NORTHEAST USA

INTEGRATED SCIENCES BUILDING

Technical Report I

ASHRAE 62.1-2007 Analysis

ASHRAE 90.1-2007 Analysis

October 4, 2010

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Contents

Executive Summary

The purpose of this report is to examine the compliance of the Integrated Sciences Building with ASHRAE Standard 62.1-2007 and ASHRAE Standard 90.1-2007.

The Integrated Sciences Building is under construction and is expected to be complete in July of 2011 and is expected to achieve LEED Gold certification. The building will be over 133,000 square feet and 5 levels with a mechanical penthouse above. As a University building in downtown Northeast USA, it will include a 240-seat Auditorium, research and teaching laboratories, lecture halls and classrooms, faculty offices and an atrium complete with a four-level biowall. It will be a model building for the campus and its surrounding community.

The mechanical systems that serve the building include nine air handling units (AHU). Those air handling units that serve laboratory spaces are 100% outdoor air variable air volume (VAV) systems, while the others are traditional variable air volume systems. The exhaust air streams recover energy with the use of a glycol heat recovery run-around loop. Heating loads are served by a campus steam system that produces hot water via heat exchangers. Cooling loads are served by two 620-ton centrifugal chillers.

The ASHRAE Standard 62.1-2007 compliance evaluation shows the building is compliant with the standard with only one minor exception. The exception is almost negligible, and aside from this instance, the Integrated Sciences Building exhibits exceptional design for indoor air quality systems and equipment as well as ventilation requirements. As a result, the minor issue can be easily remedied so the building can comply with the standard.

The ASHRAE Standard 90.1-2007 compliance evaluation also shows the building is near full compliance with the standard, except two minor details. The two areas pale in comparison to the total evaluation of the system, and should have negligible effects on the overall energy efficiency of the entire building. Aside from these details, the building exhibits exceptional potential for becoming a very well performing and efficient building. The efforts to improve overall efficiency are a major part in the Integrated Science Building's bid to become a LEED Gold building.

Although the reasons for these causes of non-conformity to ASHRAE Standards is not fully known, they are likely to be noticed during construction by the LEED Accredited Professionals, as every piece of equipment is scrutinized for its compliance with code requirements. There is also the possibility the mechanical standard on this project, the International Mechanical Code with local provisions, allows this difference and the building is fully compliant with applicable codes.

ASHRAE Standard 62.1-2007 Section 5 – Systems & Equipment

5.1 Natural Ventilation

Natural ventilation was not intended to be a significant method for air distribution in the building. However, motor-actuated, operable awning windows are used for atrium smoke evacuation purposes with the aid of an exhaust fan.

Also, temperature control in the south stairwell is implemented when the outdoor air temperature is above 65°F without rain and the interior temperature reaches 85°F. Under these conditions, the window control system opens the motor-actuated windows and cycles an exhaust fan on and off to maintain an acceptable temperature. This method is used because the stairwell faces the south wall and the temperature in the space does not require precise control. The naturally ventilated space is no more than 25 feet from the windows and the window area is greater than 4% of the net occupied floor area, which means the small natural ventilation system in the building fully complies with ASHRAE Standard 62.1-2007 requirements.

5.2 Ventilation Air Distribution

The VAV terminal boxes control the amount of air supplied to each space as required by Section 6 of ASHRAE 62.1-2007. Analysis of Section 6 of this standard is discussed later in this report. VAV boxes deliver a minimum amount of air to satisfy occupancy and space requirements along with sufficient amounts of treated air to control temperature. All air delivered to interior building spaces is done so through ducted supply and return systems. The construction documents include air balance schedules that list the design supply airflow, exhaust airflow, infiltration, air change, and exfiltration rate requirements for each space.

5.3 Exhaust Duct Location

All exhaust ducts that remove potentially harmful contaminants are negatively pressurized to ensure that the exhaust cannot leak into occupied spaces or supply, return or outdoor air ducts. This includes all general laboratory exhaust air ductwork, fume hood exhaust, flammable cabinet exhaust, and chemical storage exhaust.

5.4 Ventilation System Controls

The building automation system provides occupied and unoccupied modes are determined by a schedule based on hours of operation and in some locations are aided by occupancy sensors with different spaces. Initial hours of operation will be confirmed by the building owner during initial setup. Air flow is maintained at a minimum rate to satisfy ventilation requirements and provide a level of cooling for space temperature control. Additional heating or cooling capacity is achieved by heating or cooling coil modulation in the terminal units and air handler temperature adjustments at the request of a zone controller. During unoccupied hours temperature set points are reduced to conserve energy.

5.5 Airstream Surfaces

The duct surfaces in contact with airstreams are primarily sheet metal surfaces which are exempt from requirements to resist microbial growth and erosion. Flexible ducts must comply with the requirements of UL 181-1994 which includes an acceptable standardized test method in determining resistance to microbial growth and erosion. Ducts with acoustical liners are required to have an interior surface coating that "shall contain an immobilized, EPA registered, anti-microbial agent so it will not support microbial growth as tested in accordance with ASTM G22 and G22." Therefore, all ductwork in contact with an airstream has acceptable resistance to microbial growth and erosion.

5.6 Outdoor Air Leaks

As verified on the design drawings, the outdoor air intakes are located such that they are separated from the nearest outdoor contaminant sources are as required in table 5-1 of ASHRAE 62.1-2007, which is shown below in Figure 1. The air handler intakes are grouped in the same area of the rooftop mechanical space. The cooling tower, diesel generator, and exhaust stacks are located in other quadrants of the building and are well over the minimum distance from the intakes.

TABLE 5-1 Air Intake Minimum Separation Distance

Object	Minimum Distance, ft (m)
Significantly contaminated exhaust (Note 1)	15 (5)
Noxious or dangerous exhaust (Notes 2 and 3)	30 (10)
Vents, chimneys, and flues from combustion appliances and equipment (Note 4)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 5)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 5)	25 (7.5)
Driveway, street, or parking place (Note 5)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual[5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment, (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

Figure 1 - Table 5-1 from ASHRAE Standard 62.1-2007

Louvers are designed and tested in accordance with AMCA Standard 500-L-99 to limit water penetration during wet and windy conditions. The outdoor air plenums are sloped and installed with drains according to section 5.11 of ASHRAE 62.1, which complies with requirements for preventing snow entrainment.

Bird screens are made of a 5/8" flattened aluminum mesh with extruded aluminum frames and are given a mill finish. The aluminum material and finish are corrosion resistant and are assembled so as to inhibit birds from nesting on the frame. However, the size of the mesh in the bird screen does not meet the maximum ½" probing diameter.

5.7 Local Capture of Contaminants

All laboratories are served by 100% outdoor air units. Fume hoods are installed in all laboratories for use with materials that can be considered contaminant sources. The fume hood are required to meet or exceed the American Standard for Laboratory Ventilation and the American Industrial Hygiene Association standards. Specifications dictate that the fume hoods must also be tested in accordance with ANSI/ASHRAE 110-1995. The fume hoods are connected directly to an exhaust ductwork system and no fume hood exhaust air is recirculated back into the building.

5.8 Combustion Air

The building is served by a campus steam system for heating purposes, which eliminates the need for boilers. The only combustion equipment associated with the building is the emergency diesel generator. The generator is located on the roof to ensure that it has access to the proper amount of combustion air as well as easy exhaust venting and is located away from air handler units to eliminate contamination of air intakes.

5.9 Particulate Matter Removal

All air handler units have a pre-filter section with a minimum efficiency rating value (MERV) of 7 and a final filter with a MERV 13 rating. The pre-filter is a two inch, 30 percent efficient filter. The final filter is a twelve inch, 90 percent efficient filter. The filters meet requirements being rated MERV 6 or better. All filters are upstream of the chilled water coil and humidification sections of the air handler units.

5.10 Dehumidification Systems

Indoor relative humidity levels will be controlled to 55% during summer months and 30% during winter months which complies with the maximum 65% relative humidity limit.

The requirements of ASHRAE 62.1-2007 Section 5.10.2 state that the building must have a net positive pressure at all times when systems are dehumidifying. This is the case for the Integrated Sciences Building under all conditions because of the pressurization methods employed within the building. Exhaust air is primarily taken from the laboratory spaces, which ensures that they are negatively pressurized and prevent contaminants from entering other areas of the building. Under all operating conditions, the exhaust air from the entire building is, in fact, less than the amount of outside air that is brought into the building.

5.11 Drain Pans

The drain pans are sloped to ensure positive drainage to a minimum of one drain connection per pan. The drain diameter is 1 inch in diameter and is located at the low point of the drain. Specifications dictate that all drain pans are required to comply with ASHRAE 62.1-2004, which has the same drain pan requirements as ASHRAE 62.1-2007.

5.12 Finned-Tube Coils and Heat Exchangers

All condensate-producing heat exchangers are equipped with an appropriate drain pan as described in section 5.11. Air handlers are provided with cleaning and maintenance instructions for all coils and components, rendering them exempt from section 5.12.12 of ASHRAE 62.1-2007.

5.13 Humidifiers and Water Spray Systems

Humidifying capability is provided by direct steam injection humidifiers that bring steam directly to the air handling units from the campus steam system which is of suitable water quality. Turning vanes and other duct obstructions are location downstream of the humidification spray system and exceed the manufacturer's requirements for absorption distance.

5.14 Access for Inspection, Cleaning, & Maintenance

All air handling units are located with sufficient working space and have access doors for inspection and maintenance. The access doors have double wall construction with two inches of insulation between sheets of 16-guage and 22-guage galvanized steel. Each door also features a 10" round double pane glass window.

Ducts include access doors at fire and smoke dampers, control dampers, upstream of all reheat coils, at any device requiring maintenance, any location required by code, and locations indicated on drawings. There are three typical access doors which are 24", 18", and 12" square, or as indicated on drawings as needed. There are non-insulated and insulated access doors for ducts. All doors are made of dual thickness sheet metal and the insulated doors include a 1-inch layer of fiberglass insulation.

