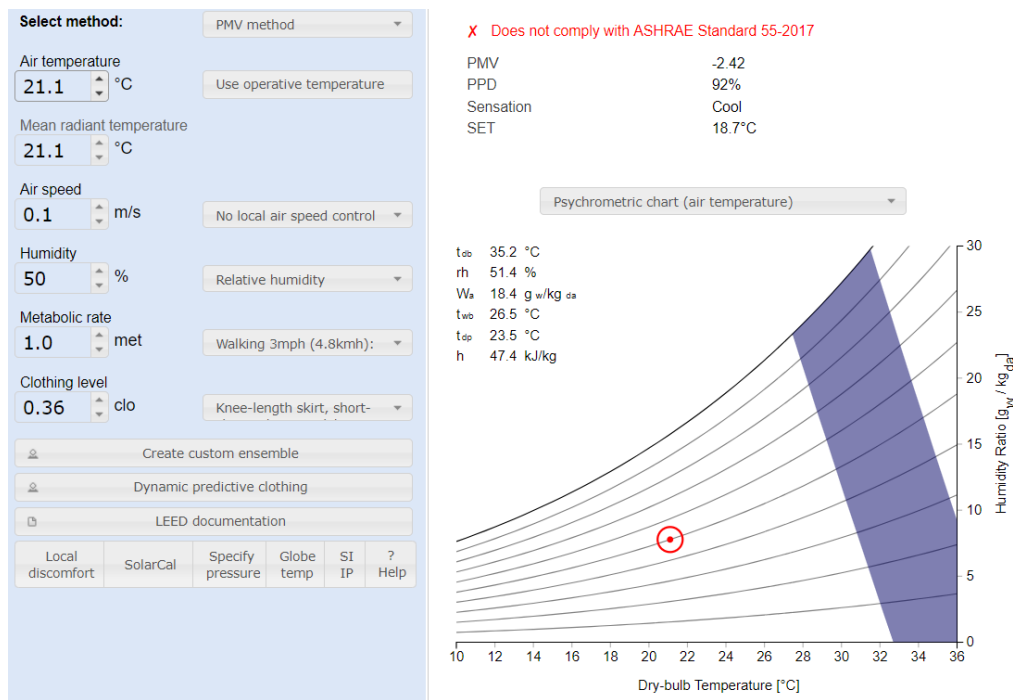


Figure 6: Thermal Comfort Scenario 1

SCENARIO 2 - HEAVY CLOTHING, WALKING [NONCOMPLIANCE]

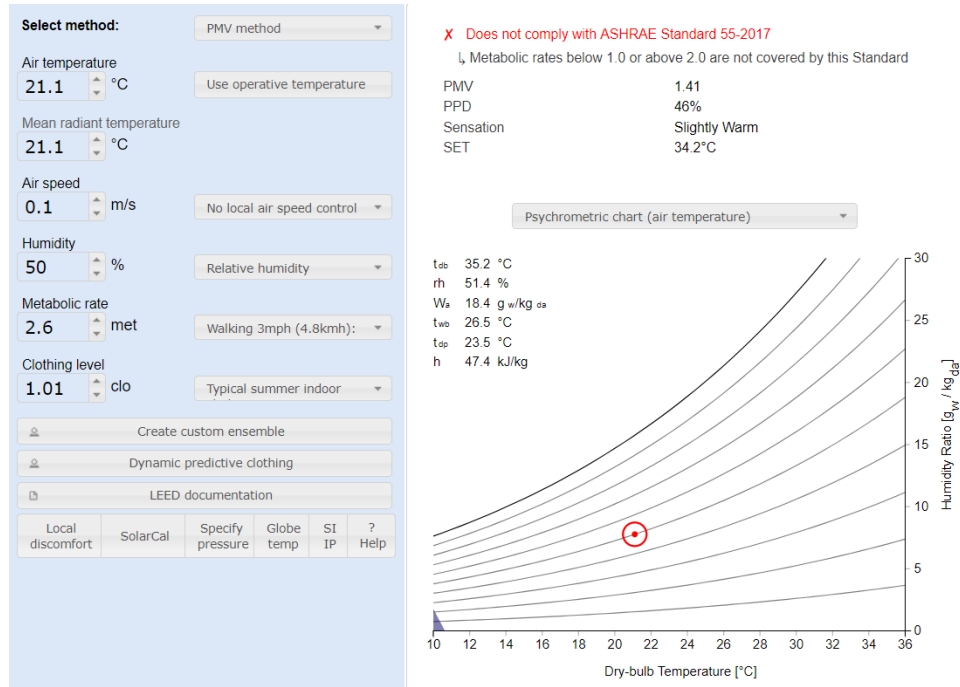


Figure 7: Thermal Comfort Scenario 2

SCENARIO 3 - MEDIUM CLOTHING, STUDYING [NONCOMPLIANCE]

