Senior Thesis Capstone Project

**Technical Assignment 3**

Mechanical Systems Existing Conditions

# Interdisciplinary Science and Engineering Building

University of Delaware
Newark, DE 19716

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## Executive Summary

The fallowing mechanical systems evaluation was conducted on the University of Delaware's newly designed Interdisciplinary Science and Engineering building (ISEB). The building will be built on university property, will be approximately 194,000 square feet, and is scheduled for completion in Fall 2013. The building will facilitate both research labs and educational/office spaces. Chilled water and steam, from campus utility plants, meet the building's heating and cooling requirements.

Design objectives and factors, design conditions, energy sources, design heating and cooling loads, and designer annual energy use calculations, were all examined in order to asses the mechanical design of ISEB. This report lists all of the major mechanical equipment and describes each pieces role in the total system operation. A mechanical system first cost would have been a great tool in this evaluation but this information could not be obtained. Also, construction had not yet been completed at the time that this report was written, therefore operational history of the system was not available. LEED NC 2004 was also used as a tool to evaluate the existing mechanical system.

ISEB is a technically advanced building with major design challenges. The design specified in the design documents is true to the initial design objectives. There were many factors that had to be addressed by the mechanical system and ISEB's mechanical design does so. Ventilation rates are well within the standards set by ASHRAE 62.1. The designed mechanical system reduces the energy use by about 29% when compared to the LEED baseline design.

## Building Overview

The building receives steam and chilled water from the Campus Utilities Plant (CUP). The steam is converted to hot water in a steam-to-water heat exchanger, which provides the buildings heating requirements. Chilled water, from the University of Delaware's campus chilled water plant, is fed to a water-to-water flat plate heat exchanger that meets the buildings chilled water needs. An electric drive stand-by chiller is on site, in the basement mechanical room, and consists of 6 modules each sized at 50 tons (two of which incorporate hot gas bypass). The heat from this chiller will be recovered when possible and injected into the buildings heating/reheat loops. Two fluid coolers with a nominal cooling capacity of 240 tons are on site to provide to reject heat from the standby chiller if the heating/reheat loops do not need it.

There are ten total AHU's serving the building that are located in the fifth floor mechanical penthouses. Each of these seven AHU's fall into one of two system types, either recirculating or 100 percent outdoor air.

Air handling units 1, 2, & 10 are of the recirculating air system type. They serve the builds classrooms, offices, common spaces, and corridors. Pressure independent, Variable Air Volume (VAV) terminal units will be provided for each temperature control zone of the system. Each will be equipped with a hot water reheat coil to maintain space temperature. Because of the extreme variance in occupancy over a large span of operating hours in spaces served by this type of unit, the system will be designed to minimize energy consumption through unoccupied modes of operation. Supply fan volume control will be accomplished through the use of Variable Frequency Controllers (VFCs), which will modulate fan speed (and air flow) to maintain a constant duct static pressure.

The other seven AHU's (3, 4, 5, 6, 7, 8, & 9) are the 100% outdoor air units that serve the builds cleanroom, research, and instructional labs. These seven 100% outdoor air units all contain some form of energy recovery. Enthalpy wheels are used for spaces in which contamination of the supply air from the exhaust air is not critical and heat pipes for the units in which supply air contamination can not be risked (with the exception of AHU 9 which handles the clean room make-up air and has no energy recovery).

## Design Objectives and Factors

There are many factors that go into designing a mechanical system for a building and it is safe to say that not all buildings are created equal. ISEB is a unique building due to the cohabitation of education and laboratory spaces. The labs require strict environmental controls, continuous ventilation, and include process loads, while the education spaces have large occupancy fluctuations. This building was designed to foster cutting edge scientific research and education, and the mechanical system design needed to reflect that.

In the case of the labs, which have large ventilation loads, reducing energy lost through exhaust air was one of the design objectives. Another objective that arises from the lab spaces is building pressurization. The lab spaces must be negatively pressurized, in reference to the rest of the building spaces, in order to prevent contamination into and out of the labs. Large process loads and simultaneous heating/cooling throughout the building made heat reclamation another objective of the design.

The educational spaces result in large occupancy fluctuations throughout the day and therefore can result in large energy consumption due to lighting and ventilation if not dealt with properly. In order to reduce re-heat of supply air and lighting energy, occupancy sensing controls were a large objective of the design. As with most mechanical designs, temperature and humidity control of the building environment in order to provide thermal comfort to the occupants was a major design objective of this building.

The University of Delaware is a district heating/cooling system supplied by campus steam and chilled water plants. This meant that the design of ISEB required steam-water and water-water heat exchangers in lieu of on site boilers and chillers. Constant steam and chilled water supply temperatures mean that variable frequency controllers needed to be used on pumps if energy was to be conserved.

## Energy Sources and Rates

Fuel costs were obtained from the energy analysis report conducted by the design engineers. The rates, illustrated in table 1 below, were based on EIA averages for Maryland and were calculated using the formulas on page 14 of *Treatment of District or Campus Thermal Energy in LEED V2 and LEED 2009 – Design & Construction* dated August 13, 2010.

Table 1: Utility Rates used in TRACE Simulation

| Unit | Cost |
|---|---|
| Electricity | $ 0.1184 / kW-hr |
| Chilled Water | $ 0.828 / Therm |
| Steam | $ 2.34 / Therm |

## Design Conditions

The site for ISEB is located on the University of Delaware's campus, which resides in Newark, DE. The nearest location that ASHRAE Handbook of funamentals has design conditions recorded for is Wilmington, DE. These conditions are reported in Table 2 below.

Table 2: Design Outdoor Air Conditions

| ASHRAE HOF 2009 CH.14 APPENDIX | |
|---|---|
| Wilmington, DE | dB Temp |
| 0.4% Cooling | 93.1 °F |
| 99.6% Heating | 11.7 °F |

The indoor design conditions needed to be determined and specified for each space. For this building the engineer has specified two indoor condition types, lab and non-lab. These conditions were found in the design documents and are shown below in table 3.

Table 3:Indoor Air Design Conditions

| Indoor Design Conditions | | |
|---|---|---|
| | Winter | Summer |
| Lab Spaces | 72 °F | 72 °F |
| Non Lab Spaces | 70 °F | 75 °F |

## Building Ventilation

Table 4: Ventilation Calculations

| AHU-1 62.1 VENTILATION CALCULATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Az | Ra | Pz | Rp | Vbz ( = Voz) | Design Supply | Zp | Zone Design | Compliance? |
| | ft^2 | CFM / SF | # People | cfm / person | CFM OA | CFM | % O.A | O.A. CFM | |
| 209 Group Study | 714 | 0.06 | 7 | 5 | 77.84 | 1,173 | 7 | 97.0 | YES |
| 207 Classroom | 1,069 | 0.12 | 41 | 10 | 538.28 | 1,585 | 34 | 672.0 | YES |
| 205 Classroom | 1,025 | 0.12 | 41 | 10 | 533 | 1,584 | 34 | 665.0 | YES |
| 202 Classroom | 1,019 | 0.12 | 41 | 10 | 532.28 | 1,607 | 34 | 665.0 | YES |
| 204 Storage | 76 | 0.12 | 0 | 0 | 9.12 | 60 | 16 | 9.1 | YES |
| 201 Group Study | 368 | 0.06 | 4 | 5 | 42.08 | 2,036 | 3 | 52.0 | YES |
| 206 Electric Room | 86 | 0.06 | 0 | 0 | 5.16 | 165 | 4 | 6.5 | YES |
| 208 Copy/Print | 118 | 0.06 | 0 | 0 | 7.08 | 127 | 6 | 8.9 | YES |
| 101 Lobby | 170 | 0.06 | 0 | 5 | 10.2 | 1,320 | 1 | 12.8 | YES |
| 309 Group Study | 704 | 0.06 | 7 | 5 | 77.24 | 1,380 | 6 | 96.6 | YES |
| 307 Classroom | 1,070 | 0.12 | 41 | 10 | 538.4 | 1,585 | 34 | 673.0 | YES |
| 305 Classroom | 1,025 | 0.12 | 41 | 10 | 533 | 1,584 | 34 | 665.0 | YES |
| 302 Classroom | 1,025 | 0.12 | 41 | 10 | 533 | 1,598 | 34 | 678.0 | YES |
| 304 Storage | 76 | 0.12 | 0 | 0 | 9.12 | 60 | 16 | 9.1 | YES |
| 301 Group Study | 368 | 0.06 | 4 | 5 | 42.08 | 2,038 | 3 | 53.0 | YES |
| 306 Electric Room | 86 | 0.06 | 0 | 0 | 5.16 | 173 | 3 | 7.0 | YES |
| 308 Copy/Print | 197 | 0.06 | 0 | 0 | 11.82 | 133 | 9 | 15.0 | YES |
| 404 Reception/Huddle | 439 | 0.06 | 2 | 5 | 36.34 | 2,013 | 2 | 45.0 | YES |
| 402H Director | 191 | 0.06 | 1 | 5 | 16.46 | 264 | 7 | 21.0 | YES |
| 402G Faculty Office | 161 | 0.06 | 1 | 5 | 14.66 | 244 | 7 | 18.0 | YES |
| 402F Faculty Office | 164 | 0.06 | 1 | 5 | 14.84 | 245 | 7 | 18.0 | YES |
| 402E Meeting | 158 | 0.06 | 6 | 5 | 39.48 | 301 | 14 | 50.0 | YES |
| 402D Faculty Office | 160 | 0.06 | 1 | 5 | 14.6 | 244 | 6 | 18.0 | YES |
| 402C Faculty Office | 165 | 0.06 | 1 | 5 | 14.9 | 245 | 7 | 18.0 | YES |
| 402B CITA | 158 | 0.06 | 1 | 5 | 14.48 | 243 | 6 | 18.0 | YES |
| 402A Conference | 232 | 0.06 | 12 | 5 | 73.92 | 515 | 15 | 92.0 | YES |
| TA (x6) | 282 | 0.06 | 6 | 5 | 46.92 | 1,005 | 5 | 47.0 | YES |
| Circulation/Common Area | 1,142 | 0.06 | 0 | 0 | 68.52 | 541 | 13 | 69.0 | YES |
| 402L Huddle | 163 | 0.06 | 6 | 5 | 39.78 | 100 | 40 | 40.0 | YES |
| TA (x2) | 98 | 0.06 | 2 | 5 | 15.88 | 100 | 16 | 13.0 | YES |
| TA (x4) | 196 | 0.06 | 4 | 5 | 31.76 | 516 | 7 | 32.0 | YES |
| 402J Copy/Work Room | 118 | 0.06 | 0 | 0 | 7.08 | 163 | 5 | 9.0 | YES |
| 403 Electric Room | 141 | 0.06 | 0 | 0 | 8.46 | 180 | 5 | 11.0 | YES |
| 401 Group Study | 368 | 0.06 | 4 | 5 | 42.08 | 2,046 | 3 | 53.0 | YES |
| 402K Coffee/BreakRoom | 119 | 0.06 | 2 | 5 | 17.14 | 268 | 7 | 21.0 | YES |
| 300B Corridor | 170 | 0.06 | 0 | 0 | 10.2 | 800 | 2 | 13.0 | YES |
| | 13,821 | | | | 4,032 | 28,241 | | 4,991 | |

(red box) = Max $Z_P$

62.1 section 6. Not only does every space comply with section 6 calculations, but the design outside airflow rates for the majority of the spaces exceed the rates required by this section. Calculations for remaining units in Appendix A.