5.15 Building Envelope and Interior Surfaces

Exterior wall assemblies include a layer of Carlisle CCW-705 air barrier and vapor membrane to restrict water penetration into the envelope and condensation within the wall assembly. The exterior envelope assemblies use a variety of waterproofing systems, sealants, caulks, and gaskets to limit infiltration. The most predominant outdoor façade material, which is an aluminum honeycomb panel with recycled stone facing uses a sealant that must comply with ASTM C920-05.

All cold surfaces with potential for collecting condensation, including Domestic Cold Water Piping, Chilled Water Piping, and large portions of the ductwork system are required to be insulated to prevent thermal waste and water vapor formation.

5.16 Buildings with Attached Parking Garages

The Integrated Sciences Building does not feature any attached parking garage or structure. Thus, Section 5.16 of ASHRAE Standard 62.1-2007 does not apply.

5.17 Air Classification and Recirculation

The Integrated Sciences Building is comprised of laboratory space and other spaces such as lecture halls, offices, and an auditorium. The laboratory spaces are designated as Air Class 2 as shown in table 6-1 of ASHRAE 62.1-2007. The fume hoods within those laboratories are designated as Air Class 4. Since the air handling units in these areas are 100% outdoor air systems, there is no risk of contamination due to recirculating air. The remaining spaces in the building are designated as Air Class 1 and the air is recirculated. The recirculated air does not need to be redesignated before being recirculated because it will be sent as supply air to spaces with the same air class or higher compared to the space from which it was previously supplied.

5.18 Requirements for Building Containing ETS Areas and ETS-Free Areas

Tobacco smoking will be prohibited throughout the building but will be permitted outside in designated locations. Air handling units will be located in the mechanical penthouse at the top of the building. There will be sufficient separation to ensure that no tobacco smoke will enter the building.

ASHRAE Standard 62.1 – Section 6 – Ventilation Rate Calculation Procedure

6.1 Ventilation Rate Procedure

The Ventilated Rate Procedure is a "prescriptive procedure in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area." Minimum air flow rates are based on contaminant sources and concentrations that are listed for typical space types in ASHRAE 62.1 tables.

The procedure listed below includes the equations used to analyze the Integrated Sciences Building's compliance with the ventilation rate procedure. The outputs of the data are listed in Appendix B.

6.2 Ventilation Rate Procedure

6.2.1 Outdoor Air Treatment

If outdoor air quality is unacceptable in accordance with section 4.1 of ASHRAE 62.1, all air handling units that supply outdoor air through use of a supply fan must comply with sections 6.2.1.1 through 6.2.1.2.

6.2.1.1 Particulate Matter

The location is listed as "unclassifiable" in 40CFR81 for PM10. However, the construction specifications show that all air handling units are equipped with MERV 7 pre-filters and MERV 14 secondary filters and therefore comply with requirements for PM10 removal.

6.2.1.2 Ozone

The second highest daily maximum one-hour average ozone concentration for this location is 0.11 ppm. This is less than 0.16 ppm, which is the level at which air-cleaning devices for ozone are required. Therefore, ozone filters are not required.

6.2.1.3 Other Outdoor Contaminants

Other outdoor contaminants are not considered hazards as they are below dangerous levels. Sulfur dioxide levels are better than national standards, carbon monoxide high concentration recordings are lower than the NAAQS levels outlined in table 4-1 in AHRAE 62.1-2007. Lead and Nitrogen dioxide levels are also lower than outlined in that table.

6.2.2 Zone Calculations

6.2.2.1 Breathing Zone Outdoor Airflow

For Design airflow calculations, the following formula, ASHRAE equation 6-1, was used to determine the *Breathing Zone Outdoor Airflow, V_{bz}.*

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

Where:

A_z = zone floor area: net occupiable floor area of the zone (ft^2)

P_z = zone population: largest number of people expected to occupy the zone during typical usage.

R_p = outdoor air flow rate required per person (CFM/person) as determined from table 6-1 in ASHRAE Standard 62.1

R_a = outdoor air flow rate required per unit area (CFM/ft^2) as determined from table 6-1 in ASHRAE Standard 62.1

6.2.2.2 Zone Air Distribution Effectiveness

Zone Air Distribution Effectiveness, E_z, values are determined using table 6-2 of ASHRAE Standard 62.1.

6.2.2.3 Zone Outdoor Airflow

The outdoor airflow that must be provided to a zone by the supply air distribution system, or the *Zone Outdoor Airflow, V_{oz}*, is determined by equation 6-2 in ASHRAE 62.1.

$$V_{oz} = V_{bz}/E_z \qquad (6\text{-}2)$$

6.2.3 Single Zone Systems

There are two single-zone systems in the Integrated Sciences Building, which include the atrium system and the auditorium system. The *Outdoor Air Intake Flow, V_{ot}*, for single zone systems served by air handlers that supply a mixture or outdoor air and recirculated air is calculated in accordance with equation 6-3 of ASHRAE 62.1.

$$V_{ot} = V_{oz} \qquad (6\text{-}3)$$

6.2.4 100% Outdoor Air Systems

There are also four 100% outdoor air systems that serve the laboratory zones of the Integrated Sciences Building. For these systems, the *Outdoor AirIintake Flow*, *V_{ot},* is calculated using equation 6-4 of ASHRAE 62.1.

$$V_{ot} = \Sigma_{All\ Zones}\, V_{oz} \qquad (6\text{-}4)$$

6.2.5 Multiple-Zone Recirculating Systems

There are also several multiple-zone recirculating systems that serve lecture halls, conference rooms, offices, and electrical and data rooms.

6.2.5.1 Primary Outdoor Air Fraction

When system ventilation efficiency is determined using Table 6-3 in ASHRAE 62.1, the P*rimary Outdoor Air Fraction, Z_p*, for Multiple-Zone Recirculating Systems is calculated using equation 6-5 of ASHRAE 62.1.

$$Z_p = V_{oz}/V_{pz} \qquad (6\text{-}5)$$

V_{pz} is the *Zone Primary Airflow*, or the total amount of outdoor airflow and recirculated return airflow. In VAV systems, which are used in the Integrated Sciences Buidling, V_{pz} is the minimum expected primary airflow.

6.2.5.2 System Ventilation Efficiency

E_v, the *System Ventilation Efficiency*, is determined using Table 6-3 of ASHRAE 62.1.

6.2.5.3 Uncorrected Outdoor Air Intake

To account for population diversity within zones of a building, the *Uncorrected Outdoor Air Intake, V_{ou}* is calculated using equations 6-6 and 6-7 of ASHRAE 62.1.

$$V_{ou} = D\,\Sigma_{\text{All Zones}}\,(R_p \cdot P_z) + D\,\Sigma_{\text{All Zones}}\,(R_a \cdot A_z) \qquad (6\text{-}6)$$

$$\text{Where } D = P_s / \Sigma_{\text{All Zones}} \cdot P_z \qquad (6\text{-}7)$$

6.2.5.4 Outdoor Air Intake

Design *Outdoor Air Intake Flow, V_{ot}*, is calculated using equation 6-8 of ASHRAE 62.1.

$$V_{ot} = V_{ou} / E_v$$

The calculations described above were completed using ASHRAE 62.1 Spreadsheet software and the results are shown in Appendix A of this report. In Table 1, below, minimum outside air rates from these calculations are compared to the actual design airflow rates for the Integrated Sciences Building air handlers. Note that Air Handling Units 5-8 are those which serve laboratory spaces. These air handlers always supply 100% outdoor air. Their minimum air change rates are sufficient to ensure that the minimum calculated outdoor air requirements as dictated by ASHRAE 62.1 are always met.

Unit	Calculated Outdoor Air Required (62.1)	Maximum Design Supply Air	Minimum Design Outdoor Air	ASHRAE 62.1 Compliance
AHU-1	2257	6000	3400	Yes
AHU-2	2986	19000	9500	Yes
AHU-3	2305	16000	7800	Yes
AHU-4	2517	20000	6900	Yes
AHU-5	5206	42500	100% OA	Yes
AHU-6	4781	28000	100% OA	Yes
AHU-7	2466	27000	100% OA	Yes
AHU-8	5350	20000	100% OA	Yes
AHU-9	1030	12000	1200	Yes

Table 1 – Minimum Outside Air Evaluation for Air Handling Units

ASHRAE Standard 62.1-2007 – Compliance Conclusion

The ventilation systems in the Integrated Sciences Building comply very closely with ASHRAE Standard 62.1-2007. The only part of Section 5, Systems and Equipment, which the HVAC systems do not specifically follow, is the bird screen mesh size. This breach is relatively minor in the grand scope of the standard and can easily be resolved. One area in which the system design exceeds this section is the filtering equipment. The MERV 7 and MERV 13 filters which will be installed ensure that the quality of the supply air is very good, which is appropriate for a building with LEED Gold status.

The building also exceeds all minimum outside air requirements for the ventilation rate calculation procedure outlined in Section 6 of ASHRAE Standard 62.1-2007. The air handlers all have minimum outdoor air intake settings that exceed all requirements based on the building occupancy and space types. Since this building will be used for scientific research and therefore has the potential to hold many different contaminants, the large amounts of outdoor air will enhance the ability of the mechanical systems to purge the building of any harmful substances. Since the air handlers serving the laboratory spaces use 100% outdoor air, they guarantee that the contaminants released in these spaces will enter other spaces in the building.

ASHRAE Standard 90.1 – Compliance Evaluation

Section 5 - Building Envelope

5.1 General

The Integrated Sciences Building is a nonresidential conditioned space located in climate zone 4A. The climate zone was determined using the ASHRAE 90.1 Climate Zone map, which is labeled as Figure 2.