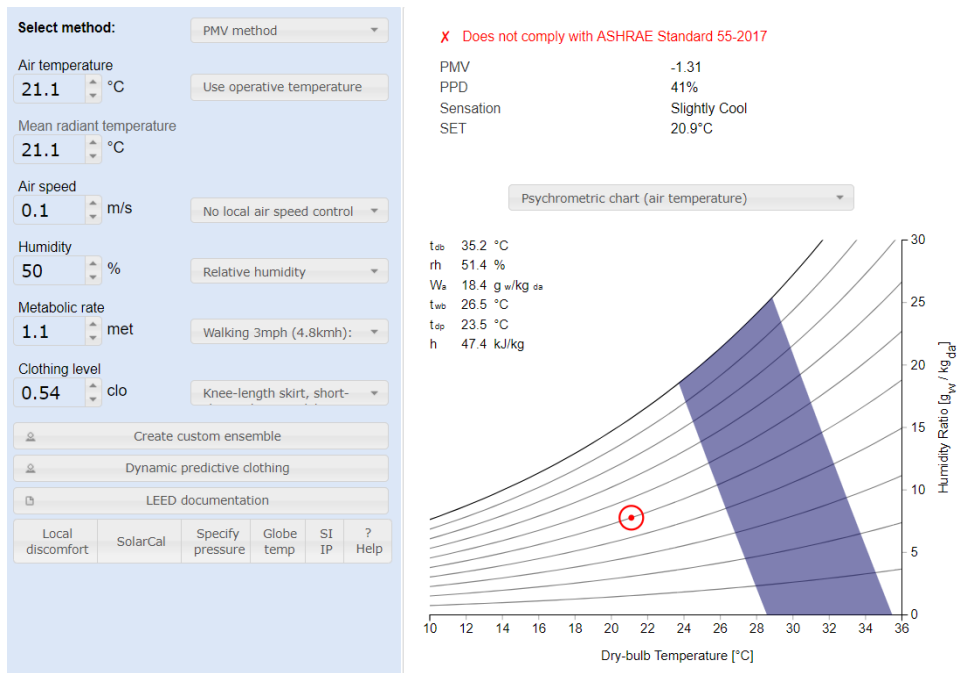


Figure 8: Thermal Comfort Scenario 3

Compliance Summary

Each of the conditions inputted into the software were realistic values for temperature, relative humidity, metabolic rate, and clothing insulation that an occupant would experience within Glen Library. However, none of the scenarios tested complied with ASHRAE Standard 55. Scenario 3 was the closest to compliance with a slightly cool sensation. Additional combinations could be tested with different variables for the factors listed above.

APPENDIX I - REFERENCES

ASHRAE, *ASHRAE/ANSI Standard 55-2017 Thermal environmental conditions for human occupancy*. 2010, American Society of Heating, Refrigerating, and Air-Conditioning Engineers: Atlanta, GA.

ASHRAE, *ANSI/ASHRAE Standard 62.1-2016. Ventilation for acceptable indoor air quality*. 2010, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.: Atlanta, GA.

CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley. Hoyt Tyler, Schiavon Stefano, Piccioli Alberto, Cheung Toby, Moon Dustin, and Steinfeld Kyle, 2017, <http://comfort.cbe.berkeley.edu/>

APPENDIX II – LIST OF TABLES AND FIGURES

List of Tables

Table 1: Air Handling Units 5

Table 2: Air Recirculation Unit 5

Table 3: Air Class Definitions by ASHRAE Standard 62.1 6

Table 4: Air Intake Minimum Separation Distance (ASHRAE Standard 62.1) 9

Table 5: Filter Ratings (ASHRAE Handbook of Fundamentals Chapter 28.11) 10

Table 6: Minimum Water Quality Requirements 11

Table 7: Minimum Ventilation Rates in Breathing Zone (Table 6.2.2.1 Summary) 15

Table 8: Minimum Exhaust Airflow Rates (Table 6.5 Summary) 16

Table 9: Existing Exhaust Fan Summary 16

Table 10: Ventilation Calculations Summary 17

Table 11: Calculated Equipment Outdoor and Exhaust Airflow Summary 17

Table 12: Metabolic Rates for Typical Tasks (Table 5.2.1.2) 19

Table 13: Clothing Insulation I_{cl} Values for Typical Ensembles (Table 5.2.2.2A) 19