## Heating/Cooling Loads

Trane's TRACE 700 program was used for both the load calculations and energy simulation conducted in this report. The variation in load characteristics, ventilation rates, and energy recovery opportunities between lab and non-lab spaces makes running and analyzing the energy analysis for ISEB a complex process. After the TRACE load calculations were completed, they were compared to the loads presented in the design documents.

Table 5: Design vs. TRACE Calculated Loads

| | Peak Cooling | Peak Heating |
|---|---|---|
| **TRACE CALC** | **1410 Tons** | **9,924 MBH** |
| **Design Docs.** | **1350 Tons** | **11,628 MBH** |
| **Difference** | **4.2%** | **14.6%** |

## Annual Energy Use

Table 6: Energy Simulation Results from Design Engineer

| Electricity (kW-hr/yr) | Chilled Water (ton-hr/yr) | Steam (BTUH/yr) | Total Cost/Year |
|---|---|---|---|
| 6,998,096 | 1,152,946 | 6,958 | $1,085,495 |

Table 7: TRACE Energy Simulation Results

| Electricity (kW-hr/yr) | Chilled Water (ton-hr/yr) | Steam (BTUH/yr) | Total Cost/Year |
|---|---|---|---|
| **7,601,151** | **1,589,141** | **6,562** | **$1,268,803** |
| **+ 8%** | **+ 27%** | **- 6%** | **+14%** |

## Mechanical Equipment

**Table 8: AHU Schedule**

| AHU Schedule | | | | | |
|---|---|---|---|---|---|
| AHU | CMF Max | GPM | Cooling (MBH) | GPM | Heating (MBH) |
| 1 | 24,000 | 152 | 985 | 144 | 540,760 |
| 2 | 20,000 | 132 | 564 | 117 | 518,919 |
| 3 | 35,000 | 232 | 1,701 | 412 | 641,056 |
| 4 | 35,000 | 232 | 1,652 | 412 | 518,951 |
| 5 | 8,000 | 53 | 423 | 104 | 40,153 |
| 6 | 20,000 | 132 | 972 | 236 | 247,004 |
| 7 | 27,000 | 179 | 1,312 | 318 | 286,413 |
| 8 | 33,000 | 218 | 160 | 389 | 239,351 |
| 9 | 32,000 | 132 | 1,696 | 260 | 107,614 |
| 10 | 42,000 | 278 | 1,360 | 263 | 811,990 |

**Table 9: Water-Water HX Schedule**

| Water to Water Heat Exchanger | | | | | |
|---|---|---|---|---|---|
| | | Tube | | Shell | |
| | Capacity (MBH) | Flow (GPM) | EWT / LWT | Flow (GPM) | EWT / LWT |
| 1 | 459 | 92 | 50 / 60 | 92 | 70 / 60 |
| 2 | 459 | 92 | 50 / 60 | 92 | 70 / 60 |

**Table 10: steam-Water HX Schedule**

| Steam to Water Converter | | | | |
|---|---|---|---|---|
| | Capacity (MBH) | Water Flow (GPM) | EWT / LWT | Steam input (lbs/hr) |
| 1 | 13,779 | 700 | 120/160 | 14,425 |
| 2 | 9,842 | 500 | 120/160 | 10,300 |
| 3 | 13,779 | 700 | 120/160 | 14,425 |

**Table 11: Chiller Schedule**

| Standby Chiller (6 modules @ 80 tons ea.) | | | | |
|---|---|---|---|---|
| Capacity | Max Input | Evaporator | Condenser | |
| (tons) | (Kw) | EWT / LWT | EWT / LWT | Refrig. |
| 480 | 283 | 60 / 44 | 85 / 95 | R-134a |

**Table 12: Humidifier Schedule**

| Humidifiers | | |
|---|---|---|
| | Input Capacity | Output Capacity |
| Unit | MBH | lbs/hr. |
| 3 | 814 | 793 |
| 4 | 814 | 793 |
| 5 | 331 | 324 |
| 6 | 450 | 453 |
| 7 | 625 | 611 |
| 8 | 734 | 747 |
| 9a | 813 | 811 |
| 9b | 813 | 811 |
| 10 | 291 | 237 |

**Table 12: Fluid Cooler Schedule**

| Fluid Coolers | | | | |
|---|---|---|---|---|
| Capacity | Entering Water | Leaving Water | Ambiant | Water Flow |
| (tons) | Temp (F) | Temp (F) | Wet Bulb (F) | Rate (GPM) |
| 240 | 95 | 85 | 78 | 772 |

## System Operation

### Heating System (steam/water side)

The heating system for ISEB has both a steam and hot water side. Steam is supplied to the building from the campus steam plant loop at 100 psi. The steam then goes through a 2-stage pressure reducing station which has first reduces the pressure to 60 psi then again to 15 psi. The medium pressure (60 psi) steam is sent to 2 steam powered pumps which are used to return the systems condensate. A flash tank is provided for the medium pressure condensate before it goes to the condensate receiver tank. The lower pressure (15 psi) steam is then supplied to the building's domestic hot water heaters or either one of ISEB's 2 hot water converters.

Hot water converter 1 is used to meet the systems winter heating loads (ie: when the OA temp. are below 60oF). The hot water in this system is supplied to the buildings many AHU's and FCU's. Hot water system 1 will use 160o water in the winter but will fallow a linear reset schedule based on the outdoor air temperature; this is shown below in table 1. Preheat coils in the AHU's are equipped with in line circulating pumps and will operate when the outdoor air temperature falls below 40oF to prevent coil freezing. Hot water converter 2 is used to meet the summer reheat loads associated with the zone air terminal units. This reheat system is used to prevent sub-cooling of the supply air during dehumidification. This water will be maintained a constant supply temperature of 160oF. The pumps for both hot water systems (1 and 2) are provided with variable frequency controllers to reduce energy consumption at part load.

In order to offset some of the steam load supplied to ISEB, a heat recovery water loop is supplied to the building from the East Campus Chiller Plant. This water is supplied at 140oF and is returned to the plant at 120oF. This water will be used to preheat return water to ISEB's 2 hot water converters or preheat water to the domestic water heaters for the building.

### Cooling System (water side)

Campus chilled water is supplied to the building at 42oF to meet the chilled water loads of ISEB. The building chilled water loop supplies the AHU's, FCU's, and a water-to-water, heat exchanger that meets the building's lab process cooling loads. Chilled water distribution throughout the building will be variable flow. The distribution pumps for the chilled water loop are variable frequency controlled in order to reduce energy consumption at part load. The chilled water system will operate when the outdoor air temperature rises above 50oF and will be controlled to maintain the chilled water supply temperature at 44oF and return temperature of 60oF.

The water-to-water heat exchanger will be a closed loop system, in order to prevent impurities from the campus chilled water loop from entering the lab equipment.

The building also incorporates a standby chiller to serve the critical lab spaces during times when the campus chilled water plant is off-line or when cooling loads are low. This chiller is comprised of six 50 ton modules that can operate independently, resulting in good turn down of the chiller's capacity at low load conditions. Heat from the standby chiller's condenser is normally rejected into the building's heat/re-heat loop but at times of low heating load, this condenser heat can be rejected to two fluid-coolers on the roof.

## Air-Side (Re-circulating Units)

The re-circulation type AHU's in ISEB supply a mixture of return air from the spaces and outdoor air required for ventilation.