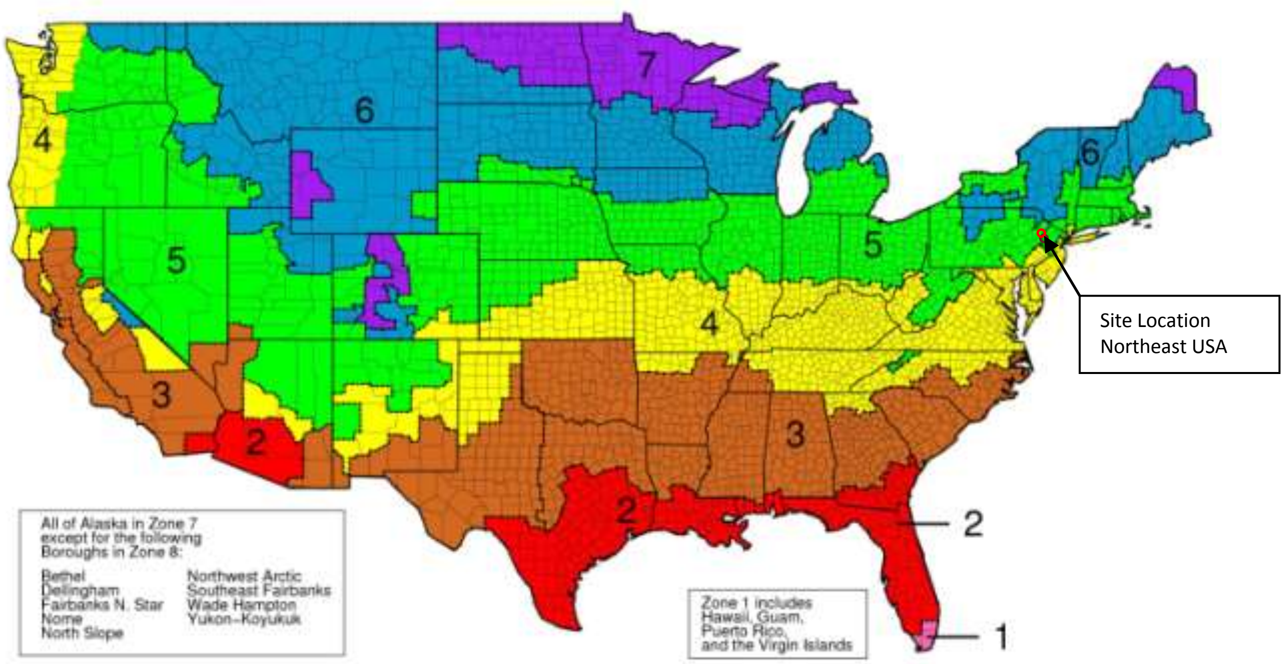

Figure 2 – Figure B-1 from ASHRAE Standard 90.1-2007

5.2 Compliance Paths

The Integrated Sciences Building complies with the requirements in section 5.2.1 to be categorized under the Prescriptive Building Envelope Option and therefore must be analyzed under Section 5.5 of ASHRAE Standard 90.1. The building qualifies for the prescriptive building envelope option because the vertical fenestration area is approximately 24.5% of the gross wall area, which is less than the maximum 40%, and the skylight fenestration does not exceed 5% of the gross roof area.

5.4 Mandatory Provisions

5.4.3.1 Air Leakage – Building Envelope Sealing

As mentioned in the evaluation of ASHRAE 62.1-2007 compliance, the exterior envelope assemblies use a variety of waterproofing systems, sealants, caulks, and gaskets to limit infiltration. The most predominant outdoor façade material, which is an aluminum honeycomb panel with recycled stone facing uses a sealant that must comply with ASTM C920-05. For fenestration and curtain wall seals, silicone caulking and rubber weather seals are also used. Architectural specifications dictate that all wall types and changes in exterior assembly be sealed to minimize or eliminate infiltration with the intent to reduce energy waste.

All entrances to the building are constructed with a vestibule that is larger than the minimum seven foot distance between doors. The door type used at the vestibule also feature the required automatic closing devices mentioned in section 5.4.3.4 of ASHRAE Standard 90.1.

5.5 Prescriptive Building Envelope Option

Tables 2 and 3, below, show information for opaque wall assembly and fenestration data for the Integrated Sciences Building external wall construction. Maximum U-values and minimum R-Values were given in Table 5.5-4 in ASHRAE 90.1-2007 which is the appropriate table for Building Envelope Requirements for Climate Zone 4. Due to the construction schedule and the lack of submittals on actual materials, data for this section was calculated using design documents, which show wall and floor assembly construction, in conjunction with the prescribed calculation procedures outlined in Appendix A of ASHRAE Standard 90.1-2007.

Opaque Elements	Non-Residential Category Requirements		Actual Constructed		Compliance
	Assembly Maximum	Insulation Minimum R-Value	Assembly Maximum	Insulation Minimum R-Value	
Roof					
Assembly R-1	U-0.048	R-20.0	U-0.035	R-28.6	Yes
Assembly R-2	U-0.048	R-20.0	U-0.045	R-22	Yes
Walls, Above Grade					
Mass	U-0.104	R-9.5	U-0.089	R-10	Yes
Walls, Below Grade	C-1.14	NR	C-0.089	NR	Yes
Mass Floors	U-0.087	R-8.3 c.i.	R-0.058	R-14	Yes
Slab-on-Grade Floors, Unheated	F-0.730	NR	R-0.058	NR	Yes
Opaque Doors					
Swinging	U-0.7	-	U-0.5	-	Yes

Table 2 – Opaque Building Envelope U-Value and R-Value Compliance Comparison

	Non-Residential		Specific Material		
Fenestration	**Assembly Maximum U-value**	**Insulation Maximum SHGC**	**Assembly Maximum**	**Insulation Minimum R-Value**	**Compliance**
Vertical Glazing	U-0.40	SHGC-0.40	U-0.30	SHGC-0.33	Yes

Table 3 – Fenestration Building Envelope U-Values and Solar Heat Gain Coefficient Compliance

Section 6 - HVAC Systems

The Integrated Sciences Building is a new building that has 5 usable stories with a mechanical penthouse, and is over 133,000 square feet. Therefore, the compliance path for the HVAC Systems section of ASHRAE Standard 90.1-2007 that will be used for analysis of the building will be the Prescriptive Path. The Simplified Approach Option for HVAC Systems does not apply to the building because it is greater than the two-story, 25,000 square foot area requirements for that option.

6.4 Mandatory Provisions

ASHRAE Standard 90.1-2007 provides minimum efficiency levels for HVAC equipment in tables 6.8.1A-G for Standard Rating and Operating Conditions as well as in section 6.4.1.2 for Nonstandard Conditions.

The Water-Cooled Centrifugal Chillers used for the Integrated Sciences Building fall under section 6.4.1.2 of ASHRAE 90.1 because they are not designed to operate at ARI Standard 550/590 test conditions. A compliance comparison is shown in Table 4 below for the applicable equipment in the building under sections 6.4.1.1 and 6.4.1.2. The comparison shows that the building's equipment exceeds the minimum requirements.

Unit heaters on this project have hot water coils. ASHRAE Standard 90.1 only lists minimum efficiencies for gas-fired and oil-fired unit heaters. Therefore, the unit heaters in this project are not addressed and may be used as stated in section 6.4.1.3.

Equipment Type	Rating Condition	Minimum Efficiency	Efficiency Table	Equipment Efficiency	Compliance
Water-Cooled Centrifugal Chillers	≥300 tons	COP-5.44	6.8.1J	COP-5.56	Yes
Axial Fan Cooling Tower	95°F EWT 85°F LWT 75°F OA WB	≥38.2 gpm/hp	6.8.1.G	38.75 gpm/hp	Yes
Rooftop Split Air Conditioner	< 65.000 Btu/hr	13.0 SEER	6.8.1.A	13.8 SEER	Yes
Rooftop Mounted Condensing Units	≥240,00 Btu/hr and <760,000 Btu/hr	9.8 SEER	6.8.1A	10.2 SEER	Yes

Table 4 – Equipment Compliance Evaluation for Applicable Mechanical Equipment

As a part of the commissioning requirements, all suppliers must include documentation and product specifications that explicitly list the efficiencies of the equipment they provide.

There will be thermostats in each zone to control the temperature in each space. Temperature controls include the 5°F dead band characteristic that is required and are designed to eliminate set point overlaps as explained in section 6.4.3.2. The control system allows for detailed schedules to be programmed via the desktop computer interface. Any number of schedules can be programmed and each terminal unit controller is assigned a specific operating schedule to be stored in its local RAM. Typically, there will be two modes for each controller, including occupied mode and unoccupied mode. The setback temperatures for heating mode is 64°F and setup temperature for cooling mode is 82°F and these levels are adjustable within the ranges outlined in section 6.4.3.3.2.

Ventilation system controls are in place to meet all of the requirements set forth in section 6.4.3.4 of ASHRAE Standard 90.1-2007. The specific building automation system specifications include sections dedicated to each of the subsections including shutoff damper controls, dampers, ventilation fans, humidification and dehumidification, and freeze protection.

Duct insulation schedules are listed in the mechanical specifications. The values are listed in thermal conductivity values for an average temperature of 75°F, which matches the values listed in ASHRAE Standard 90.1-2007. The R-value of the fiberglass insulation to be used is either R-4 or R-8 according to location and complies with table 6.8.2B.

Piping insulation thickness table from the mechanical specifications for hot and cold piping are shown in Figure 3. Thermal conductivity of all piping insulation is 0.23 Btu-in/hr-ft^2-^{o}F, which is acceptable for all temperatures. The only insulation thickness not met according to chart 6.8.3 in ASHRAE 90.1 is that of 200 psi, 8" steam piping. However, since the thermal conductivity of the insulation is less than required, acceptable thermal performance is likely.

