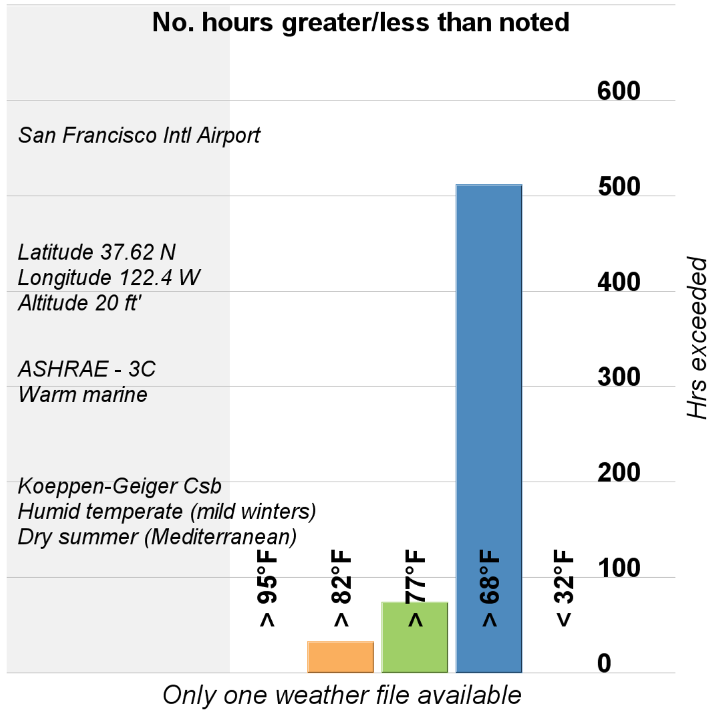
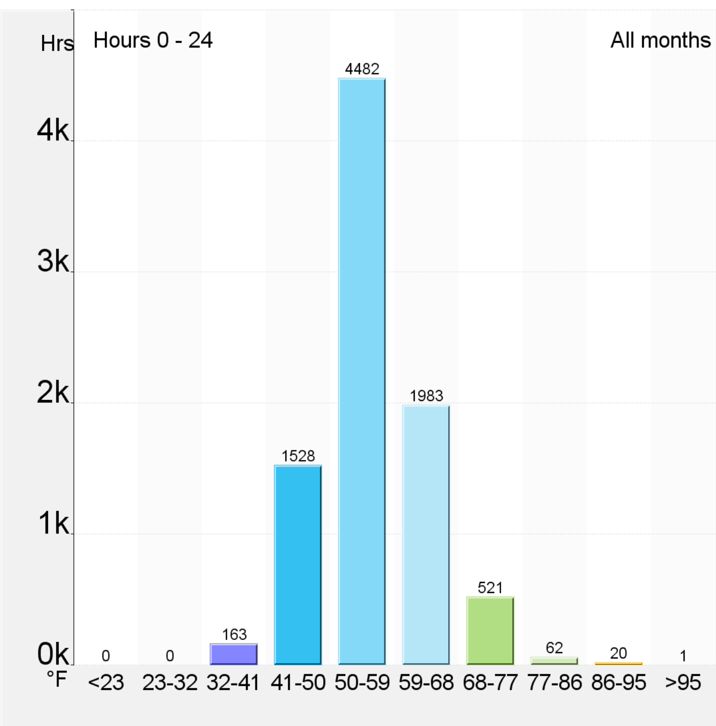
Supporting Documents

APPENDIX A: DESIGN CONDITIONS

WEATHER DATA:



As can be seen in the graphs to the left, San Francisco's location is ideal for passive conditioning methods. The majority of the time, the temperature is between 50°F and 59°F. It is because of this reasonable climate that natural ventilation was a crucial design aspect in the mechanical system. By incorporating natural ventilation into the design we were able to see dramatic energy savings.