List of Figures

Figure 1: Air-Side System Zoning 4

Figure 2: Roof Exhaust Fan Locations 7

Figure 3: Outdoor Air Intakes and Exhaust Air Reliefs 8

Figure 4: Typical Drain Pan and Piping Detail 11

Figure 5: Air Handling Units Equipment Access 12

Figure 6: Thermal Comfort Scenario 1 20

Figure 7: Thermal Comfort Scenario 2 21

Figure 8: Thermal Comfort Scenario 3 21

APPENDIX III – VENTILATION CALCULATIONS

Level	Building Area	Room Number	Room Name	Occupancy Category	Az - Floor Area	Occupant Density (#/1000 SF)	Pz - Number of People in Zone	Rp - People Outdoor Air Rate (CFM/person)	Ra - Area Outdoor Air Rate (CFM/SF)	Exhaust Rate (CFM/unit)	Exhaust Rate (CFM/SF)	Air Class	Vbz - Breathing Zone Outdoor Airflow	Voz + 30%	Total Exhaust (CFM/unit)	Total Exhaust (CFM/SF)
1	N	1108	Mechanical Room	Mechanical Equipment	4537	0	0	0	0.06	0	0	1	272.22	353.886	0	0
1	N	1106	Corridor	Corridor	252	0	0	0	0.06	0	0	1	15.12	19.656	0	0
1	N	1119	Corridor	Corridor	445	0	0	0	0.06	0	0	1	26.7	34.71	0	0
1	N	01	Stairs	Stairs	189	0	0	0	0	0	0	1	0	0	0	0
1	N	1112	BAS/FACP	Electrical Equipment	131	0	0	0	0.06	0	0	1	7.86	10.218	0	0
1	N	1104B	Service Area	Kitchen Prep	430	20	8.6	5	0.06	0	0	1	68.8	89.44	0	0
1	N	1105	Control Room	Electrical Equipment	187	0	0	0	0.06	0	0	1	11.22	14.586	0	0
1	N	1104	Cafe	Cafe Dining	950	70	66.5	7.5	0.18	0	0	1	669.75	870.675	0	0
1	N	1001	Lobby	Main Entry Lobby	4352	10	43.52	5	0.06	0	0	1	478.72	622.336	0	0
1	N	1101	Vestibule	Vestibule	162	0	0	0	0	0	0	1	0	0	0	0
1	N	1000	Vestibule	Vestibule	296	0	0	0	0	0	0	1	0	0	0	0
1	N	1202	Nursing Mothers	Break Room	94	25	2.35	5	0.06	0	0	1	17.39	22.607	0	0
1	N	1201	Wheelchair Storage	Storage	163	0	0	0	0	0	0	1	0	0	0	0
1	N	1205	Women's Toilet	Toilet - Public	296	0	7	0	0	50	0	2	0	0	350	0
1	N	1203	Single Toilet	Toilet - Private	81	0	1	0	0	25	0	2	0	0	25	0
1	N	1215	Furniture Storage	Storage	773	0	0	0	0	0	0	1	0	0	0	0
1	N	1213	Janitor	Janitor, Trash and Recycling	104	0	0	0	0	0	1	3	0	0	0	104
1	N	1209	IDF	Electrical Equipment	89	0	0	0	0.06	0	0	1	5.34	6.942	0	0
1	N	1211	Electrical	Electrical Equipment	67	0	0	0	0.06	0	0	1	4.02	5.226	0	0
1	N	1105B	Upper Control Room	Electrical Equipment	319	0	0	0	0.06	0	0	1	19.14	24.882	0	0
1	N	1004	Corridor	Corridor	382	0	0	0	0.06	0	0	1	22.92	29.796	0	0
2	N	2110	Multipurpose	Multiuse Assembly	5334	100	533.4	7.5	0.06	0	0	1	4320.54	5616.702	0	0
2	N	2102	Gallery Office	Office Space	222	5	1.11	5	0.06	0	0	1	18.87	24.531	0	0
2	N	01	Stairs 01	Stairs	188	0	0	0	0	0	0	1	0	0	0	0
2	N	2005	Corridor	Corridor	210	0	0	0	0.06	0	0	1	12.6	16.38	0	0