TABLE 1- HOT SYSTEMS INSULATION THICKNESSES

Service	Fluid Design Operating Temperature Range °F	Nominal Pipe Size Insulation Thickness					
		Runouts Up To 2	1-1/2 & Less	1-3/4 To 2	2-1/2 To 4	6	8 & Up
Dom. Hot Water & Recirc Piping & Tempered Water	From 105F and up to 140° F(60° C.)	1.0" 25 mm	1.0" 25mm	1.0" 25mm	1.5" 40mm	1.5" 40mm	1.5" 40mm
Hot water Heating, Glycol and Reheat	Up to 200° F.Up to 93° C.	1.0" 25 mm	1.5" 40mm	2" 50mm	2" 50mm	2" 50mm	2" 50mm
200 PSI (1725 kPa) Steam	Up to 406° F.Up to 208° C.	1.5" 40mm	2.5" 65mm	3" 75mm	3.0" 75mm	3.5" 90mm	3.5" 90mm
60 PSI (690 kPa) Steam	Up to 338° F.Up to 170° C.	1.5" 40mm	2.0" 50mm	3" 75mm	3" 75mm	3.5" 90mm	3.5" 90mm
15 PSI (103 kPa) Steam	Up to 250° F.Up to 121° C.	1.0" 25mm	1.5" 40mm	3" 75mm	3" 75mm	3" 75mm	3.5" 90mm
Condensate Lines (Low Pressure)	Up to 200° F.Up to 93° C.	1/2" 12mm	1.5" 40mm	1.5" 40mm	1.5" 40mm	1.5" 40mm	1.5" 40mm
Condensate Lines (High Pressure)	Up to 250° F.Up to 121° C.	1.0" 25mm	1.5" 40mm	1.5" 40mm	2.0" 50mm	2.0" 50mm	3.5" 90mm
Equipment Drain Lines, Safety Valve Vents, etc.	Up to 200° F.Up to 93° C.	1/2" 12mm	1.5" 40mm	1.5" 40mm	1.5" 40mm	1.5" 40mm	1.5" 40mm

Figure 3 – Hot Piping Insulation Schedule from Mechanical Specifications

Cold water piping insulation also meets the requirements in table 6.8.3 of ASHRAE Standard 90.1. The insulation schedule for cold systems as listed in the mechanical design specifications is shown below, Figure 4.

TABLE 1- COLD SYSTEMS INSULATION THICKNESSES								
Service	Fluid Design Operating Temperature Range °F	Nominal Pipe Size Insulation Thickness						
		Runouts Up To 2	1-1/2 & Less	1-3/4 To 2	2-1/2 To 4	6	8 & Up
Domestic Cold Water	40 to 50	1" (25mm)	1" (25mm)	1" (25mm)	1.5" (40mm)	1" (25mm)	1" (25mm)
Storm Water		1" (25mm)	1" (25mm)	1" (25mm)	1" (25mm)	1" (25mm)	1" (25mm)
Chilled Water Piping	40 to 50	1" (25mm)	1" (25mm)	1.5" (40mm)	1.5" (40mm)	1.5" (40mm)	1.5" (40mm)
Condenser Water Piping Exterior to the Building	85 to 95	1" (25mm)	1" (25mm)	1" (25mm)	1" (25mm)	1.5" (40mm)	1.5" (40mm)

Figure 4 – Cold Piping Insulation Schedule from Mechanical Specifications

6.5 Prescriptive Path

6.5.1 Economizers

According to section 6.5.1 exceptions and table 6.5.1 in ASHRAE 90.1, the Integrated Sciences Building does not require any air or water economizers. However, the air handling units that do not serve the labs are equipped with economizers to provide free cooling on days when the outdoor wet bulb temperature is below the minimum supply air temperature of 53^{o}F. They are also used to control the temperature based upon the desired temperature of supply air, outside air temperature, and return air temperature. To eliminate thermal waste through exhausting air with desired thermal properties, glycol heat recovery run-around coils pre-treat incoming outside air after being circulated through a coil in the exhaust air streams.

6.5.2 Simultaneous Heating and Cooling Limitation

Zone thermostatic controls are programmed to eliminate simultaneous heating and cooling in accordance with this section. The most common point where simultaneous heating and cooling occurs is when the VAV terminal unit must reheat supply air because the load characteristics do not match other zones that are served by the same air handling unit.

The hydronic systems that supply hot water and cold water for temperature control do not share any common piping, eliminating the potential thermal waste through the use of three-pipe and two-pipe changeover systems.

The humidification system in the air handling units, which uses steam to humidify, only operates during the winter months specified by the control systems scheduling software, and the maximum relative humidity to which the system operates is 30% relative humidity. This is below the 35% relative humidity level at which water economizers are required under ASHRAE Standard 90.1-2007.

6.5.3 Air System Design & Control

The equations to determine that fan power limitation values are from Table 6.5.3.1.1A, which is shown below in Figure 5.

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate hp	Allowable Nameplate Motor hp	$hp \le CFM_S \cdot 0.0011$	$hp \le CFM_S \cdot 0.0015$
Option 2: Fan System bhp	Allowable Fan System bhp	$bhp \le CFM_S \cdot 0.00094 + A$	$bhp \le CFM_S \cdot 0.0013 + A$

[a] where
CFM_S = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = the maximum combined motor nameplate horsepower
bhp = the maximum combined fan brake horsepower
A = sum of $(PD \times CFM_D/4131)$
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1.1B in in. w.c.
CFM_D = the design airflow through each applicable device from Table 6.5.3.1.1B in cubic feet per minute

Figure 5 – Fan Power Limitation Equation Table 6.5.3.1.1A from ASHRAE Standard 90.1-2007

Option one did not identify all of the pressure drops that were associated with different pieces of equipment such as heat recovery devices, MERV 14 filters, and the fact that exhausts are fully ducted. Option two does allow adjustments for these items as listed in table 6.5.3.1.1B, and upon applying them, all of the fans over 5 horsepower were compliant. This table is shown below in Figure 6.

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. w.c.
Return and/or exhaust airflow control devices	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	0.5 in. w.c.
Particulate Filtration Credit: MERV 13 through 15	0.9 in. w.c.
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Heat recovery device	Pressure drop of device at fan system design condition
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	0.15 in. w.c.
Deductions	
Fume Hood Exhaust Exception (required if 6.5.3.1.1 Exception [c] is taken)	–1.0 in. w.c.

Figure 6 – Fan Power Limitation Pressure Drop Adjustment Table 6.5.3.1.1B from ASHRAE Standard 90.1-2007.

Table 5, below, shows the calculations performed for both options and the compliance results for each fan.

Fan Number	CFM_S	HP	BHP	Applicable Equations			
				Option 1	Compliance	Option 2	Compliance
SF-AH1	6000	10	7.06	9	No	9.1	Yes
SF-AH2	19000	25	19.08	28.5	Yes	28.8	Yes
RF-AH2	9500	5	2.77	14.25	Yes	14.4	Yes
SF-AH3	10000	20	15.73	15	No	15.8	Yes
RF-AH3	8100	5	2.77	12.15	Yes	12.3	Yes
SF-AH4	20000	25	19.53	30	Yes	30.4	Yes
SF-AH5	42500	60	46.14	46.75	No	59.2	Yes
SF-AH6	28000	40	36	30.8	No	39.0	Yes
SF-AH7	27000	40	31.71	29.7	No	37.8	Yes
SF-AH8	20000	30	24.62	22	No	27.9	Yes
SF-AH9	12000	15	12.7	18	Yes	18.2	Yes
RF-AH9	12000	7.5	5.79	18	Yes	18.2	Yes
EF-4A & 4B	10000	20	16.93	15	No	17.3	Yes
EF-5	40000	40	31.26	60	Yes	60.7	Yes
EF-6	30000	30	24.99	45	Yes	45.5	Yes
EF-7	5000	7.5	4.41	7.5	Yes	7.6	Yes
EF-8	20000	20	16.65	30	Yes	30.4	Yes
EF-9A,9B & 9C	35000	30	25.88	52.5	Yes	53.1	Yes

Table 5 – Fan Power Limitation Calculations performed in accordance with ASHRAE 90.1-2007.

All fans that are incorporated into VAV air handling units are equipped with Variable Frequency Drives to run the fans at optimum efficiency and conserve electricity.

As the control system for the Integrated Sciences Building has direct digital control (DDC) where all zone boxes report to the central control panel, static pressure set points are based on the zone with the worst pressure. This means that the static pressure set points are lowered until the zone with the zone with the highest pressure requirement is wide open. This enables the supply fan to run only as fast as required to meet the load without wasting fan energy.

6.5.4 Hydronic System Design and Control

The chilled and hot water hydronic system pumps are controlled using a variable volume pumping strategy made possible by variable frequency drives on the pumps in those systems. Although the pumps are not exceeding 50HP and 100 feet of pump head, variable frequency drives are used to minimize energy consumption. Upon chiller shutdown, the pumps that serve that chiller are also signaled to shut down. Since the system uses variable pumping flow to modulate pumping energy, chilled water reset temperatures are not mandatory. Hot water reset is utilized over a range of 110-180^{o}F.

6.5.5 Heat Rejection Equipment

The equipment used for heat rejection has energy usage characteristics that are included in the equipment efficiency ratings in section 6.8. These efficiencies were examined in section 6.4.

6.5.6 Energy Recovery

There is a domestic water heat recovery preheat tank to take advantage of condenser heat that is rejected and would otherwise be lost to the cooling tower. However, since this building does not operate to full occupancy 24 hours per day, the heating capacity in 6.5.6.2.2 is not required.

6.5.7 Exhaust Hoods

The only kitchen hood exhaust fan included in the building is for the future café which is not in the scope of construction. This kitchen hood is well below the 5000 CFM minimum for makeup air requirements, at 500CFM and is exempt from this section

The Research and Teaching lab fume hoods were the focus of an energy study. According to the simulation, the VAV fume hood exhaust control systems that will be implemented will decrease fume hood exhaust between 5pm and 7pm to 20% of design airflow for teaching laboratories and 45% for research laboratories. This exceeds the minimum fume hood requirements listed in section 6.5.7.2 of ASHRAE 90.1.

6.7 Submittals

Two sets of "As-Built" drawings as well as operating and maintenance manuals for mechanical systems are required to be turned over to the owner within 60 days of contract completion. Manuals are required to be separated into six sections including General, Piping and Pump Systems, HVAC, Automatic Controls, Sprinkler System, and Air and Hydronic Balancing Report.