### Summer:

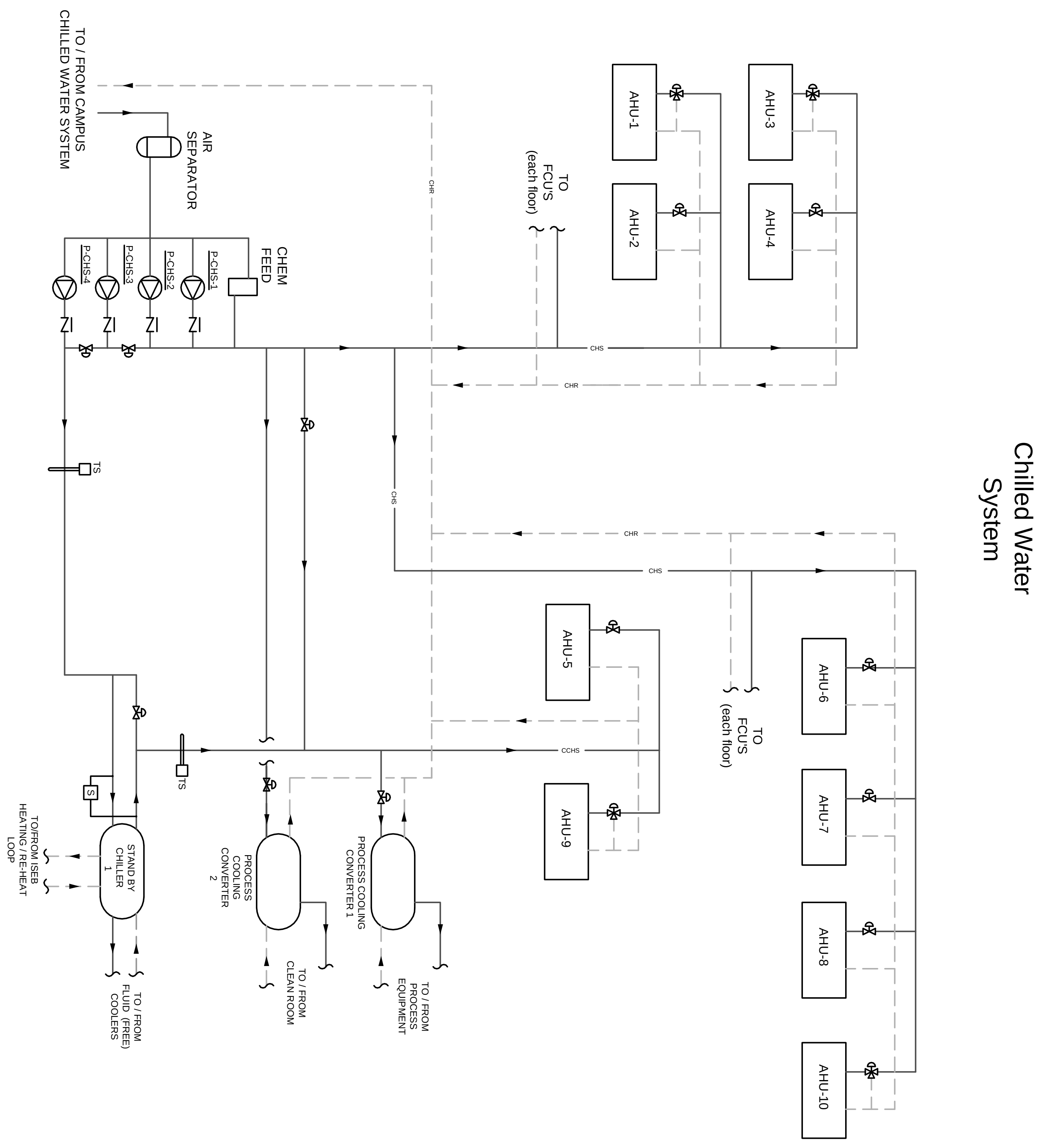
Damper D-1 modulates to provide the minimum amount of outdoor air determined by occupancy sensors in the spaces. An economizer cycle is provided in these units, which allows the use excess outdoor air for free cooling when the outdoor air temperature is below 50oF. Temperature sensor TS-1 measures the mixed air temperature and modulates dampers D-2, D-3, and D-4 to achieve a mixed are temperature of 55oF when the unit is in free cooling mode. The mixed air is then drawn through the cooling coil section of the unit. The chilled water flow through this type of unit is controlled by TS-3 in order to provide cooling and dehumidification of the mixed air to the design supply air conditions of 75oF and 55%RH. The use of sub-cooling for dehumidification is accounted for by reheat in the air terminal units to each zone. Further down stream in the system TS-4 and HS-1 measure the temperature and humidity level of the supply air and reset the setpoint of sensor TS-3 if needed. The supply fan is fitted with a VFC in order to maintain a constant duct static pressure. The return fan is also equipped with a VFC that will track the supply fan speed in order to maintain minimum ventilation rates and building pressurization.

### Winter:

Damper D-1 modulates to provide the minimum required amount of outdoor air, determined by occupancy sensors, to the spaces. The mixed air then passes through a filter before entering the pre-heat coil section of the unit. The flow of hot water through the preheat coils is controlled by TS-2 in order to raise the supply temperature of the mixed air to the design conditions of 72oF and 30%RH. The freeze state FZ-1 monitors the temperature off of the pre-heat coil to prevent freezing of the cooling coil. It can also be noted that the preheat coils contain in line circulating pumps that operate when the O.A. temp. falls below 40oF, in order to prevent freezing of the preheat coils. Further down stream in the system TS-4 and HS-1 measure the temperature and humidity level of the supply air and reset the setpoint of sensor TS-2 if needed. The fan controls are the same as in summer mode.

### Air-Side (100% OA)

The 100% outdoor air AHU's serve the many lab spaces throughout ISEB. In these units the outdoor air is brought in through damper D-1, which will modulate to provide the minimum amount of supply air needed. The supply air to the labs will be determined by either, 12 air changes per hour, amount required to offset heat gains, or amount required to supply make-up to fume hoods, whichever is the largest. Because these units supply lab spaces, they must operate 24 hrs. a day in order to negatively pressurize the lab spaces in reference to the rest of the building. With such a large, steady amount of outdoor air being brought into these units energy recovery is essential. The unit shown uses heat pipes to reject heat to the exhaust air stream in cooling mode, and transfer heat from the exhaust air when in heating mode, other 100% O.A. units may use enthalpy wheels in place. Dampers D-2 and D-3 modulate in unison to direct supply air over or around the energy recovery section, based on the temperature that TS-1 is sensing. Heating and cooling is done with the use of hydronic coils controlled by variable DDC room sensors. Freeze protection is provided by the freeze state FZ-1 which will modulate flow through the heating coils if outdoor air temperature falls below 40oF, in order to prevent freezing of the coils.