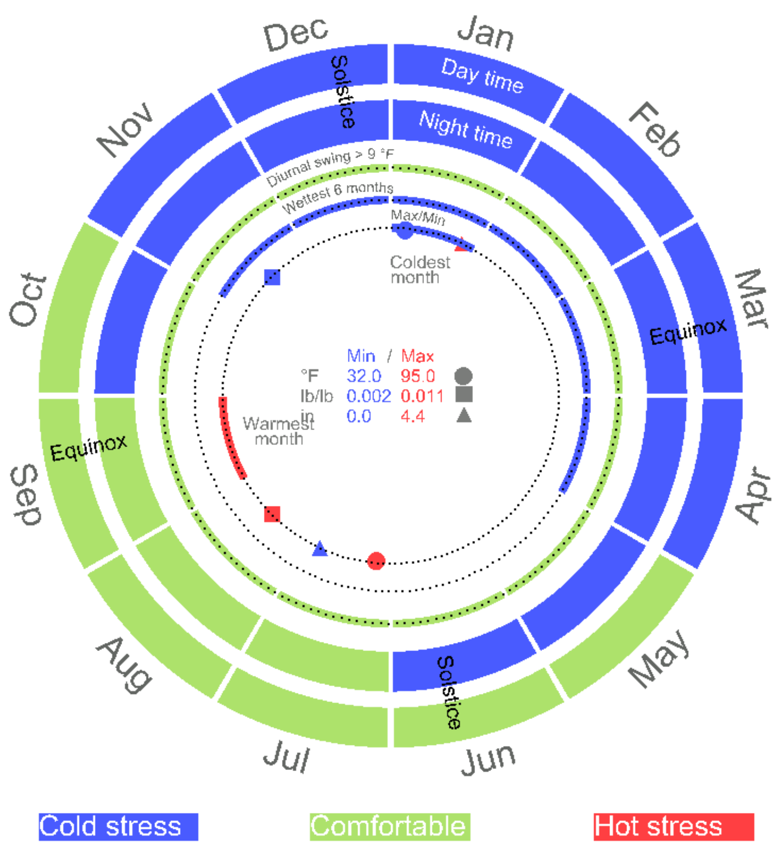


From IES CVE Climatic Report

DESIGN DATA:

HDD: 3016
CDD: 2883
*Taken from ASHRAE

ASHRAE Locality: 3C
*Taken from IES CVE Climatic Report



Coldest Month: January
Warmest Month: September
*Taken from IES CVE Climatic Report

The above graphic was a crucial instrument in the beginning phases of the design process. This graphic effectively displays numerous design criteria such as hottest/coolest months in the year, maximum and minimum temperatures, and typical day/nighttime comfort conditions.

At first glance it is easy to see that the most saving could potentially be obtained in the summer months where the benefits of natural ventilation could be exploited. The circle graph shows that the outside ambient conditions are considered comfortable in the months from May to October. In addition, it indicates that there are not any months with hot stress, indicating that the heating load of the building will be more influential than the cooling load.

Appendix B: Combined Heat and Power

CO_2 and Fuel Conservation Calculations:

Below can be found the formulas/equations that were used to calculate the Carbon and Fuel reductions associated with incorporating a CHP System. The calculation method was taken from "Fuel and carbon dioxide emissions savings calculations methodology for CHP system" prescribed by the EPA.

Formula 1: Fuel Savings from CHP

$$F_S = (F_T + F_G) - F_{CHP}$$

F_S - Total Fuel Savings (Btu)
F_T - Fuel Use from Displaced On-site Thermal Production (Btu)
F_G - Fuel Use from Displaced Grid Electricity (Btu)
F_{CHP} - Fuel Used by CHP System (Btu)

Formula 2: $C0_2$ Savings from CHP

$$C_S = (C_T + C_G) - C_{CHP}$$

C_S - Total CO_2 Emissions Savings (lbs.CO_2)
C_T - Fuel Use from Displaced On-site Thermal Production (lbs.CO_2)
C_G - Fuel Use from Displaced Grid Electricity (lbs.CO_2)
C_{CHP} - CO_2 Emissions from the CHP System (lbs.CO_2)

Formula 3: Fuel Use from Displaced On-Site Thermal Production

$$F_T = CHP_T / \eta_T$$

F_T - Fuel Use from Displaced On-Site Thermal Production (Btu)
CHP_T - CHP System Thermal Output (Btu)
* $CHP_T = F_{CHP}*45\%$ (Heat Recovery Efficiency)
η_T - Efficiency of the Thermal Equipment