Section 7 - Service Water Heating

The Service water heating needs of the Integrated Sciences Building is supplied by a campus steam system that supplies 200 psi steam. The steam goes through two pressure reducing steps from 200psi to 60psi and then 60psi to 12 psi. There are two domestic hot water tanks which, each with a capacity of 250 gallons and capable of providing 1520 gallons of domestic hot water per hour. There are four steam-to-glycol heat exchangers in the basement mechanical room to serve heating loads throughout the building. None of the steam equipment or heat exchangers are listed on table 7.8 in ASHRAE 90.1 and are therefore exempt for the performance requirements according to section 7.4.2. There is one supplementary hot water heater. The specifications state only that the electric water heater must meet ASHRAE 90.1 standards. The manufacturers spec sheet confirms that the equipment does, in fact meet or exceed the standby loss requirements, although it does not give detailed efficiency ratings.

Section 8 – Power

The mandatory provisions of ASHRAE 90.1 Section 8 prescribe maximum voltage drop percentages of full design load. Feeder conductors have a maximum allowed voltage drop of 2% while branch circuits have a maximum allowed voltage drop of 3%. In Table 6, the specified maximum voltage drops in the Integrated Sciences Building for different branches and feeders are compared to the ASHRAE maximum allowances. The table shows that 480V Feeders are not specified to meet ASHRAE requirements, and therefore there is the possibility that they do not comply.

Voltage Test Requirements			
Voltage	Maximum Project Voltage Drop	ASHRAE 90.1 Voltage Drop	Compliance
120V Branch	2%	3%	Yes
208V Branch	2%	3%	Yes
208V Feeder	2%	2%	Yes
480V Feeder	3%	2%	No

Table 6 – Compliance Comparison for Voltage Drop allowances

Complete system single-line, as-built drawings are to be turned over the owner on 36”x30” monochrome prints as outlined in section 8.7.1. Three copies of printed Operation and Maintenance manuals are required to be provided to the building owner and are to include equipment data, maintenance procedures, service contacts, and detailed descriptions of system operation as required in section 8.7.2.

Section 9 – Lighting

The lighting system in the Integrated Sciences Building includes the capability to control all lighting zones and levels either automatically or manually as part of the Building Automation System. Each zone is given a unique code and is to be controlled based on occupancy or schedule. During scheduled, unoccupied hours, the lighting is to be switched off. All spaces have manual switches that work in conjunction with occupancy sensors, Grafik eye controllers, remote station, time switch, or photocells to control lighting. All occupancy sensors are capable of being adjusted to modify the amount of unoccupied time before the lights are switched off to between 30 seconds and 12 minutes, which is less than the required 30 minute time delay specified in ASHRAE 90.1. All exterior lighting fixtures are on time switches and are controlled by either the BAS system or photocells. In addition, all display, task-specific, or non-visual lighting fixtures have separate control devices from those that control the rooms they are in. Exit signs are well within the 5 watt limit listed in section 9.4.3 as they operate with only 2 watts. Table 7 shows the lighting power density compliance evaluation as outlined by section 9 of ASHRAE Standard 90.1-2007.

Floor Level	Floor Area (SF)	Watts per Floor	Lighting Density	ASHRAE 90.1 University Maximum Lighting Density	Compliance Evaluation
Basement	8621	4660	0.54 W/ft^2	1.2 W/ft^2	YES
First	22601	18571	0.82 W/ft^2	1.2 W/ft^2	YES
Second	21027	24518	1.17 W/ft^2	1.2 W/ft^2	YES
Third	22027	26242	1.19 W/ft^2	1.2 W/ft^2	YES
Fourth	22027	26242	1.19 W/ft^2	1.2 W/ft^2	YES
Fifth	17437	20820	1.19 W/ft^2	1.2 W/ft^2	YES
Penthouse	13053	5056	0.39 W/ft^2	1.2 W/ft^2	YES

Table 7 – Lighting Power Density Compliance Calculation summary.

Section 10 - Electric Motor Efficiency

Section 10 of ASHRAE Standard 90.1 describes minimum electric motor efficiency requirements. Table 10.8 of this standard gives "minimum nominal efficiency for general purpose Design A and Design B motors." Since limited information has been provided regarding the actual installed motors, the mechanical specification requirements were examined motor efficiency guidelines for the Integrated Sciences Building. The mechanical specifications list of minimum required efficiencies for these motors show that the Integrated Sciences Building motors must exceed all efficiency requirements laid out in AHSRAE Standard 90.1. Therefore, all motors being installed in the Integrated Sciences Building meet and exceed the requirements of Section 10. A comparison of the mechanical specification motor efficiency requirements and those outlined in table 10.8 of ASHRAE Standard 90.1 is given in Appendix B.

ASHRAE Standard 62.1-2007 – Compliance Conclusion

Due to the governing characteristics of the Integrated Sciences Building, the Prescriptive Building Envelop Option was used to determine compliance with ASHRAE Standard 90.1-2007. The building is striving for LEED Gold certifications, and efforts to make the building as energy efficient as possible exceed the expectations of ASHRAE Standard 90.1-2007. The building complies very closely with this standard.

The only portions of ASHRAE Standard 90.1-2007 that are not specifically obeyed are very miniscule details. This includes one insulation thickness on a table that includes requirements for many pipe sizes, and the voltage drop allowance for 480V electrical feeders. However, the building is still under construction, and the enhanced commissioning and construction process, as well as the LEED Accredited professionals on the team are likely to eliminate these issues.

References

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Appendix A – ASHRAE 62.1-2007 Section 6 Ventilation Calculations

Air Handling Unit 1 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-1 - 240-Seat Auditorium
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

	Name	Units		System	Potentially Critical Zones			Check Figures / Totals/averages	
Inputs for System	**Name**	**Units**		**System**				**Check Figures**	
Floor area served by system	As	sf		2,786					
System population (including diversity)	Ps	P		418				150.0 P/1000 sf	
Design primary supply fan airflow rate	Vpsd	cfm		3,400				1.22 cfm/sf	
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.06				0.06 ave cfm/sf	
Average outdoor airflow rate per person for the system	Rps	cfm/p		5.0				5.0 ave cfm/p	
Inputs for Potentially Critical Zones					**Potentially Critical Zones**				
Zone Name			*Zone title turns purple italic for critical zone(s)*		*Auditorium*	-	-	**Totals/averages**	
Zone Tag					*120*	-	-		
Space type		Select from pull-down list			**Auditorium seating area**	**Lecture classroom**	**Lecture classroom**		
Floor Area of zone	Az	sf			2,786	0	0	2786 total sf	
Design population of zone	Pz	P	(default value listed; may be overridden)		417.9	0	0	418 total P	
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm			3,400	0		3400 total cfm	
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			None	None	None		
Local recirc air fraction representative of ave system return air	Er							1.00 average	
Inputs for Operating Condition Analyzed									
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100% average	
Air distribution type at conditioned analyzed		Select from pull-down list			FSCR	CS	CS		
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00 average	Primary airflow rate to zones
Primary air fraction of supply air at conditioned analyzed	Ep							1.00 average	3400 cfm
Results									100% Percent of design
System Ventilation Efficiency	Ev			**1.00**					
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm		**2257**					
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf		**0.81**					
Outdoor air intake rate per person served by system (including diversit	Vot/Ps	cfm/p		**5.4**					
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%		**66%**					
Uncorrected outdoor air intake airflow rate	Vou	cfm		**2257**					

	Name	Units	Formula		System	Auditorium	Lecture classroom	Lecture classroom	
Detailed Calculations									
Initial Calculations for the System as a whole									
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	3400				417.9 System population without diversity
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	2257				1.00 System population diversity, D
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.66				
Initial Calculations for individual zones									
OA rate per unit area for zone	Ra	cfm/sf				0.06	0.06	0.06	
OA rate per person for zone	Rp	cfm/p				5.00	7.50	7.50	
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds			3400	0	0	3400
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=		2256.7	0.0	0.0	2257
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=		2257	0	0	2257
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=		1.00	1.00	1.00	
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=		1.00	1.00	1.00	
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=		0.66	0.00	0.00	0.66 Maximum Zd
System Ventilation Efficiency									
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=		1.00	1.66	1.66	
System Ventilation Efficiency	Ev		= min (Evz)	=	**1.00**				

Air Handling Unit 2 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-2 - Lecture Halls & Classrooms
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

Item	Name	Units	Formula / Note		System				Poter
Inputs for System	Name	Units			System				
Floor area served by system	As	sf			7,716				
System population (including diversity)	Ps	P			483				
Design primary supply fan airflow rate	Vpsd	cfm			7,885				
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf			0.06				
Average outdoor airflow rate per person for the system	Rps	cfm/p			7.3				
Inputs for Potentially Critical Zones									
Zone Name			*Zone title turns purple italic for critical zone(s)*			Break Room/Kitche n	Conference Room	Lecture Room	Lecture Room
Zone Tag						102	103	104	105
Space type			Select from pull-down list			Office space	Conference/ meeting	Lecture classroom	Lecture classroom
Floor Area of zone	Az	sf				121	769	1,116	443
Design population of zone	Pz	P	(default value listed; may be overridden)			0.605	38.45	72.54	28.795
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm				125	860	1150	430
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A			None	None	None	None
Local recirc air fraction representative of ave system return air	Er								
Inputs for Operating Condition Analyzed									
Percent of total design airflow rate at conditioned analyzed	Ds	%			100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed			Select from pull-down list			CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez					1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep								
Results									
System Ventilation Efficiency	Ev				**0.78**				
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm			**5096**				
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf			**0.66**				
Outdoor air intake rate per person served by system (including diversity	Vot/Ps	cfm/p			**10.6**				
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%			**65%**				
Uncorrected outdoor air intake airflow rate	Vou	cfm			**3986**				
Detailed Calculations									
Initial Calculations for the System as a whole									
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	7885				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	3986				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.51				
Initial Calculations for individual zones									
OA rate per unit area for zone	Ra	cfm/sf				0.06	0.06	0.06	0.06
OA rate per person for zone	Rp	cfm/p				5.00	5.00	7.50	7.50
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds			125	860	1150	430
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=		10.3	238.4	611.0	242.5
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=		10	238	611	243
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=		1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=		0.08	0.28	0.53	0.56
System Ventilation Efficiency									
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=		1.42	1.23	0.97	0.94
System Ventilation Efficiency	Ev		= min (Evz)	=	**0.78**				