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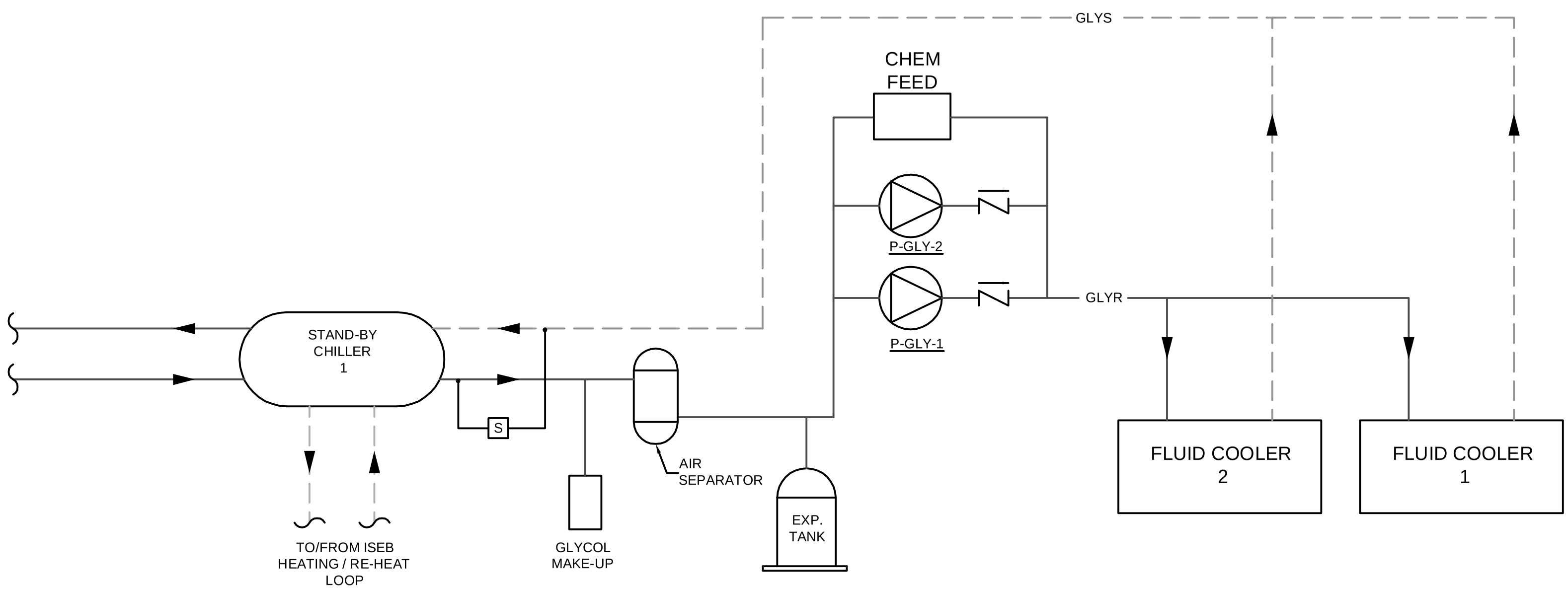
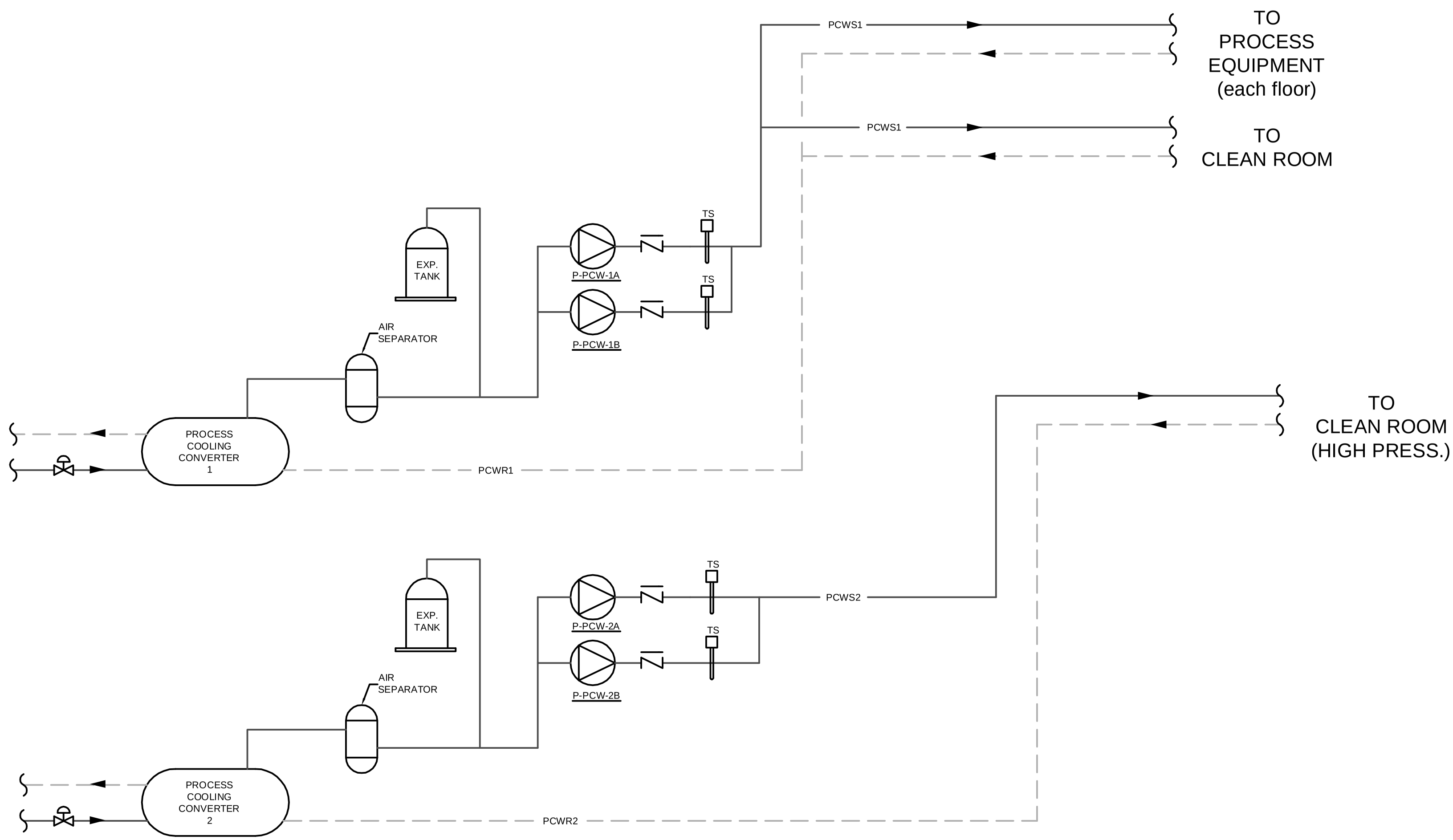
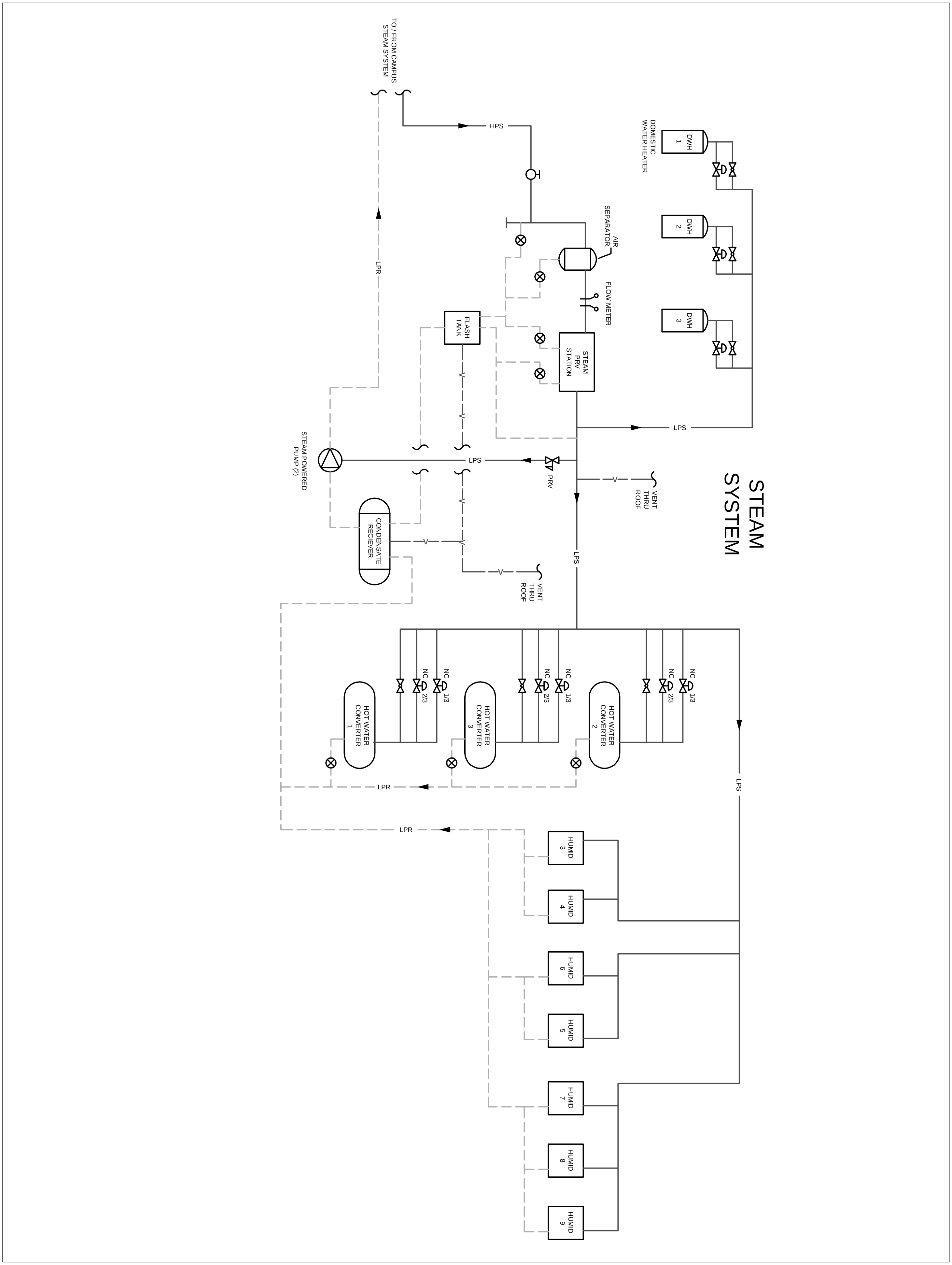



# STAND BY CHILLER

# Chilled Water System



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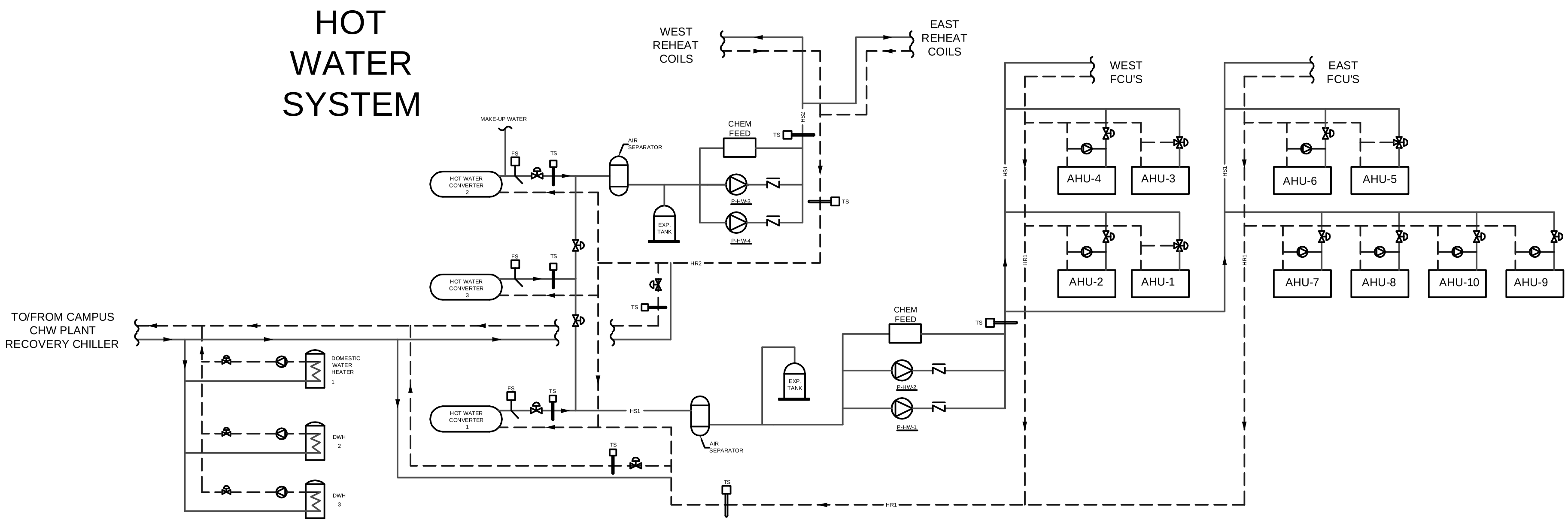
# HOT WATER SYSTEM