2	N	2004	Corridor	Corridor	328	0	0	0	0.06	0	0	1	19.68	25.584	0	0
2	N	2108	Gallery AV Closet	Electrical Equipment	291	0	0	0	0.06	0	0	1	17.46	22.698	0	0
2	N	2104	Catering Storage	Storage	241	2	0.482	5	0.06	0	0	1	16.87	21.931	0	0
2	N	2106	Multi-Purpose Furniture	Storage	581	0	0	0	0	0	0	1	0	0	0	0
2	N	2112	Exhibit Storage	Storage	25	0	0	0	0	0	0	1	0	0	0	0
2	N	02	Stairs 02	Stairs	271	0	0	0	0	0	0	1	0	0	0	0
2	N	2116	Work Group Meeting	Office Space	219	5	1.095	5	0.06	0	0	1	18.615	24.1995	0	0
2	N	2114	Work Group Meeting	Office Space	223	5	1.115	5	0.06	0	0	1	18.955	24.6415	0	0
2	N	2001	Gallery and Lobby	Main Entry Lobby	8190	10	81.9	5	0.06	0	0	1	900.9	1171.17	0	0
2	N	2000	Vestibule	Vestibule	399	0	0	0	0	0	0	1	0	0	0	0
2	N	2113	Janitor	Janitor, Trash and Recycling	45	0	0	0	0	0	1	3	0	0	0	45
2	N	2117	Corridor	Corridor	155	0	0	0	0.06	0	0	1	9.3	12.09	0	0
2	N	2111	Men's Toilet	Toilet - Public	185	0	7	0	0	50	0	2	0	0	350	0
2	N	2007	Corridor	Corridor	1036	0	0	0	0.06	0	0	1	62.16	80.808	0	0
2	N	2109	Gallery Storage	Storage	700	0	0	0	0	0	0	1	0	0	0	0
2	N	2122	Janitor	Janitor, Trash and Recycling	80	0	0	0	0	0	0	3	0	0	0	0
2	N	2110E	AV Control	Electrical Equipment	91	0	0	0	0.06	0	0	1	5.46	7.098	0	0
2	N	2115	Women's Toilet	Toilet - Public	199	0	7	0	0	50	0	2	0	0	350	0
2	N	07	Stairs 07	Stairs	98	0	0	0	0	0	0	1	0	0	0	0
2	N	2201	Service Desk	Reception Area	433	30	12.99	5	0.06	0	0	1	90.93	118.209	0	0
2	N	2205	Device Storage	Storage	149	0	0	0	0	0	0	1	0	0	0	0
2	N	2204	AV Closet	Electrical Equipment	77	0	0	0	0.06	0	0	1	4.62	6.006	0	0
2	N	2203	Electrical	Electrical Equipment	75	0	0	0	0.06	0	0	1	4.5	5.85	0	0
2	N	2206B	AV Room	Electrical Equipment	43	0	0	0	0.06	0	0	1	2.58	3.354	0	0
2	N	2207	Men's Toilet	Toilet - Public	209	0	7	0	0	50	0	2	0	0	350	0
2	N	2208	Women's Toilet	Toilet - Public	251	0	7	0	0	50	0	2	0	0	350	0
2	N	2211	AV Closet	Electrical Equipment	87	0	0	0	0.06	0	0	1	5.22	6.786	0	0
2	N	2200	Learning Commons	Library	4677	10	46.77	5	0.12	0	0	1	795.09	1033.617	0	0
2	N	2206	Immersion Theater	Media Center	323	25	8.075	10	0.12	0	0	1	119.51	155.363	0	0
2M	N	3215	Group Study	Office Space	96	5	0.48	5	0.06	0	0	1	8.16	10.608	0	0
2M	N	3214	Presentation	Office Space	193	5	0.965	5	0.06	0	0	1	16.405	21.3265	0	0
2M	N	3213	Group Study	Office Space	187	5	0.935	5	0.06	0	0	1	15.895	20.6635	0	0
2M	N	3212	Group Study	Office Space	222	5	1.11	5	0.06	0	0	1	18.87	24.531	0	0
2M	N	3211	Group Study	Office Space	242	5	1.21	5	0.06	0	0	1	20.57	26.741	0	0
2M	N	3209	Group Study	Office Space	200	5	1	5	0.06	0	0	1	17	22.1	0	0