Air Handling Unit 2 Calculations

Check Figures

62.6 P/1000 sf
1.02 cfm/sf
0.06 ave cfm/sf
7.3 ave cfm/p

ntially Critical Zones

Lecture Room	*Lecture Room*	Lecture Room	Lecture Room	Lecture Room	Totals/averages
106	*107*	108	109	112	
Lecture classroom	Lecture classroom	Lecture classroom	Lecture classroom	Lecture classroom	
1,490	687	1,110	447	1,533	7716 total sf
96.85	44.655	72.15	29.055	99.645	483 total P
1560	520	1150	430	1,660	7885 total cfm
None	None	None	None	None	
					1.00 average
100%	100%	100%	100%	100%	100% average
CS	CS	CS	CS	CS	
1.00	1.00	1.00	1.00	1.00	1.00 average
					1.00 average

Primary airflow rate to zones
7885 cfm
100% Percent of design

482.745 System population without diversity
1.00 System population diversity, D

0.06	0.06	0.06	0.06	0.06	
7.50	7.50	7.50	7.50	7.50	
1560	520	1150	430	1660	7885
815.8	376.1	607.7	244.7	839.3	3986
816	376	608	245	839	3986
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
0.52	0.72	0.53	0.57	0.51	0.72 Maximum Zd
0.98	0.78	0.98	0.94	1.00	

Air Handling Unit 3 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-3 - Atrium & Adjacent Corridors
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

Inputs for System	Name	Units		System				
Floor area served by system	As	sf		18,021				
System population (including diversity)	Ps	P		203				
Design primary supply fan airflow rate	Vpsd	cfm		15,970				
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.06				
Average outdoor airflow rate per person for the system	Rps	cfm/p		6.0				
Inputs for Potentially Critical Zones								Potentially C
Zone Name			*Zone title turns purple italic for critical zone(s)*		Ist Floor Atrium	*Elevator Lobbies*	Corridor	Corridor
Zone Tag					1-ATR	*331-531*	435	334
Space type		Select from pull-down list			Main entry lobbies	Lobbies	Corridors	Corridors
Floor Area of zone	Az	sf			6,798	811	2,537	2,537
Design population of zone	Pz	P	(default value listed; may be overridden)		67.98	121.65	0	0
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm			800	660	2180	2180
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			None	None	None	None
Local recirc.air fraction representative of ave system return air	Er							
Inputs for Operating Condition Analyzed								
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list			CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep							

Results			
System Ventilation Efficiency	Ev		**0.15**
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm	**15468**
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf	**0.86**
Outdoor air intake rate per person served by system (including diversity	Vot/Ps	cfm/p	**76.2**
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%	**97%**
Uncorrected outdoor air intake airflow rate	Vou	cfm	**2305**

Detailed Calculations									
Initial Calculations for the System as a whole									
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	15970				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	2305				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.14				
Initial Calculations for individual zones									
OA rate per unit area for zone	Ra	cfm/sf				0.06	0.06	0.06	0.06
OA rate per person for zone	Rp	cfm/p				5.00	5.00	0.00	0.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds			800	660	2180	2180
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=		747.8	656.9	152.2	152.2
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=		748	657	152	152
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=		1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=		0.93	1.00	0.07	0.07
System Ventilation Efficiency									
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=		0.21	0.15	1.07	1.07
System Ventilation Efficiency	Ev		= min (Evz)	=	**0.15**				

Air Handling Unit 3 Calculations

Check Figures

11.3 P/1000 sf
0.89 cfm/sf
0.06 ave cfm/sf
6.0 ave cfm/p

ritical Zones

Corridor	Storage	Corridor	Restrooms	**Totals/averages**	
232	534	532 & 543	544-545		
Corridors	Storage rooms	Corridors	Health club/ aerobics room		
3,127	98	190	337	16435 total sf	
0	0	0	13.48	203 total P	
5750	100	4000	300	15970 total cfm	
None	None	None	None		
				1.00 average	
100%	100%	100%	100%	100% average	
CS	CS	CS	CS		
1.00	1.00	1.00	1.00	1.00 average	Primary airflow rate to zones
				1.00 average	15970 cfm
					100% Percent of design

203.11 System population without diversity
1.00 System population diversity, D

0.06	0.12	0.06	0.06	
0.00	0.00	0.00	20.00	
5750	100	4000	300	15970
187.6	11.8	11.4	289.8	2210
188	12	11	290	2210
1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	
0.03	0.12	0.00	0.97	1.00 Maximum Zd
1.11	1.03	1.14	0.18	

Air Handling Unit 4 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-4 - Faculty Office & Support
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

Inputs for System	Name	Units	System
Floor area served by system	As	sf	7,716
System population (including diversity)	Ps	P	247
Design primary supply fan airflow rate	Vpsd	cfm	14,708
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf	0.07
Average outdoor airflow rate per person for the system	Rps	cfm/p	8.1

Inputs for Potentially Critical Zones	Name	Units	Note						
Zone Name			*Zone title turns purple italic for critical zone(s)*	Building Manager Office	Teaching Assistant Offices	Student Lounge	Administration Offices	Future Use - (Assuming Planned Café)	Faculty Offices
Zone Tag				117	121	122	123	124	216
Space type			Select from pull-down list	Office space	Office space	Reception areas	Office space	Cafeteria/fast food dining	Office space
Floor Area of zone	Az	sf		123	914	781	1,204	918	1,743
Design population of zone	Pz	P	(default value listed; may be overridden)	0.615	4.57	23.43	6.02	91.8	8.715
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm		78	910	525	715	2500	1595
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A	None	None	None	None	None	None
Local recirc air fraction representative of ave system return air	Er								

Inputs for Operating Condition Analyzed	Name	Units	Note	System	117	121	122	123	124	216
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed			Select from pull-down list		CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep									

Results	Name	Units	Value
System Ventilation Efficiency	Ev		**0.63**
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm	**3983**
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf	**0.52**
Outdoor air intake rate per person served by system (including diversity	Vot/Ps	cfm/p	**16.1**
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%	**27%**
Uncorrected outdoor air intake airflow rate	Vou	cfm	**2517**

Detailed Calculations

Initial Calculations for the System as a whole	Name	Units	Formula	Value
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds =	14708
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	2517
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.17

Initial Calculations for individual zones	Name	Units	Formula	117	121	122	123	124	216
OA rate per unit area for zone	Ra	cfm/sf		0.06	0.06	0.06	0.06	0.18	0.06
OA rate per person for zone	Rp	cfm/p		5.00	5.00	5.00	5.00	7.50	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds	78	910	525	715	2500	1595
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =	10.5	77.7	164.0	102.3	853.7	148.2
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =	10	78	164	102	854	148
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er =	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep =	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz =	0.13	0.09	0.31	0.14	0.34	0.09

System Ventilation Efficiency	Name	Formula	System	117	121	122	123	124	216
Zone Ventilation Efficiency	Evz	= (Fa + FbXs - FcZ) / Fa =		1.04	1.09	0.86	1.03	0.83	1.08
System Ventilation Efficiency	Ev	= min (Evz) =	**0.63**						

Air Handling Unit 4 Calculations

Check Figures

32.1 P/1000 sf
1.91 cfm/sf
0.07 ave cfm/sf
8.1 ave cfm/p

Potentially Critical Zones

Restrooms & Janitorial	Corridor	Lounge	Faculty Offices	Restrooms & Housekeeping	Corridor	Lounge	Faculty Offices	Restrooms & Housekeeping	Corridors	Lounge	Totals/averages
228	236	238	314	328	336	338	414	428	436	438	
Health club/ weight rooms	Corridors	Reception areas	Office space	Health club/ aerobics room	Corridors	Reception areas	Office space	Health club/ aerobics room	Corridors	Reception areas	
417	571	661	1,759	379	572	661	1,759	395	572	661	14090 total sf
4.17	0	19.83	8.795	15.16	0	19.83	8.795	15.8	0	19.83	247 total P
700	130	1100	1330	630	130	1020	1405	630	255	1,055	14708 total cfm
None	None	None	None	None	None	None	None	None	None	None	
											1.00 average
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100% average
CS	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 average
											1.00 average

Primary airflow rate to zones
14708 cfm
100% Percent of design

											247.36 System population without diversity
											1.00 System population diversity, D
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
20.00	0.00	5.00	5.00	20.00	0.00	5.00	5.00	20.00	0.00	5.00	
700	130	1100	1330	630	130	1020	1405	630	255	1055	14708
108.4	34.3	138.8	149.5	325.9	34.3	138.8	149.5	339.7	34.3	138.8	2949
108	34	139	150	326	34	139	150	340	34	139	2949
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
0.15	0.26	0.13	0.11	0.52	0.26	0.14	0.11	0.54	0.13	0.13	0.54 Maximum Zd
1.02	0.91	1.04	1.06	0.65	0.91	1.04	1.06	0.63	1.04	1.04	

Air Handling Unit 5 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-5 - Research Laboratories
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

Inputs for System	**Name**	**Units**		**System**
Floor area served by system	As	sf		7,716
System population (including diversity)	Ps	P		388
Design primary supply fan airflow rate	Vpsd	cfm		17,330
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.17
Average outdoor airflow rate per person for the system	Rps	cfm/p		10.0

Inputs for Potentially Critical Zones	Name	Units		System				
Zone Name			*Zone title turns purple italic for critical zone(s)*		Ecology Library	Vestibule	Laboratory Equipment & Autoclave	Vestibule
Zone Tag					302	303	394	306
Space type		Select from pull-down list			Science laboratories	Corridors	Science laboratories	Corridors
Floor Area of zone	Az	sf			132	126	948	99
Design population of zone	Pz	P	(default value listed; may be overridden)		3.3	0	23.7	0
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm			120	100	1240	420
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			None	None	None	None
Local recirc air fraction representative of ave system return air	Er							
Inputs for Operating Condition Analyzed								
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list			CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep							