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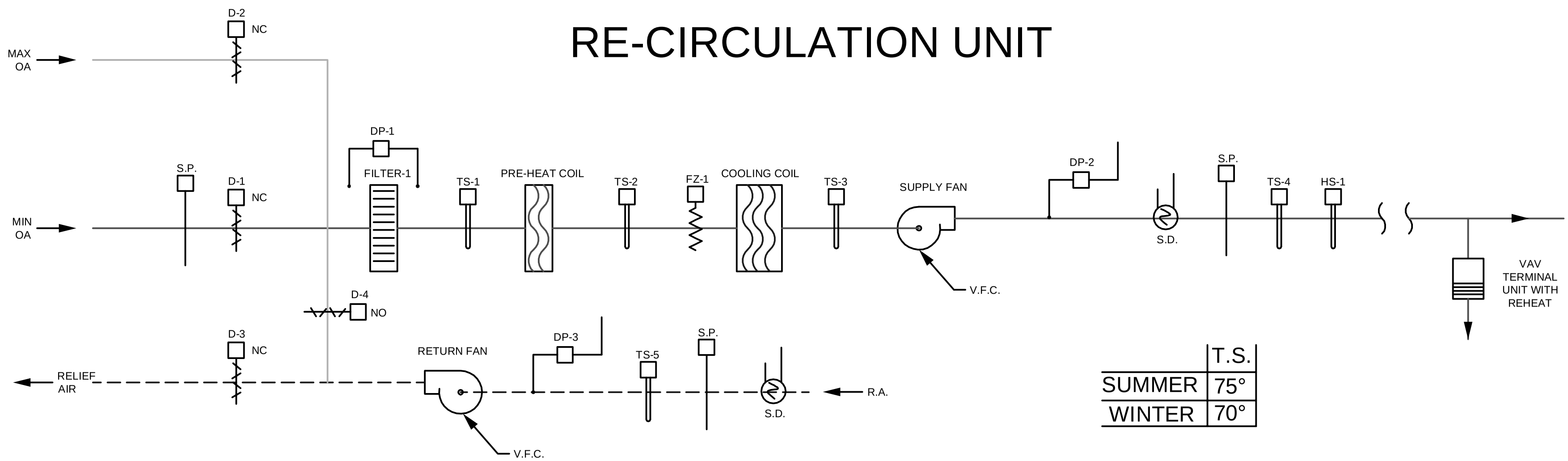
# RE-CIRCULATION UNIT




| | T.S. |
|---|---|
| SUMMER | 75° |
| WINTER | 70° |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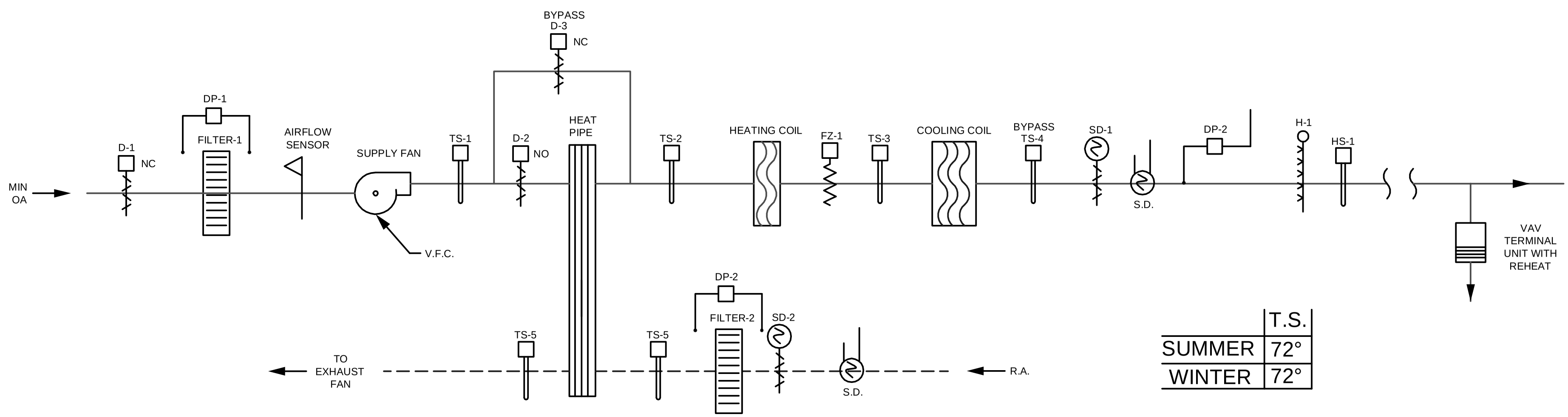
# 100% O.A. UNIT




| | T.S. |
|---|---|
| SUMMER | 72° |
| WINTER | 72° |

Humidity control is provided by the use of humidifier H-1 and by the use of cooling coil dehumidification with use of VAV terminal reheat.

## Lost Usable Space

**Table 13: Lost Usable Space due to Mechanical Equipment**

| Lost Usable Space | |
|---|---|
| **Space** | **Floor Area (S.F.)** |
| **Shafts** | **2,623** |
| **Pump Room** | **372** |
| **Basement Mechanical Room** | **6,028** |
| **Service Chase** | **425** |
| **Lab Mechanical Rooms** | **515** |
| **Penthouses** | **12,024*** |
| **Lost Usable Space** | **9,963** |
| * Penthouse area not considered usable space | |

# LEED NC 2004 Assesment

## Energy and Atmosphere

### ●EA Prerequisite 1: **Fundamental Commissioning of Building Energy Systems**

A LEED analysis for this building could not be obtained. For the sake of analyzing ISEB's mechanical system's compliance with LEED NC, it will be assumed that commissioning would be used making this prerequisite attainable.

### ●EA Prerequisite 2: **Minimum Energy Performance**

Due to the size of the building (194,000 ft2), option 1 Whole Building Energy Simulation must be used. According to the energy simulation conducted by the design engineer, the total building mechanical system will save 29% on energy cost, when compared to the LEED baseline case.

### ●EA Prerequisite 3: **Fundamental Refrigerant Management**

Building chilled water is processed from an off site chilled water plant. There is however one stand-by chiller which uses R-410a, which is a HCFC refrigerant and therefore complies with this prerequisite.

- EA Credit 1: **Optimize Energy Performance (option 1)**

According to the energy simulation conducted by the design engineer, the total building mechanical system will save 29% on energy cost, when compared to the LEED baseline case. This will result in ISEB attaining 9 out of the possible 19 points for this section.

**+ 9**

- EA Credit 2: **On-site Renewable Energy**

Although photovoltaic solar panels are present in the design documents for this project, there is insufficient information on these units and it will be assumed, due to the size/use of this building and the small number of solar panels, that they do not meet the criteria for this credit.

**+ 0**

- EA Credit 3: **Enhance Commissioning**

Information on the use of a commissioning agent for LEED analysis of ISEB could not be obtained but as with prerequisite 1 it will be assumed that this credit is attainable for this project.

**+ 2**

- EA Credit 4: **Enhanced Refrigerant Management**

Although refrigerant is not used for every day operation of ISEB, the 300 ton standby chiller for the building uses R-134a. When the equations for option 2 are used the LCGWP is 218 which is not less than the required limit of 100 (based on a lifecycle of 10 years).

**+ 0**

- EA Credit 5: **Measurement and Verification**

The University of Delaware has a dedicated facilities staff consisting of certified engineers and service technicians. Therefore, it is well within the ability of the owner to continue to monitor any energy savings after to constructions. This credit is attainable.

**+ 3**

- EA Credit 6: **Green Power**

"Engage in at least a 2-year renewable energy contract to provide at least 35% of the building's electricity from renewable sources." Due to the insignificant amount of renewable energy on the site of ISEB, this credit is not attainable.

**+ 0**

## Indoor Environmental Quality

● IEQ Prerequisite 1: **Minimum Indoor Air Quality Performance**

"Meet the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality." Most spaces in the building are 100% ventilation air and the spaces served by re-circulating type units are designed to be well within the ASHRAE Standard 62.1 requirements, as shown in tech report 1.

● IEQ Prerequisite 2: **Environmental Tobacco Smoke (ET S) Control**

This prerequisite is fulfilled based on case 1 of the requirement. ISEB is owned by and on the University of Delaware's Campus which is a smoke free campus.

● IEQ Credit 1: **Outdoor Air Delivery Monitoring (Case 1)**

In the case of the non-100% O.A. spaces, variable volume supply air terminal units are implemented for the control of supply/ventilation air to each zone. These terminal units are controlled by occupancy sensors in each space and will throttle the amount of ventilation air to meet the critical space in that zone.

**+ 1**

● IEQ Credit 2: **Increased Ventilation**

Ventilation rates in the design documents for ISEB do not indicate rates 30% above the minimum values set by ASHRAE Standard 62.1.

**+ 0**

● IEQ Credit 3.1: **Construction Indoor Air Quality Management Plan—During Construction**

It will be assumed for this report that this credit is feasible due to the fact that at the time this report was written construction on ISEB has not yet started.

**+ 1**

● IEQ Credit 3.2: **Construction Indoor Air Quality Management Plan—Before Occupancy**

It will be assumed for this report that this credit is feasible due to the fact that at the time this report was written construction on ISEB has not yet started.

**+ 1**

● IEQ Credit 6.1: **Controllability of Systems—Lighting**

In order to reduce energy consumption in the building, ISEB incorporates occupancy sensors to control the lighting in most areas. This along with the fact that the lab areas are strictly controlled due to necessity result in the conclusion that less than 90% of the occupants having control over the lighting

**+ 0**

- IEQ Credit 7.1: **Thermal Comfort—Design**

The heating, ventilating and air conditioning (HVAC) systems and the building envelope of ISEB have been designed based on the requirements of ASHRAE Standard 55-2004.

**+ 1**

- IEQ Credit 7.2: **Thermal Comfort—Ventilation**

Due to the fact that ISEB is an educational and research building, it should be reasonable to survey the occupants on a regular basis. It will be assumed for this report that this credit is attainable.

**+ 1**

- IEQ Credit 8.1: **Daylight and Views—Daylight**

"Through 1 of the 4 options, achieve daylighting in at least the following spaces".

| Regularly Occupied Spaces | Points |
|---|---|
| 75% | 1 |

**+ 1**

- IEQ Credit 8.1: **Daylight and Views—Views**

"Achieve a direct line of sight to the outdoor environment via vision glazing between 30 inches and 90 inches above the finish floor for building occupants in 90% of all regularly occupied areas."

**+ 1**

## Overall System Evaluation

The designed of ISEB's mechanical system is very sophisticated; it needs to be in order to meet the stringent requirements of the spaces it serves. It is apparent from the mechanical system design that the owner spared no expense in order to have a building that will operate as efficiently as possible. The energy recovery methods, off site heating/cooling plants utilization, and advanced control strategies are all on the cutting edge of mechanical system design. This is apparent in the energy simulation conducted by the design team, which is compared to ASHRAE Standard 90.1's baseline design. The design meets all standards for ventilation set by ASHRAE standard 62.1. Although the mechanical system is very efficient and designed to reduce unneeded energy loss, one area that LEED points were not attainable in was the area of renewable energy. The availability of steam and chilled water from a district plant makes on-site energy use very unattractive. In all, the mechanical system design of ISEB is very well designed.