Formula 4: $C0_2$ Emissions from Displaced On-Site Thermal Production

$$C_T = F_T * EF_F * (1*10^{-6})$$

C_T - CO_2 Emissions from Displaced On-Site Thermal Production (lbs. CO_2)
F_T - Thermal Fuel Savings (BTU)
EF_F - Fuel Specific CO_2 Emission factor (lbs. CO_2/MMBtu)
$1*10^{-6}$ - Conversion factor from Btu to MMBtu

Formula 5: Displaced Grid Electricity from CHP

$$E_G = CHP_E / (1-L_{T\&D})$$

E_G - Displaced Grid Electricity (kWh)
CHP_E - CHP System Electricity Output (kWh)
$L_{T\&D}$ - Transmission and Distribution Losses

Formula 6: Fuel Use from Displaced Grid Electricity

$$F_G = E_G * HR_G$$

F_G - Fuel Use from Displaced Grid Electricity (Btu)
E_G - Displace Grid Electricity from CHP (kWh)
HR_G - Grid Electricity Heat Rate (Btu/kWh) per subregion
*taken from www.epa.gove/cleanenergy/documents pdf file Appendix B

Formula 7: CO2 Emissions from Displaced Grid Electricity

$$C_G = E_G * EF_G$$

C_G - CO_2 Emissions from Displaced Grid Electricity (lbs. CO_2)
E_G - Displace Grid Electricity from CHP (kWh)
EF_G - Grid Electricity Emission Factor (CO_2/kWh) per subregion

Formula 8: CO2 Emissions from CHP System

$$C_{CHP} = F_{CHP} * EF_F$$

1,395,837(lbs CO_2) = 11,930,234,483(Btu) x 117(CO_2/MMBtu)

C_{CHP} - CO_2 Emissions from CHP System (lbs. CO_2)
F_{CHP} - Fuel used by CHP System (Btu)
EF_F - Fuel Specific Emission Factor (lbs. CO_2/MMBtu)

PROCEDURE:

CO_2 and Fuel Conservation Known Quantities

	Quantity	Units
CHP_E	1,014,000	kWh
F_{CHP}	11,930,234,483	Btu
CHP_T	5,368,605,517	Btu
η_T	80%	
EF_F	117	lbs. CO_2/MMBtu
$L_{T\&D}$	0	
HR_G	5,774	Btu/kWh
EF_G	953	lbs. CO_2/MWh

Formula 1: $\mathbf{F_S = (F_T + F_G) - F_{CHP}}$

635 (MMBtu) = (6,710 + 5,854) - 11,930 (MBtu)

Formula 2: $\mathbf{C_S = (C_T + C_G) - C_{CHP}}$

355,663 (CO_2) = (785,159 + 966,342) - 1,395,837 (CO_2)

Formula 3: $\mathbf{F_T = CHP_T / \eta_T}$

6,710,756,897 (Btu) = 5,368,605,517(Btu)/.8

Formula 4: $\mathbf{C_T = F_T * EF_F * (1*10^{-6})}$

785,159 (CO_2) = 6,710,756,897(Btu) x 117 (CO_2/MMBtu) * $1*10^6$

Formula 5: $\mathbf{E_G = CHP_E / (1-L_{T\&D})}$

1,014,000(kWh) = 1,014,000(kWh) / (1 – 0)

Formula 6: $\mathbf{F_G = E_G * HR_G}$

5,854,836,000 (Btu) = 1,014,000(kWh) x 5,774(Btu/kWh)

Formula 7: $\mathbf{C_G = E_G * EF_G}$

966,342 (CO_2) = 1,014,000(kWh) x .953(CO_2/kWh)

Formula 8: $\mathbf{C_{CHP} = F_{CHP} * EF_F}$

1,395,837 (CO_2) = 11,930,234,483(Btu) x 117(CO_2/MMBtu)

Combine Heat and Power System Design:

Max Load Capacities		
Max Heating Capacity	2,100	kBtu/hr
Max Cooling Capacity	7,380	kBtu/hr

65 kW Capstone Microturbines		
Electrical Efficiency	29%	
Generation Capacity	627	kW
Quantity	10	
Actual Capacity	650	kW