Results			
System Ventilation Efficiency	Ev		**0.79**
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm	**6591**
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf	**0.85**
Outdoor air intake rate per person served by system (including diversit	Vot/Ps	cfm/p	**17.0**
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%	**38%**
Uncorrected outdoor air intake airflow rate	Vou	cfm	**5206**

Detailed Calculations									
Initial Calculations for the System as a whole									
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	17330				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	5206				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.30				
Initial Calculations for individual zones									
OA rate per unit area for zone	Ra	cfm/sf				0.18	0.06	0.18	0.06
OA rate per person for zone	Rp	cfm/p				10.00	0.00	10.00	0.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds			120	100	1240	420
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=		56.8	7.6	407.6	5.9
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=		57	8	408	6
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=		1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=		0.47	0.08	0.33	0.01
System Ventilation Efficiency									
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=		0.83	1.22	0.97	1.29
System Ventilation Efficiency	Ev		= min (Evz)	=	**0.79**				

Air Handling Unit 5 Calculations

Check Figures

50.3 P/1000 sf
2.25 cfm/sf
0.17 ave cfm/sf
10.0 ave cfm/p

Potentially Critical Zones

Data Analysis Office	Vestibule	Research Lab	Vestibule	Cell Culture & Microscope & Autoclave	Vestibules	Research Laboratory	Research Laboratory	Research Laboratory	*Research Laboratory*	Totals/averages
308	309	402	403	405	406,407	503	504	301	*401*	
Office space	Corridors	Science laboratories	Corridors	Science laboratories	Corridors	Science laboratories	Science laboratories	Science laboratories	Science laboratories	
352	86	364	99	1,275	185	1,195	1,281	5,325	4,927	16394 total sf
1.76	0	9.1	0	31.875	0	29.875	32.025	133.125	123.175	388 total P
360	100	350	500	1620	620	1190	1270	5290	4,150	17330 total cfm
None	None	None	None	None	None	None	None	None	None	
										1.00 average
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100% average
CS	CS	CS	CS	CS	CS	CS	CS	CS	CS	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 average
										1.00 average

Primary airflow rate to zones
17330 cfm
100% Percent of design

387.935 System population without diversity
1.00 System population diversity, D

308	309	402	403	405	406,407	503	504	301	401	
0.06	0.06	0.18	0.06	0.18	0.06	0.18	0.18	0.18	0.18	
5.00	0.00	10.00	0.00	10.00	0.00	10.00	10.00	10.00	10.00	
360	100	350	500	1620	620	1190	1270	5290	4150	17330
29.9	5.2	156.5	5.9	548.3	11.1	513.9	550.8	2289.8	2118.6	6708
30	5	157	6	548	11	514	551	2290	2119	6708
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
0.08	0.05	0.45	0.01	0.34	0.02	0.43	0.43	0.43	0.51	0.51 Maximum Zd
1.22	1.25	0.85	1.29	0.96	1.28	0.87	0.87	0.87	0.79	

Air Handling Unit 6 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-6 - Research Laboratories
Operating Condition Description:	Mimum Outside Air Requirements
Units (select from pull-down list)	IP

Inputs for System	Name	Units		System
Floor area served by system	As	sf		11,118
System population (including diversity)	Ps	P		278
Design primary supply fan airflow rate	Vpsd	cfm		10,870
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.18
Average outdoor airflow rate per person for the system	Rps	cfm/p		10.0

Inputs for Potentially Critical Zones	Name	Units			Potentially Critical Zones		
Zone Name		*Zone title turns purple italic for critical zone(s)*		Research Laboratory	Research Laboratory	Research Laboratory	*Research Laboratory*
Zone Tag				310	312	410	*411*
Space type		Select from pull-down list		Science laboratories	Science laboratories	Science laboratories	Science laboratories
Floor Area of zone	Az	sf		2,117	3,451	2,117	1,362
Design population of zone	Pz	P	(default value listed; may be overridden)	52.925	86.275	52.925	34.05
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm		2,070	3,340	2090	1280
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A		None	None	None	None
Local recirc.air fraction representative of ave system return air	Er						

Inputs for Operating Condition Analyzed	Name	Units	System				
Percent of total design airflow rate at conditioned analyzed	Ds	%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list		CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez			1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep						

Results	Name	Units	
System Ventilation Efficiency	Ev		**0.98**
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm	**4867**
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf	**0.44**
Outdoor air intake rate per person served by system (including diversity	Vot/Ps	cfm/p	**17.5**
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%	**45%**
Uncorrected outdoor air intake airflow rate	Vou	cfm	**4781**

Detailed Calculations								
Initial Calculations for the System as a whole								
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	= 10870				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	= 4781				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	= 0.44				
Initial Calculations for individual zones								
OA rate per unit area for zone	Ra	cfm/sf			0.18	0.18	0.18	0.18
OA rate per person for zone	Rp	cfm/p			10.00	10.00	10.00	10.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds		2070	3340	2090	1280
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=	910.3	1483.9	910.3	585.7
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=	910	1484	910	586
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=	1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=	1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=	1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=	0.44	0.44	0.44	0.46
System Ventilation Efficiency								
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=	1.00	1.00	1.00	0.98
System Ventilation Efficiency	Ev		= min (Evz)	= **0.98**				

Air Handling Unit 6 Calculations

Check Figures

25.0 P/1000 sf
0.98 cfm/sf
0.18 ave cfm/sf
10.0 ave cfm/p

Research Laboratory	**Research Laboratory**	**Totals/averages**	
412	**413**		
Science laboratories	**Science laboratories**		
684	1,387	11118 total sf	
17.1	34.675	278 total P	
690	1,400	10870 total cfm	
None	None		
		1.00 average	
100%	100%	100% average	
CS	CS		
1.00	1.00	1.00 average	Primary airflow rate to zones
		1.00 average	10870 cfm
			100% Percent of design

		277.95 System population without diversity
		1.00 System population diversity, D
0.18	0.18	
10.00	10.00	
690	1400	10870
294.1	596.4	4781
294	596	4781
1.00	1.00	
1.00	1.00	
1.00	1.00	
0.43	0.43	0.46 Maximum Zd
1.01	1.01	

Air Handling Unit 7 Calculations Page 1 of 1

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-7 - Teaching Laboratories
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

Inputs for System	Name	Units	System	Check Figures
Floor area served by system	As	sf	5,264	
System population (including diversity)	Ps	P	201	38.1 P/1000 sf
Design primary supply fan airflow rate	Vpsd	cfm	7,300	1.39 cfm/sf
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf	0.14	0.14 ave cfm/sf
Average outdoor airflow rate per person for the system	Rps	cfm/p	8.6	8.6 ave cfm/p

Inputs for Potentially Critical Zones	Name	Units	Notes	Potentially Critical Zones			Totals/averages
Zone Name			*Zone title turns purple italic for critical zone(s)*	Teaching Laboratory - Organic Chemistry	*Teaching Laboratory - Organic Chemistry*	None	
Zone Tag				501	*502*	-	
Space type			Select from pull-down list	Science laboratories	Lecture classroom	Lecture classroom	
Floor Area of zone	Az	sf		3,543	1,722	0	5265 total sf
Design population of zone	Pz	P	(default value listed; may be overridden)	88.575	111.93	0	201 total P
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm		5,380	1,920		7300 total cfm
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A	None	None	None	
Local recirc. air fraction representative of ave system return air	Er						1.00 average

Inputs for Operating Condition Analyzed	Name	Units	Notes	System	Zone 501	Zone 502	Zone -	Totals/averages	
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100% average	
Air distribution type at conditioned analyzed			Select from pull-down list		CS	CS	CS		
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00 average	Primary airflow rate to zones
Primary air fraction of supply air at conditioned analyzed	Ep							1.00 average	7300 cfm
									100% Percent of design

Results	Name	Units	Value
System Ventilation Efficiency	Ev		0.85
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm	2912
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf	0.55
Outdoor air intake rate per person served by system (including diversit	Vot/Ps	cfm/p	14.5
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%	40%
Uncorrected outdoor air intake airflow rate	Vou	cfm	2466

Detailed Calculations

Initial Calculations for the System as a whole	Name	Units	Equation		Value			
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	7300			200.505 System population without diversity
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	2466			1.00 System population diversity, D
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.34			

Initial Calculations for individual zones	Name	Units	Equation		Zone 501	Zone 502	Zone -	
OA rate per unit area for zone	Ra	cfm/sf			0.18	0.06	0.06	
OA rate per person for zone	Rp	cfm/p			10.00	7.50	7.50	
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds		5380	1920	0	7300
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=	1523.5	942.8	0.0	2466
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=	1523	943	0	2466
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=	1.00	1.00	1.00	
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=	1.00	1.00	1.00	
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=	1.00	1.00	1.00	
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=	0.28	0.49	0.00	0.49 Maximum Zd

System Ventilation Efficiency

Air Handling Unit 8 Calculations Page 1 of 2

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-8 - Teaching Laboratories
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