2M	N	3208	Group Study	Office Space	200	5	1	5	0.06	0	0	1	17	22.1	0	0
2M	N	3205	IDF	Electrical Equipment	70	0	0	0	0.06	0	0	1	4.2	5.46	0	0
2M	N	3206	Electrical	Electrical Equipment	67	0	0	0	0.06	0	0	1	4.02	5.226	0	0
2M	N	3207	Janitor	Janitor, Trash and Recycling	94	0	0	0	0	0	1	3	0	0	0	94
2M	N	3201	Gaming	Media Center	603	25	15.075	10	0.12	0	0	1	223.11	290.043	0	0
2M	N	3219	Group Study	Office Space	102	5	0.51	5	0.06	0	0	1	8.67	11.271	0	0
2M	N	3220	Group Study	Office Space	102	5	0.51	5	0.06	0	0	1	8.67	11.271	0	0
2M	N	3218	Group Study	Office Space	102	5	0.51	5	0.06	0	0	1	8.67	11.271	0	0
2M	N	3217	Group Study	Office Space	102	5	0.51	5	0.06	0	0	1	8.67	11.271	0	0
2M	N	3032	Corridor	Corridor	477	0	0	0	0.06	0	0	1	28.62	37.206	0	0
3	N	4160	Director	Office Space	243	5	1.215	5	0.06	0	0	1	20.655	26.8515	0	0
3	N	01	Stair 01	Stairs	205	0	0	0	0	0	0	1	0	0	0	0
3	N	4140	IEI Commons	Media Center	4498	25	112.45	10	0.12	0	0	1	1664.26	2163.538	0	0
3	N	4129	Director	Office Space	257	5	1.285	5	0.06	0	0	1	21.845	28.3985	0	0
3	N	4128	Assistant Director	Office Space	145	5	0.725	5	0.06	0	0	1	12.325	16.0225	0	0
3	N	4127	Assistant Director	Office Space	143	5	0.715	5	0.06	0	0	1	12.155	15.8015	0	0
3	N	4126	Focus Booth	Office Space	50	5	0.25	5	0.06	0	0	1	4.25	5.525	0	0
3	N	4125	Focus Booth	Office Space	50	5	0.25	5	0.06	0	0	1	4.25	5.525	0	0
3	N	4124	Assistant Director	Office Space	145	5	0.725	5	0.06	0	0	1	12.325	16.0225	0	0
3	N	4123	Assistant Director	Office Space	141	5	0.705	5	0.06	0	0	1	11.985	15.5805	0	0
3	N	4120	Open Meeting	Office Space	141	5	0.705	5	0.06	0	0	1	11.985	15.5805	0	0
3	N	4121	Resource	Office Space	413	5	2.065	5	0.06	0	0	1	35.105	45.6365	0	0
3	N	4121A	Exhibit Control	Storage	134	0	0	0	0	0	0	1	0	0	0	0
3	N	4104	Project Team	Office Space	698	5	3.49	5	0.06	0	0	1	59.33	77.129	0	0
3	N	4122	Media Production	Media Center	225	25	5.625	10	0.12	0	0	1	83.25	108.225	0	0
3	N	4100	Corridor	Corridor	3546	0	0	0	0.06	0	0	1	212.76	276.588	0	0
3	N	4106	Meeting Room	Office Space	1509	5	7.545	5	0.06	0	0	1	128.265	166.7445	0	0
3	N	4106A	Resource Storage	Storage	125	0	0	0	0	0	0	1	0	0	0	0
3	N	4109	Hunt Office	Office Space	251	5	1.255	5	0.06	0	0	1	21.335	27.7355	0	0
3	N	4107	Large Group Meeting	Office Space	789	5	3.945	5	0.06	0	0	1	67.065	87.1845	0	0
3	N	4105	Large Group Meeting	Office Space	728	5	3.64	5	0.06	0	0	1	61.88	80.444	0	0
3	N	4110	Control/ IT	Electrical Equipment	54	0	0	0	0.06	0	0	1	3.24	4.212	0	0
3	N	4108	Janitor	Janitor, Trash and Recycling	57	0	0	0	0	0	1	3	0	0	0	57
3	N	02	Stair 02	Stairs	285	0	0	0	0	0	0	1	0	0	0	0
3	N	4103	Executive Conference	Conference/ Meeting	893	50	44.65	5	0.06	0	0	1	276.83	359.879	0	0
3	N	4101	Large Group Workroom	Office Space	820	5	4.1	5	0.06	0	0	1	69.7	90.61	0	0
3	N	4201	Conference	Conference/ Meeting	851	50	42.55	5	0.06	0	0	1	263.81	342.953	0	0
3	N	4131	Library	Library	693	10	6.93	5	0.12	0	0	1	117.81	153.153	0	0
3	N	4315	Group Study	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0
3	N	4314	Group Study	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
3	N	4313	Group Study	Office Space	155	5	0.775	5	0.06	0	0	1	13.175	17.1275	0	0
3	N	4312	Group Study	Office Space	109	5	0.545	5	0.06	0	0	1	9.265	12.0445	0	0
3	N	4311	Group Study	Office Space	135	5	0.675	5	0.06	0	0	1	11.475	14.9175	0	0
3	N	4130	Meeting	Conference/ Meeting	275	50	13.75	5	0.06	0	0	1	85.25	110.825	0	0
3	N	4011	Men's Toilet	Toilet - Public	207	0	7	0	0	50	0	2	0	0	0	350
3	N	4300	Graduate Commons	Conference/ Meeting	4644	50	232.2	5	0.06	0	0	1	1439.64	1871.532	0	0
3	N	4013	Women's Toilet	Toilet - Public	194	0	7	0	0	50	0	2	0	0	0	350
3	N	4204	IDF	Electrical Equipment	130	0	0	0	0.06	0	0	1	7.8	10.14	0	0
3	N	4202	Janitor	Janitor, Trash and Recycling	78	0	0	0	0	0	1	3	0	0	0	78
3	N	4200	Flexible Collection	Library	5163	10	51.63	5	0.12	0	0	1	877.71	1141.023	0	0
3	N	4020	Corridor	Corridor	80	0	0	0	0.06	0	0	1	4.8	6.24	0	0
3	N	4304	AV Closet	Electrical Equipment	128	0	0	0	0.06	0	0	1	7.68	9.984	0	0
3	N	4210	Group Study	Office Space	126	5	0.63	5	0.06	0	0	1	10.71	13.923	0	0
3	N	4302	Group Study	Office Space	159	5	0.795	5	0.06	0	0	1	13.515	17.5695	0	0
3	N	4211	Music	Office Space	85	5	0.425	5	0.06	0	0	1	7.225	9.3925	0	0
4	N	5903	Open Meeting	Conference/ Meeting	7670	50	383.5	5	0.06	0	0	1	2377.7	3091.01	0	0
4	N	01	Stair 01	Stairs	188	0	0	0	0	0	0	1	0	0	0	0
4	N	5147	Head Office	Office Space	233	5	1.165	5	0.06	0	0	1	19.805	25.7465	0	0
4	N	5145	Office	Office Space	130	5	0.65	5	0.06	0	0	1	11.05	14.365	0	0
4	N	5143	Office	Office Space	122	5	0.61	5	0.06	0	0	1	10.37	13.481	0	0
4	N	5141	Office	Office Space	184	5	0.92	5	0.06	0	0	1	15.64	20.332	0	0
4	N	5139	Head Office	Office Space	299	5	1.495	5	0.06	0	0	1	25.415	33.0395	0	0
4	N	5149	Office	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0