## References

ASHRAE Standard 62.1-2007

ASHRAE Standard 90.1-2007

ASHRAE Handbook of Fundementals–2008

National Electrical Code – 2007

http://www.NEMA.org

*Mechanical & Electrical Equipment for Builders*, tenth edition

Thomas Syvertsen

Mueller Associates

EMO Energy Solutions

# Appendix A

| AHU-2 62.1 VENTILATION CALCULATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp | Zone Design OA | |
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) | CFM | Compliance? |
| **102 Commons** | 604 | 0.06 | 38 | 5 | 226.24 | 2,290 | **10** | 227.00 | YES |
| **200A Corridor 1** | 295 | 0.06 | 0 | 0 | 17.7 | 45 | **40** | 18.00 | YES |
| **102 Commons** | 302 | 0.06 | 38 | 5 | 208.12 | 2,240 | **10** | 260.00 | YES |
| **102 Commons** | 302 | 0.06 | 38 | 5 | 208.12 | 2,240 | **10** | 209.00 | YES |
| **200A Corridor 1** | 590 | 0.06 | 0 | 0 | 35.4 | 95 | **38** | 36.00 | YES |
| **102 Commons** | 604 | 0.06 | 38 | 5 | 226.24 | 2,500 | **10** | 282.00 | YES |
| **102 Commons (west)** | 3,576 | 0.06 | 150 | 5 | 964.56 | 8,515 | **12** | 1204.00 | YES |
| **102A Food Services** | 482 | 0.18 | 4 | 7.5 | 116.76 | 820 | **15** | 146.00 | YES |
| **101 Lobby** | 1,000 | 0.06 | 0 | 0 | 60 | 910 | **7** | 60.00 | YES |
| **103 Entry Foyer** | 345 | 0.06 | 0 | 5 | 20.7 | 91 | **23** | 21.00 | YES |
| **200A Corridor 1** | 295 | 0.06 | 0 | 0 | 17.7 | 45 | **40** | 18.00 | YES |
| **200B Balcony** | 511 | 0.06 | 0 | 0 | 30.66 | 1,426 | **3** | 31.00 | YES |
| **300A Corridor 1** | 1,120 | 0.06 | 0 | 0 | 67.2 | 1,957 | **4** | 84.00 | YES |
| **400A Corridor 1** | 960 | 0.06 | 0 | 0 | 57.6 | 1,918 | **4** | 72.00 | YES |
| | **10,986** | | | | **2,257** | **25,092** | | **2,668** | |

| AHU-3 62.1 VENTILATION CALCULATIONS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp | Zone Design OA | |
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) | CFM | Compliance? |
| 001 Building Storage | 125 | 0.12 | 0 | 0 | 15 | 50 | **30** | 15.00 | YES |
| 001A Basement Corridor | 1,405 | 0.06 | 0 | 0 | 84.3 | 500 | **17** | 85.00 | YES |
| 106 Prep | 798 | 0.18 | 8 | 10 | 223.64 | 1,771 | **13** | 280.00 | YES |
| 107 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.81 | 1,995 | **14** | 332.00 | YES |
| 109 Food SVC Storage | 399 | 0.12 | 0 | 0 | 47.88 | 414 | **12** | 60.00 | YES |
| 111 Informal Gathering | 580 | 0.06 | 12 | 5 | 94.8 | 658 | **15** | 119.00 | YES |
| 104 Fire Security Room | 100 | 0.06 | 0 | 0 | 6 | 410 | **2** | 12.00 | YES |
| 105 Storage | 79 | 0.12 | 0 | 0 | 9.48 | 53 | **18** | 10.00 | YES |
| 100C Corridor | 775 | 0.06 | 0 | 0 | 46.5 | 896 | **6** | 58.00 | YES |
| 113 Women | 206 | 0.06 | 0 | 0 | 12.36 | 155 | **8** | 25.00 | YES |
| 114 Men | 206 | 0.06 | 0 | 0 | 12.36 | 145 | **9** | 25.00 | YES |
| 211 Storeroom | 798 | 0.12 | 0 | 0 | 95.76 | 659 | **15** | 120.00 | YES |
| 212 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.81 | 1,995 | **14** | 332.00 | YES |
| 216 Informal Gathering | 594 | 0.06 | 12 | 5 | 95.64 | 693 | **14** | 120.00 | YES |
| 215 AV | 322 | 0.12 | 0 | 0 | 38.64 | 193 | **21** | 39.00 | YES |
| 214 Vending | 30 | 0.06 | 0 | 0 | 1.8 | 791 | **1** | 2.00 | YES |
| 210 Tech Offices | 198 | 0.06 | 2 | 5 | 21.88 | 107 | **21** | 27.00 | YES |
| 218 Women | 206 | 0.06 | 0 | 0 | 12.36 | 140 | **9** | 25.00 | YES |
| 219 Men | 206 | 0.06 | 0 | 0 | 12.36 | 140 | **9** | 25.00 | YES |
| 200C Corridor | 1,175 | 0.06 | 0 | 0 | 70.5 | 662 | **11** | 88.00 | YES |
| 311 Glasswash | 798 | 0.06 | 2 | 0 | 47.88 | 1,228 | **4** | 91.00 | YES |
| 312 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.81 | 1,995 | **14** | 332.00 | YES |
| 315 PBL Classroom | 1,407 | 0.12 | 47 | 10 | 638.84 | 1,369 | **47** | 800.00 | YES |
| 316 Informal Gathering | 580 | 0.06 | 12 | 5 | 94.8 | 689 | **14** | 120.00 | YES |
| 314 Physics Storage | 399 | 0.12 | 0 | 0 | 47.88 | 630 | **8** | 60.00 | YES |
| 310 Tech Offices | 198 | 0.06 | 2 | 5 | 21.88 | 107 | **21** | 28.00 | YES |
| 318 Women | 206 | 0.06 | 0 | 0 | 12.36 | 140 | **9** | 25.00 | YES |
| 319 Men | 206 | 0.06 | 0 | 0 | 12.36 | 143 | **9** | 25.00 | YES |
| 300B Corridor | 1,420 | 0.06 | 0 | 0 | 85.2 | 1,070 | **8** | 107.00 | YES |
| 406 Prep | 798 | 0.18 | 8 | 0 | 143.64 | 1,728 | **9** | 208.00 | YES |
| 407 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.81 | 1,995 | **14** | 332.00 | YES |
| 410 PBL Classroom | 1,407 | 0.12 | 49 | 10 | 658.84 | 1,864 | **36** | 824.00 | YES |
| 411 Informal Gathering | 580 | 0.06 | 12 | 5 | 94.8 | 690 | **14** | 119.00 | YES |
| 409 Physics Storage | 399 | 0.12 | 0 | 0 | 47.88 | 650 | **8** | 60.00 | YES |
| 413 Women | 206 | 0.06 | 0 | 0 | 12.36 | 170 | **8** | 25.00 | YES |
| 414 Men | 206 | 0.06 | 0 | 0 | 12.36 | 170 | **8** | 25.00 | YES |
| 400B Corridor | 1,175 | 0.06 | 0 | 0 | 70.5 | 1,115 | **7** | 88.00 | YES |
| 405 Tech Office | 175 | 0.06 | 2 | 5 | 20.5 | 131 | **16** | 26.00 | YES |
| | 19,824 | 3 | 218 | 100 | 3,883 | 26,895 | | 4,955 | |

AHU-4 62.1 VENTILATION CALCULATIONS

| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp | Zone Design OA | Compliance? |
|---|---|---|---|---|---|---|---|---|---|
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) | CFM | |
| 119 Prep Room | 450 | 0.18 | 5 | 10 | 131 | 1,180 | **12** | 164.00 | YES |
| 112 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.9 | 1,995 | **14** | 332.00 | YES |
| 110 PBL Classroom | 1,407 | 0.12 | 10 | 10 | 268.84 | 1,999 | **14** | 824.00 | YES |
| 115 Electrical Room | 141 | 0.06 | 0 | 0 | 8.46 | 407 | **3** | 11.00 | YES |
| 118 Media Services Office | 258 | 0.06 | 3 | 5 | 30.48 | 247 | **13** | 31.00 | YES |
| 120 Storage | 192 | 0.12 | 0 | 0 | 23.04 | 246 | **10** | 23.00 | YES |
| 100C Corridor | 775 | 0.06 | 0 | 0 | 46.5 | 300 | **16** | 58.00 | YES |
| 223 Prep Room | 424 | 0.18 | 10 | 10 | 176.32 | 955 | **19** | 120.00 | YES |
| 217 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.9 | 1,995 | **14** | 332.00 | YES |
| 220 Electrical Room | 141 | 0.06 | 0 | 0 | 8.46 | 412 | **3** | 11.00 | YES |
| 215 PBL Classroom | 1,407 | 0.12 | 10 | 10 | 268.84 | 1,364 | **20** | 799.00 | YES |
| 222 PBL Corner Classroom | 511 | 0.12 | 20 | 10 | 261.32 | 1,540 | **17** | 327.00 | YES |
| 200C Corridor | 1,018 | 0.06 | 0 | 0 | 61.08 | 300 | **21** | 76.00 | YES |
| 323 Prep | 422 | 0.18 | 10 | 10 | 175.96 | 952 | **19** | 157.00 | YES |
| 317 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.9 | 1,995 | **14** | 332.00 | YES |
| 322 PBL Corner Classroom | 509 | 0.12 | 20 | 10 | 261.08 | 1,620 | **17** | 326.00 | YES |
| 320 Electrical Room | 141 | 0.06 | 0 | 0 | 8.46 | 412 | **3** | 11.00 | YES |
| 300B Corridor | 1,018 | 0.06 | 0 | 0 | 61.08 | 300 | **21** | 76.00 | YES |
| 418 Prep | 424 | 0.18 | 10 | 10 | 176.32 | 1,050 | **17** | 145.00 | YES |
| 412 Instructional Lab | 755 | 0.18 | 13 | 10 | 265.9 | 1,995 | **14** | 332.00 | YES |
| 415 Electrical Room | 141 | 0.06 | 0 | 0 | 8.46 | 408 | **3** | 11.00 | YES |
| 417 Seminar | 495 | 0.06 | 13 | 5 | 94.7 | 1,530 | **7** | 118.00 | YES |
| 400B Corridor | 1,018 | 0.06 | 0 | 0 | 61.08 | 300 | **21** | 76.00 | YES |
| | **13,912** | | | | **3,195** | **23,502** | | **4,692** | |