	Name	Units		System				
Inputs for System								
Floor area served by system	As	sf		12,449				
System population (including diversity)	Ps	P		311				
Design primary supply fan airflow rate	Vpsd	cfm		9,150				
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.18				
Average outdoor airflow rate per person for the system	Rps	cfm/p		10.0				
Inputs for Potentially Critical Zones								
Zone Name			*Zone title turns purple italic for critical zone(s)*		*Teaching Laboratory - Tissue/Cell Biomedics*	Teaching Laboratory - Biochemistry	Teaching Laboratory - Biochemistry	Teaching Laboratory - Sophomore Classes
Zone Tag					*201*	202	203	204
Space type		Select from pull-down list			Science laboratories	Science laboratories	Science laboratories	Science laboratories
Floor Area of zone	Az	sf			1,337	1,126	1,130	1,133
Design population of zone	Pz	P	(default value listed; may be overridden)		33.425	28.15	28.25	28.325
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm			850	760	760	760
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			None	None	None	None
Local recirc.air fraction representative of ave system return air	Er							
Inputs for Operating Condition Analyzed								
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list			CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep							
Results								
System Ventilation Efficiency	Ev			**0.91**				
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm		**5890**				
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf		**0.47**				
Outdoor air intake rate per person served by system (including diversit	Vot/Ps	cfm/p		**18.9**				
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%		**64%**				
Uncorrected outdoor air intake airflow rate	Vou	cfm		**5350**				
Detailed Calculations								
Initial Calculations for the System as a whole								
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds =	9150				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	5350				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.58				
Initial Calculations for individual zones								
OA rate per unit area for zone	Ra	cfm/sf			0.18	0.18	0.18	0.18
OA rate per person for zone	Rp	cfm/p			10.00	10.00	10.00	10.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds		850	760	760	760
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =		574.9	484.2	485.9	487.2
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =		575	484	486	487
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er =		1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep =		1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =		1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz =		0.68	0.64	0.64	0.64
System Ventilation Efficiency								
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa =		0.91	0.95	0.95	0.94
System Ventilation Efficiency	Ev		= min (Evz) =	**0.91**				

Air Handling Unit 8 Calculations

Check Figures

25.0 P/1000 sf
0.73 cfm/sf
0.18 ave cfm/sf
10.0 ave cfm/p

Potentially Critical Zones

Microbiology Preparation Room	Microbiology Technical Office	Teaching Equipment Room	Cold Storage Room	Teaching Laboratory - Microdevelopment
205	205.01-2	206	207	210
Science laboratories	Science laboratories	Science laboratories	Science laboratories	Science laboratories
1,090	200	468	104	1,103
27.25	5	11.7	2.6	27.575
710	200	320	80	730
None	None	None	None	None
100%	100%	100%	100%	100%
CS	CS	CS	CS	CS
1.00	1.00	1.00	1.00	1.00
0.18	0.18	0.18	0.18	0.18
10.00	10.00	10.00	10.00	10.00
710	200	320	80	730
468.7	86.0	201.2	44.7	474.3
469	86	201	45	474
1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00
0.66	0.43	0.63	0.56	0.65

Teaching Laboratory - Ecology & Physiology	Glass Washing Room	Teaching Laboratory - Freshman	Teaching Laboratory	Teaching Laboratory	Totals/averages
211	212	213	214	215	
Science laboratories	Science laboratories	Science laboratories	Science laboratories	Science laboratories	
1,092	367	1,102	1,093	1,092	12437 total sf
27.3	9.175	27.55	27.325	27.3	311 total P
720	1050	730	740	740	9150 total cfm
None	None	None	None	None	
					1.00 average
100%	100%	100%	100%	100%	100% average
CS	CS	CS	CS	CS	
1.00	1.00	1.00	1.00	1.00	1.00 average
					1.00 average
0.18	0.18	0.18	0.18	0.18	
10.00	10.00	10.00	10.00	10.00	
720	1050	730	740	740	9150
469.6	157.8	473.9	470.0	469.6	5348
470	158	474	470	470	5348
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
0.65	0.15	0.65	0.64	0.63	0.68 Maximum Zd

Primary airflow rate to zones
9150 cfm
100% Percent of design

310.925 System population without diversity
1.00 System population diversity, D

Air Handling Unit 9 Calculations

Building:	Drexel Integrated Sciences Building
System Tag/Name:	AHU-9 - Supplementary Spaces
Operating Condition Description:	Minimum Outside Air Requirements
Units (select from pull-down list)	IP

	Name	Units		System				Pote
Inputs for System								
Floor area served by system	As	sf		7,211				
System population (including diversity)	Ps	P		37				
Design primary supply fan airflow rate	Vpsd	cfm		11,550				
Average outdoor airflow rate per unit area for the system	Ras	cfm/sf		0.12				
Average outdoor airflow rate per person for the system	Rps	cfm/p		5.3				
Inputs for Potentially Critical Zones								
Zone Name			*Zone title turns purple italic for critical zone(s)*		LAN Server Closet	Corridors	Electrical Rooms	*Elevator Vestibule*
Zone Tag					402	B141,515	312,441,512	*B142*
Space type			Select from pull-down list		Computer lab	Corridors	Computer (not printing)	Lobbies
Floor Area of zone	Az	sf			100	1,117	1,410	180
Design population of zone	Pz	P	(default value listed; may be overridden)		2.5	0	5.64	27
Design discharge airflow to zone (total primary plus local recirculated)	Vdzd	cfm			1,500	450	3100	150
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A		None	None	None	None
Local recirc air fraction representative of ave system return air	Er							
Inputs for Operating Condition Analyzed								
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed			Select from pull-down list		CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep							
Results								
System Ventilation Efficiency	Ev			0.12				
Outdoor air intake airflow rate required at condition analyzed	Vot	cfm		8790				
Outdoor air intake rate per unit floor area	Vot/As	cfm/sf		1.22				
Outdoor air intake rate per person served by system (including diversity	Vot/Ps	cfm/p		239.7				
Outdoor air intake rate as a % of design primary supply air	Vot/Vpsd	%		76%				
Uncorrected outdoor air intake airflow rate	Vou	cfm		1030				

	Name	Units	Equation		System	LAN Server Closet	Corridors	Electrical Rooms	Elevator Vestibule
Detailed Calculations									
Initial Calculations for the System as a whole									
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= Vpsd Ds	=	11550				
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As	=	1030				
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps	=	0.09				
Initial Calculations for individual zones									
OA rate per unit area for zone	Ra	cfm/sf				0.12	0.06	0.06	0.06
OA rate per person for zone	Rp	cfm/p				10.00	0.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm	= Vdsd Ds			1500	450	3100	150
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az	=		37.0	67.0	112.8	145.8
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez	=		37	67	113	146
Fraction of supply air to zone from sources outside the zone	Fa		= Ep + (1-Ep)Er	=		1.00	1.00	1.00	1.00
Fraction of supply air to zone from fully mixed primary air	Fb		= Ep	=		1.00	1.00	1.00	1.00
Fraction of outdoor air to zone from sources outside the zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er)	=		1.00	1.00	1.00	1.00
Outdoor air fraction required in air discharged to zone	Zd		= Voz / Vdz	=		0.02	0.15	0.04	0.97
System Ventilation Efficiency									
Zone Ventilation Efficiency	Evz		= (Fa + FbXs - FcZ) / Fa	=		1.06	0.94	1.05	0.12
System Ventilation Efficiency	Ev		= min (Evz)	=	0.12				

Air Handling Unit 9 Calculations

Check Figures

5.1 P/1000 sf
1.60 cfm/sf
0.12 ave cfm/sf
5.3 ave cfm/p

ntially Critical Zones

Fire Pump Room	General Storage	Mechanical Room	Restrooms	Data Closet	Totals/averages
B102	B106	B102A	110,111	341	
Storage rooms	Storage rooms	Storage rooms	Sports arena (play area)	Computer (not printing)	
338	1,500	1,560	850	381	7436 total sf
0	0	0	0	1,524	37 total P
1800	1000	850	1200	1,500	11550 total cfm
None	None	None	None	None	
					1.00 average
100%	100%	100%	100%	100%	100% average
CS	CS	CS	CS	CS	
1.00	1.00	1.00	1.00	1.00	1.00 average
					1.00 average

Primary airflow rate to zones
11550 cfm
100% Percent of design

36.664 System population without diversity
1.00 System population diversity, D

0.12	0.12	0.12	0.30	0.06	
0.00	0.00	0.00	0.00	5.00	
1800	1000	850	1200	1500	11550
40.6	180.0	187.2	255.0	30.5	1056
41	180	187	255	30	1056
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
1.00	1.00	1.00	1.00	1.00	
0.02	0.18	0.22	0.21	0.02	0.97 Maximum Zd
1.07	0.91	0.87	0.88	1.07	

Appendix B – ASHRAE 90.1-2007 Section 10 Motor Efficiency Comparison

RPM	Motor Efficiency Comparison											
	Open Drip Proof						Totally Enclosed Fan Cooled					
	3600		1800		900		3600		1800		900	
Motor Size	ISB	ASHRAE 90.1	ISB	ASHRAE 90.1	ISB	ASHRAE 90.1	ISB	ASHRAE 90.1	ISB	ASHRAE 90.1	ISB	ASHRAE 90.1
1	77	-	85.5	82.5	82.5	80	77	75.5	85.5	82.5	82.5	80
1.5	84	82.5	86.5	84	86.5	84	84	82.5	86.5	84	97.5	85.5
2	85.5	84	86.5	84	87.5	85.5	85.5	84	85.5	84	88.5	86.5
3	85.5	84	89.5	86.5	89.5	86.5	86.5	85.5	86.5	87.5	89.5	87.5
5	86.5	85.5	89.5	87.5	89.5	87.5	88.5	87.5	88.5	87.5	89.5	87.5
7.5	88.5	87.5	91	88.5	90.2	88.5	89.5	88.5	89.5	89.5	91	89.5
10	89.5	88.5	91.7	89.5	91.7	90.2	90.2	89.5	90.2	89.5	91	89.5
15	90.2	89.5	93	91	91.7	90.2	91	90.2	92	91	91.7	90.2
20	91	90.2	93	91	92.4	91	91	90.2	92	91	91.7	90.2
25	91.7	91	93.6	91.7	93	91.7	91.7	91	92.7	92.4	93	91.7
30	91.7	91	94.1	92.4	93.6	92.4	91.7	91	93.6	92.4	93	91.7
40	92.4	91.7	94.1	93	94.1	93	92.4	91.7	94.1	93	94.1	93
50	93	92.4	94.5	93	94.1	93	93	92.4	94.5	93	94.1	93
60	93.6	93	95	93.6	94.5	93.6	93.6	93	95	93.6	94.5	93.6