4	N	5151	Office	Office Space	121	5	0.605	5	0.06	0	0	1	10.285	13.3705	0	0
4	N	5152	Office	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5154	Office	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5144	Office	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	5146	Office	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	5148	Office	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	5136	Office	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	5134	Office	Office Space	110	5	0.55	5	0.06	0	0	1	9.35	12.155	0	0
4	N	5132	Office	Office Space	109	5	0.545	5	0.06	0	0	1	9.265	12.0445	0	0
4	N	????	Corridor	Corridor	1352	0	0	0	0.06	0	0	1	81.12	105.456	0	0
4	N	5131	Resource	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	02	Stair 02	Stairs	243	0	0	0	0	0	0	1	0	0	0	0
4	N	5142	Janitor	Janitor, Trash and Recycling	112	0	0	0	0	0	1	3	0	0	0	112
4	N	5128	Open Collab	Conference/ Meeting	513	50	25.65	5	0.06	0	0	1	159.03	206.739	0	0
4	N	5153	Office	Office Space	117	5	0.585	5	0.06	0	0	1	9.945	12.9285	0	0
4	N	5155	Office	Office Space	121	5	0.605	5	0.06	0	0	1	10.285	13.3705	0	0
4	N	5157	Office	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0
4	N	5159	Office	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0
4	N	5156	Office	Office Space	121	5	0.605	5	0.06	0	0	1	10.285	13.3705	0	0
4	N	5158	Office	Office Space	123	5	0.615	5	0.06	0	0	1	10.455	13.5915	0	0
4	N	5127	Break	Break Rooms	109	25	2.725	5	0.06	0	0	1	20.165	26.2145	0	0
4	N	5125	Office	Office Space	114	5	0.757	5	0.06	0	0	1	9.69	12.597	0	0
4	N	5123	Head Office	Office Space	268	5	1.34	5	0.06	0	0	1	22.78	29.614	0	0
4	N	5121	Office	Office Space	120	5	0.6	5	0.06	0	0	1	10.2	13.26	0	0
4	N	5119	Office	Office Space	124	5	0.62	5	0.06	0	0	1	10.54	13.702	0	0
4	N	5117	Open Meeting	Conference/ Meeting	126	50	6.3	5	0.06	0	0	1	39.06	50.778	0	0
4	N	5115	Office	Office Space	123	5	0.615	5	0.06	0	0	1	10.455	13.5915	0	0
4	N	5113	Office	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5111	Open Meeting	Conference/ Meeting	164	50	8.2	5	0.06	0	0	1	50.84	66.092	0	0
4	N	5109	Office	Office Space	122	5	0.61	5	0.06	0	0	1	10.37	13.481	0	0
4	N	5102	Corridor	Corridor	299	0	0	0	0.06	0	0	1	17.94	23.322	0	0
4	N	5106	Office	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5104	Office	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5110A	Resource	Office Space	117	5	0.585	5	0.06	0	0	1	9.945	12.9285	0	0
4	N	5112	Office	Office Space	115	5	0.575	5	0.06	0	0	1	9.775	12.7075	0	0
4	N	5116	Office	Office Space	120	5	0.6	5	0.06	0	0	1	10.2	13.26	0	0
4	N	5118	Office	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0
4	N	5100A	Conference	Conference/ Meeting	506	50	25.3	5	0.06	0	0	1	156.86	203.918	0	0
4	N	5127	Break	Break Room	109	25	2.725	5	0.06	0	0	1	20.165	26.2145	0	0
4	N	5125	Office	Office Space	114	5	0.57	5	0.06	0	0	1	9.69	12.597	0	0
4	N	5137	Office	Office Space	121	5	0.605	5	0.06	0	0	1	10.285	13.3705	0	0
4	N	5133	Office	Office Space	119	5	0.595	5	0.06	0	0	1	10.115	13.1495	0	0
4	N	5832	Focus Booth	Office Space	51	5	0.255	5	0.06	0	0	1	4.335	5.6355	0	0
4	N	5831	Focus Booth	Office Space	60	5	0.3	5	0.06	0	0	1	5.1	6.63	0	0
4	N	5100	Reception	Office Space	356	5	1.78	5	0.06	0	0	1	30.26	39.338	0	0
4	N	5100B	Conference	Conference/ Meeting	225	50	11.25	5	0.06	0	0	1	69.75	90.675	0	0
4	N	5174	Toilet Vestibule	Toilet - Public	149	0	0	0	0	50	0	2	0	0	0	0
4	N	5172	Men's Toilet	Toilet - Public	144	0	7	0	0	50	0	2	0	0	350	0
4	N	5173	Women's Toilet	Toilet - Public	122	0	7	0	0	50	0	2	0	0	350	0
4	N	5102	Corridor	Corridor	299	0	0	0	0.06	0	0	1	17.94	23.322	0	0
4	N	5000	Elevator Lobby	Main Entry Lobby	413	10	4.13	5	0.06	0	0	1	45.43	59.059	0	0
4	N	5819	Elevator Controls	Mechanical Equipment	72	0	0	0	0.06	0	0	1	4.32	5.616	0	0
4	N	5816	Women's Toilet	Toilet - Public	341	0	7	0	0	50	0	2	0	0	350	0
4	N	5130A	Resource	Office Space	101	5	0.505	5	0.06	0	0	1	8.585	11.1605	0	0
4	N	5142	Janitor	Janitor, Trash and Recycling	112	0	0	0	0	0	1	3	0	0	0	112
4	N	5107	Head Office	Office Space	225	5	1.125	5	0.06	0	0	1	19.125	24.8625	0	0
4	N	5105	Office	Office Space	120	5	0.6	5	0.06	0	0	1	10.2	13.26	0	0
4	N	5103	Office	Office Space	121	5	0.605	5	0.06	0	0	1	10.285	13.3705	0	0
4	N	5101	Office	Office Space	144	5	0.72	5	0.06	0	0	1	12.24	15.912	0	0
4	N	5231	Bookable Work	Office Space	168	5	0.84	5	0.06	0	0	1	14.28	18.564	0	0
4	N	5232	Bookable Work	Office Space	145	5	0.725	5	0.06	0	0	1	12.325	16.0225	0	0
4	N	5233	Bookable Work	Office Space	143	5	0.715	5	0.06	0	0	1	12.155	15.8015	0	0
4	N	5234	Meeting	Conference/ Meeting	234	50	11.7	5	0.06	0	0	1	72.54	94.302	0	0