AHU-5 62.1 VENTILATION CALCULATIONS

| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp | Zone Design OA | |
|---|---|---|---|---|---|---|---|---|---|
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) | CFM | Compliance? |
| 174 Microscopy & Imaging Suite | 385 | 0.18 | 1.0 | 10 | 79.3 | 645 | **13** | 99.00 | YES |
| 155 Microscopy & Imaging Suite | 355 | 0.18 | 1.0 | 10 | 73.9 | 645 | **12** | 92.00 | YES |
| 173 Microscopy & Imaging Suite | 385 | 0.18 | 1.0 | 10 | 79.3 | 645 | **13** | 99.00 | YES |
| 157 Microscopy & Imaging Suite | 375 | 0.18 | 1.0 | 10 | 77.5 | 645 | **13** | 97.00 | YES |
| 172 Microscopy & Imaging Suite | 365 | 0.18 | 1.0 | 10 | 75.7 | 645 | **12** | 95.00 | YES |
| 158 Microscopy & Imaging Suite | 370 | 0.18 | 1.0 | 10 | 76.6 | 645 | **12** | 96.00 | YES |
| 171 Microscopy & Imaging Suite | 370 | 0.18 | 1.0 | 10 | 76.6 | 645 | **12** | 96.00 | YES |
| 159 Microscopy & Imaging Suite | 370 | 0.18 | 1.0 | 10 | 76.6 | 645 | **12** | 96.00 | YES |
| 154 Microscopy & Imaging Prep | 1,150 | 0.18 | 5.0 | 10 | 257 | 645 | **40** | 259.00 | YES |
| 156 Pump Room | 185 | 0.06 | 0.0 | 0 | 11.1 | 933 | **2** | 14.00 | YES |
| 169 Pump Room | 189 | 0.06 | 0.0 | 0 | 11.34 | 955 | **2** | 15.00 | YES |
| | 4,499 | | | | 895 | 7,693 | | 1,058 | |

AHU-6 ASHRAE 62.1 VENTILATION COMPLIANCE

| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp | Zone Design OA | Compliance? |
|---|---|---|---|---|---|---|---|---|---|
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) | CFM | |
| 151 Advanced Material Characterizatior | 2,956 | 0.18 | 10 | 10 | 632.08 | 7,680 | 9 | 790.00 | YES |
| 251 Synthesis Suite | 2,946 | 0.18 | 16 | 10 | 690.28 | 14,100 | 5 | 862.00 | YES |
| 200D Corridor | 450 | 0.06 | 0 | 0 | 27 | 200 | 14 | 34.00 | YES |
| 100G Corridor | 450 | 0.06 | 0 | 0 | 27 | 275 | 10 | 34.00 | YES |
| | **6,802** | | | | **1,376** | **22,255** | | **1,720** | |

## AHU-7 62.1 VENTILATION CALCULATIONS

| | Az (ft^2) | Ra CFM / ft^2 | Pz # People | Rp cfm / person | Vbz ( = Voz) CFM OA | SUPPLY AIR CFM | Zp (cfm OA/ cfm supply) | Zone Design OA CFM | Compliance? |
|---|---|---|---|---|---|---|---|---|---|
| 351A Instrument Room | 316 | 0.18 | 0.0 | 10 | 56.88 | 969 | 6 | 71.00 | YES |
| 351 North Research Labs | 2,351 | 0.18 | 7.0 | 10 | 493.18 | 10,875 | 5 | 528.00 | YES |
| 350 North Research Labs | 723 | 0.18 | 4.0 | 10 | 170.14 | 6,699 | 3 | 212.00 | YES |
| 300D Corridor | 345 | 0.06 | 0.0 | 0 | 20.7 | 310 | 7 | 26.00 | YES |
| Environmental Room | 90 | 0.18 | 0.0 | 10 | 16.2 | 25 | 65 | ----- | N/A |
| 450 North Research Labs | 1,892 | 0.18 | 10.0 | 10 | 440.56 | 7,100 | 7 | 550.00 | YES |
| 450A Instrument Room | 309 | 0.18 | 0.0 | 10 | 55.62 | 813 | 7 | 70.00 | YES |
| 452 North Research Labs (small) | 371 | 0.18 | 1.0 | 10 | 76.78 | 1,400 | 6 | 96.00 | YES |
| 400D Corridor | 450 | 0.06 | 0.0 | 0 | 27 | 470 | 6 | 34.00 | YES |
| | **6,847** | | | | **1,357** | **28,661** | | **1,587** | |

## AHU-8 62.1 VENTILATION CALCULATIONS

| | Az (ft^2) | Ra CFM / ft^2 | Pz # People | Rp cfm / person | Vbz ( = Voz) CFM OA | SUPPLY AIR CFM | Zp (cfm OA/ cfm supply) | Zone Design OA CFM | Compliance? |
|---|---|---|---|---|---|---|---|---|---|
| 355 South Research Labs | 3,852 | 0.18 | 14 | 10 | 833.36 | 19,350 | 5 | 1040.00 | YES |
| 355B Equipment Room 2 | 231 | 0.12 | 0 | 0 | 27.72 | 870 | 4 | 52.00 | YES |
| 355A Equipment Room | 200 | 0.12 | 0 | 0 | 24 | 609 | 4 | 45.00 | YES |
| Research Commons Corridor 3 | 600 | 0.06 | 0 | 0 | 36 | 112 | 33 | 45.00 | YES |
| 359 LN2 Dewar Fill Room | 98 | 0.06 | 0 | 0 | 5.88 | 181 | 4 | 15.00 | YES |
| 455B Equipment Room 2 | 326 | 0.12 | 0 | 0 | 39.12 | 1,398 | 3 | 74.00 | YES |
| 455A Equipment Room | 243 | 0.12 | 0 | 0 | 29.16 | 1,001 | 3 | 55.00 | YES |
| 455 South Research Labs | 2,872 | 0.18 | 14 | 10 | 656.96 | 12,900 | 6 | 984.00 | YES |
| Research Commons Corridor 3 | 600 | 0.06 | 0 | 0 | 36 | 300 | 12 | 45.00 | YES |
| | **9,022** | | | | **1,688** | **36,721** | | **2,355** | |

## AHU-9 62.1 VENTILATION CALCULATIONS

| | Az (ft^2) | Ra CFM / ft^2 | Pz # People | Rp cfm / person | Vbz ( = Voz) CFM OA | SUPPLY AIR CFM | Zp % (cfm OA/ cfm supply) | Zone Design OA CFM | Compliance? |
|---|---|---|---|---|---|---|---|---|---|
| 161 Tool Gas Dispensing Room | 273 | 0.18 | 0 | 10 | 49.14 | 179 | **28** | 61.00 | YES |
| 160 Gown | 273 | 0.18 | 0 | 10 | 49.14 | 96 | **52** | 61.00 | YES |
| 160G Vestibule (Service Chase) | 3,498 | 0.06 | 0 | 0 | 209.88 | 876 | **24** | 262.00 | YES |
| 160F Cleanroom Class (342) | 816 | 0.12 | 8 | 10 | 177.92 | 3,903 | **5** | 222.00 | YES |
| 160E Cleanroom Class (343) | 1,199 | 0.12 | 10 | 10 | 243.88 | 5,706 | **5** | 305.00 | YES |
| 160C Cleanroom Class (344) | 1,050 | 0.12 | 10 | 10 | 226 | 5,017 | **5** | 282.00 | YES |
| 160B Cleanroom Class (345) | 1,042 | 0.12 | 10 | 10 | 225.04 | 4,980 | **5** | 281.00 | YES |
| 160H Cleanroom Storage | 100 | 0.12 | 0 | 0 | 12 | 45 | **27** | 15.00 | YES |
| 160J Air lock (128) | 90 | 0.06 | 0 | 0 | 5.4 | 45 | **12** | 7.00 | YES |
| 160A Air lock (132) | 87 | 0.06 | 0 | 0 | 5.22 | 45 | **12** | 7.00 | YES |
| 254 Cleanroom Mechanical | 464 | 0.18 | 0 | 10 | 83.52 | 2,238 | **4** | 105.00 | YES |
| 254 Cleanroom | 8,308 | 0.18 | 0 | 10 | 1495.44 | 200 | **748** | 1869.00 | YES |
| | **17,200** | | | | **2,783** | **23,330** | | **3,477** | |