4	N	5202	Corridor	Corridor	310	0	0	0	0.06	0	0	1	18.6	24.18	0	0
4	N	5235	Copy	Copy/ Printing	102	0	0	0	0	0	0.5	2	0	0	0	51
4	N	5720	Corridor	Corridor	213	0	0	0	0.06	0	0	1	12.78	16.614	0	0
4	N	5723	Electrical	Electrical Equipment	80	0	0	0	0.06	0	0	1	4.8	6.24	0	0
4	N	5724	IDF	Electrical Equipment	88	0	0	0	0.06	0	0	1	5.28	6.864	0	0
4	N	5812	Men's Toilet	Toilet - Public	331	0	7	0	0	50	0	2	0	0	350	0
4	N	5725	Janitor	Janitor, Trash and Recycling	92	0	0	0	0	0	1	3	0	0	0	92
4	N	1293	Work Stations	Office Space	5801	5	29.005	5	0.06	0	0	1	493.085	641.0105	0	0
4	N	5824	Manager Office	Office Space	108	5	0.54	5	0.06	0	0	1	9.18	11.934	0	0
4	N	5823	Manager Office	Office Space	105	5	0.525	5	0.06	0	0	1	8.925	11.6025	0	0
4	N	5822	Manager Office	Office Space	105	5	0.525	5	0.06	0	0	1	8.925	11.6025	0	0
4	N	5821	Manager Office	Office Space	105	5	0.525	5	0.06	0	0	1	8.925	11.6025	0	0
4	N	5707	Meeting	Mechanical Equipment	285	0	0	0	0.06	0	0	1	17.1	22.23	0	0
4	N	5726	Storage	Conference/ Meeting	182	50	9.1	5	0.06	0	0	1	56.42	73.346	0	0
4	N	5706	Meeting	Mechanical Equipment	150	0	0	0	0.06	0	0	1	9	11.7	0	0
4	N	5701	Collaboration Hub	Conference/ Meeting	1940	50	97	5	0.06	0	0	1	601.4	781.82	0	0
4	N	5004	Corridor	Corridor	785	0	0	0	0.06	0	0	1	47.1	61.23	0	0
4	N	5715	AV Closet	Electrical Equipment	86	0	0	0	0.06	0	0	1	5.16	6.708	0	0
4	N	5714	Resource	Office Space	148	5	0.74	5	0.06	0	0	1	12.58	16.354	0	0
4	N	5214	Bookable Work	Office Space	112	5	0.56	5	0.06	0	0	1	9.52	12.376	0	0
4	N	5242	Bookable Work	Office Space	116	5	0.58	5	0.06	0	0	1	9.86	12.818	0	0
4	N	5223	Focus Booth	Office Space	94	5	0.47	5	0.06	0	0	1	7.99	10.387	0	0
4	N	5222	Focus Booth	Office Space	63	5	0.315	5	0.06	0	0	1	5.355	6.9615	0	0
4	N	5224	Focus Booth	Office Space	64	5	0.32	5	0.06	0	0	1	5.44	7.072	0	0
4	N	5200	Research Commons	Conference/ Meeting	2275	50	113.75	5	0.06	0	0	1	705.25	916.825	0	0
													25888.4665	3875	745	