## AHU-10 STANDARD 62.1 VENTILATION CALCS

| | Az | Ra | Pz | Rp | Vbz ( = Voz) | SUPPLY AIR | Zp |
|---|---|---|---|---|---|---|---|
| | (ft^2) | CFM / ft^2 | # People | cfm / person | CFM OA | CFM | (cfm OA/ cfm supply) |
| 170 Core Workspace | 324 | 0.06 | 1 | 5 | 24.44 | 518 | 5 |
| 163 Core Office | 107 | 0.06 | 1 | 5 | 11.42 | 93 | 13 |
| 164 Core Office | 114 | 0.06 | 1 | 5 | 11.84 | 71 | 17 |
| 100L Corridor | 235 | 0.06 | 0 | 0 | 14.1 | 100 | 15 |
| 165 B Holding | 112 | 0.06 | 0 | 0 | 6.72 | 67 | 11 |
| 165 General Receiving | 613 | 0.06 | 0 | 0 | 36.78 | 190 | 20 |
| 165D Chemical Waste Storage | 184 | 0.12 | 0 | 0 | 22.08 | 138 | 16 |
| 100J Corridor | 1,000 | 0.06 | 0 | 0 | 60 | 309 | 20 |
| 100K/O Corridor | 930 | 0.06 | 0 | 0 | 55.8 | 643 | 9 |
| 162 Core Storage | 137 | 0.12 | 0 | 0 | 16.44 | 87 | 19 |
| 166 Women | 208 | 0.18 | 0 | 5 | 37.44 | 65 | 58 |
| 168 Men | 213 | 0.18 | 0 | 5 | 38.34 | 65 | 59 |
| 100H Corridor 3 | 1,695 | 0.06 | 0 | 0 | 101.7 | 1,479 | 7 |
| 100G Corridor 1 | 934 | 0.06 | 0 | 0 | 56.04 | 368 | 16 |
| 150 Lobby | 589 | 0.06 | 0 | 5 | 35.34 | 1,000 | 4 |
| 250A Director | 250 | 0.06 | 1 | 5 | 20 | 403 | 5 |
| 250D Associate Director | 130 | 0.06 | 1 | 5 | 12.8 | 242 | 6 |
| 250E Assistant | 150 | 0.06 | 1 | 5 | 14 | 242 | 6 |
| 250F Associate Director | 130 | 0.06 | 1 | 5 | 12.8 | 242 | 6 |
| 250B Office | 133 | 0.06 | 1 | 5 | 12.98 | 65 | 20 |
| 250C Office | 133 | 0.06 | 1 | 5 | 12.98 | 65 | 20 |
| 200F Corridor 3 | 405 | 0.06 | 0 | 0 | 24.3 | 110 | 23 |
| 250G Director | 250 | 0.06 | 1 | 5 | 20 | 403 | 5 |
| 250M Director | 250 | 0.06 | 1 | 5 | 20 | 403 | 5 |
| 250P Associate Director | 146 | 0.06 | 1 | 5 | 13.76 | 242 | 6 |
| 250X Conference | 222 | 0.06 | 6 | 5 | 43.32 | 344 | 13 |
| 250P Copy Room | 116 | 0.12 | 0 | 5 | 13.92 | 124 | 12 |
| 255T Building Manager Office | 126 | 0.06 | 1 | 5 | 12.56 | 84 | 15 |
| 250Q Office | 126 | 0.06 | 1 | 5 | 12.56 | 84 | 15 |
| 256V Core Office | 118 | 0.06 | 1 | 5 | 12.08 | 73 | 17 |
| 200F Corridor 3 | 405 | 0.06 | 0 | 0 | 24.3 | 110 | 23 |
| 250 Staff (Open Office) | 1,405 | 0.06 | 7 | 5 | 119.3 | 448 | 27 |
| 250H Reception | 93 | 0.06 | 1 | 5 | 10.58 | 55 | 20 |
| 250 Staff (Open Office Circulation) | 1,230 | 0.06 | 0 | 5 | 73.8 | 118 | 63 |
| 259 Women | 224 | 0.18 | 0 | 5 | 40.32 | 73 | 56 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 261 Men | 216 | 0.18 | 0 | 5 | 38.88 | 74 | **53** |
| 258 Core Office | 225 | 0.06 | 2 | 5 | 23.5 | 120 | **20** |
| 200F Corridor | 805 | 0.06 | 0 | 0 | 48.3 | 220 | **22** |
| 200G Closet | 90 | 0.06 | 0 | 0 | 5.4 | 86 | **7** |
| 254A Clean Room Mechanical Storage | 245 | 0.12 | 0 | 0 | 29.4 | 99 | **30** |
| 250R Assistant | 150 | 0.06 | 1 | 5 | 14 | 242 | **6** |
| 250S Associate Director | 130 | 0.06 | 1 | 5 | 12.8 | 242 | **6** |
| 250U Director | 255 | 0.06 | 2 | 5 | 25.3 | 400 | **7** |
| 255 Custodial | 231 | 0.12 | 2 | 0 | 27.72 | 227 | **13** |
| 257 Unisex Toilet | 108 | 0.18 | 0 | 5 | 19.44 | 89 | **22** |
| 256 Storage | 648 | 0.12 | 0 | 0 | 77.76 | 447 | **18** |
| 200BR Corridor | 480 | 0.06 | 0 | 0 | 28.8 | 2,500 | **2** |
| 250Y Conference Small | 327 | 0.06 | 10 | 5 | 69.62 | 763 | **10** |
| 250DD Assistant | 97 | 0.06 | 1 | 5 | 10.82 | 56 | **20** |
| 250CC Assistant | 98 | 0.06 | 1 | 5 | 10.88 | 56 | **20** |
| 250BB Assistant | 97 | 0.06 | 1 | 5 | 10.82 | 56 | **20** |
| 250AA Assistant | 97 | 0.06 | 1 | 5 | 10.82 | 56 | **20** |
| 200F Corridor 3 | 405 | 0.06 | 0 | 0 | 24.3 | 110 | **23** |
| 253 Electrical Room | 170 | 0.06 | 0 | 0 | 10.2 | 1,135 | **1** |
| 200DE Corridor 2 | 926 | 0.06 | 0 | 0 | 55.56 | 448 | **13** |
| 150 Lobby | 144 | 0.06 | 0 | 5 | 8.64 | 960 | **1** |
| 257W Kitchen/Breakroom | 245 | 0.06 | 0 | 5 | 14.7 | 377 | **4** |
| 250J Office | 274 | 0.06 | 2 | 5 | 26.44 | 136 | **20** |
| 381 Conference | 355 | 0.06 | 10 | 5 | 71.3 | 816 | **9** |
| 356 Copy | 107 | 0.06 | 0 | 5 | 6.42 | 143 | **5** |
| 357 Post Doc Cluster | 158 | 0.06 | 2 | 5 | 19.48 | 133 | **15** |
| 358 Workroom | 106 | 0.06 | 1 | 5 | 11.36 | 93 | **13** |
| 377 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 376 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 375 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 374 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 373 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 372 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 371 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 370 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 369 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 368 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 362 Mens Toilet | 160 | 0.18 | 0 | 5 | 28.8 | 68 | **43** |
| 364 Post Doc | 160 | 0.06 | 2 | 5 | 19.6 | 101 | **20** |
| 365 Post Doc | 160 | 0.06 | 2 | 5 | 19.6 | 101 | **20** |
| 366 Post Doc | 160 | 0.06 | 2 | 5 | 19.6 | 101 | **20** |
| ( Grad Clusters, Research Circ) | 2,980 | 0.06 | 24 | 5 | 298.8 | 1,160 | **26** |
| (Grad Clusters, Research Circ) | 3,820 | 0.06 | 21 | 5 | 334.2 | 1,220 | **28** |
| 300 Corridor BR | 480 | 0.06 | 0 | 0 | 28.8 | 2,500 | **2** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 363 Coffee/Breakroom | 300 | 0.06 | 1 | 5 | 23 | 793 | **3** |
| 300D Corridor 2 | 1,286 | 0.06 | 0 | 0 | 77.16 | 340 | **23** |
| 354 Storage | 109 | 0.12 | 0 | 0 | 13.08 | 14 | **94** |
| 353 Electric Room | 170 | 0.06 | 0 | 0 | 10.2 | 562 | **2** |
| 360 Womens Toilet | 207 | 0.18 | 0 | 5 | 37.26 | 130 | **29** |
| 378 Post Doc | 136 | 0.06 | 2 | 5 | 18.16 | 90 | **21** |
| 379 Post Doc | 136 | 0.06 | 2 | 5 | 18.16 | 90 | **21** |
| 380 Post Doc | 136 | 0.06 | 2 | 5 | 18.16 | 90 | **21** |
| 472 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 473 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 474 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 470 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 471 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 468 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 469 PI Office | 149 | 0.06 | 1 | 5 | 13.94 | 210 | **7** |
| 467 Conference | 365 | 0.06 | 10 | 5 | 71.9 | 640 | **12** |
| 456 Copy | 105 | 0.06 | 0 | 5 | 6.3 | 185 | **4** |
| 457 Post Grad Cluster | 182 | 0.06 | 2 | 5 | 20.92 | 209 | **11** |
| 458 Workarea | 105 | 0.18 | 1 | 5 | 23.9 | 125 | **20** |
| 459 Men | 213 | 0.18 | 0 | 5 | 38.34 | 70 | **55** |
| 462 Post Doc | 170 | 0.06 | 2 | 5 | 20.2 | 101 | **20** |
| 463 Post Doc | 170 | 0.06 | 2 | 5 | 20.2 | 101 | **20** |
| 464 Post Doct | 170 | 0.06 | 2 | 5 | 20.2 | 101 | **20** |
| 400J Corridor 3 | 150 | 0.06 | 0 | 0 | 9 | 100 | **9** |
| ( Grad Clusters, Research Circ) | 4,380 | 0.06 | 10 | 5 | 312.8 | 2,170 | **15** |
| (Grad Clusters, Research Circ) | 1,600 | 0.06 | 22 | 5 | 206 | 880 | **24** |
| 400 Corridor BR | 480 | 0.06 | 0 | 0 | 28.8 | 2,500 | **2** |
| 400K Coffee/Breakroom | 300 | 0.06 | 1 | 5 | 23 | 803 | **3** |
| 400D Corridor 2 | 695 | 0.06 | 0 | 0 | 41.7 | 300 | **14** |
| 453 Electric Room | 170 | 0.06 | 0 | 0 | 10.2 | 580 | **2** |
| 363 Commons | | 0.12 | | 7.5 | | | |
| 461 Women | 207 | 0.18 | 0 | 5 | 37.26 | 131 | **29** |
| 475 Post Doc | 133 | 0.06 | 2 | 5 | 17.98 | 92 | **20** |
| 476 Post Doc | 133 | 0.06 | 2 | 5 | 17.98 | 90 | **20** |
| 477 Post Doct | 133 | 0.06 | 2 | 5 | 17.98 | 89 | **21** |
| 454 Storage | 95 | 0.12 | 0 | 0 | 11.4 | 61 | **19** |
| Grad Clusters | 1,010 | 0.06 | 6 | 5 | 90.6 | 240 | **38** |
| | **44,525** | | **199** | | **4,016** | **39,705** | |