Level	Building Area	Room Number	Room Name	Occupancy Category	Az - Floor Area	Occupant Density (#/1000 SF)	Pz - Number of People in Zone	Rp - People Outdoor Air Rate (CFM/person)	Ra - Area Outdoor Air Rate (CFM/SF)	Exhaust Rate (CFM/unit)	Exhaust Rate (CFM/SF)	Air Class	Vbz - Breathing Zone Outdoor Airflow	Voz + 30%	Total Exhaust (CFM/unit)	Total Exhaust (CFM/SF)
ALL	ARU-1	0001	ASRS	Storage	9094	0	0	0	0.06	0	0	1	545.64	709.332	0	0

Level	Building Area	Room Number	Room Name	Occupancy Category	Az - Floor Area	Occupant Density (#/1000 SF)	Pz - Number of People in Zone	Rp - People Outdoor Air Rate (CFM/person)	Ra - Area Outdoor Air Rate (CFM/SF)	Exhaust Rate (CFM/unit)	Exhaust Rate (CFM/SF)	Air Class	Vbz - Breathing Zone Outdoor Airflow	Voz + 30%	Total Exhaust (CFM/unit)	Total Exhaust (CFM/SF)
1	N	1103	Auditorium	Auditorium Seating	5152	150	772.8	5	0.06	0	0	1	4173.12	5425.056	0	0