Energy Production		
Generation Capacity	650	kW
Operating Hours	1,560	hrs/yr
Generated Power	1,014,000	kWh/yr
Power Consumption	3,815,944	kWh/yr
Electrical Capacity Met	33%	

Heat Recovery		
Heat Recovery Efficiency	45%	
Heat Recovery	1,842	Btu/hr
Capacity Met	88%	

The combined heat and power system (CHP) was sized off of the cooling load since it has the largest capacity. All information necessary for the computation was taken from Capstone's C65 Natural Gas Microturbine Performance Specification Data Sheet. The above table summarizes the resulting plant size, electrical generation capacity, yearly electrical demand satisfied, and thermal hot water capacity met.

CHP Payback:

The following calculations estimate the time it will take in order to see a full return on the installed CHP system. Taken into account for this calculation are the savings associated with California's CHP/Cogeneration Incentive Program. From this program we were able to receive back $0.48/W. This translated into a direct rebate/savings of $312,000. The annual operation and maintenance (O&M) cost of $.012/kWh was obtain from the EPA Overview document, *Table III: Summary Table of Typical Cost and Performance Characteristics by CHP Technologies.*

CHP System Payback Period

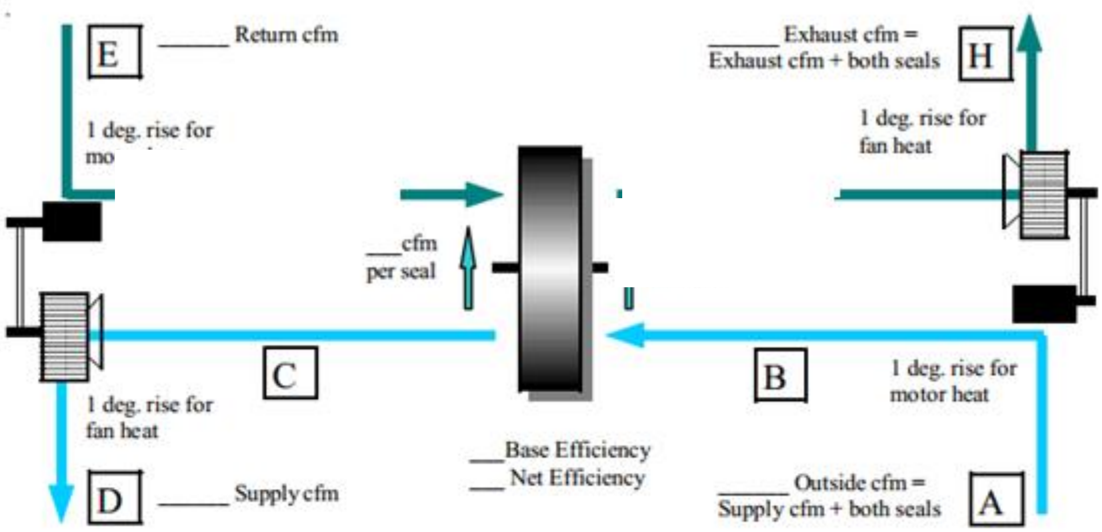
Year	Capital Investment	Yearly Maintenance	Spark Spread	Difference
1	503,000	12,168	101,400	-413,768
2	0	12,168	101,400	-324,536
3	0	12,168	101,400	-235,304
4	0	12,168	101,400	-146,072
5	0	12,168	101,400	-56,840
6	0	12,168	101,400	32,392
7	0	12,168	101,400	121,624
8	0	12,168	101,400	210,856
9	0	12,168	101,400	300,088
10	0	12,168	101,400	389,320
11	0	12,168	101,400	478,552
12	0	12,168	101,400	567,784
13	0	12,168	101,400	657,016
14	0	12,168	101,400	746,248
15	0	12,168	101,400	835,480
16	0	12,168	101,400	924,712
17	0	12,168	101,400	1,013,944
18	0	12,168	101,400	1,103,176
19	0	12,168	101,400	1,192,408
20	0	12,168	101,400	1,281,640
21	0	12,168	101,400	1,370,872
22	0	12,168	101,400	1,460,104
23	0	12,168	101,400	1,549,336
24	0	12,168	101,400	1,638,568
25	0	12,168	101,400	1,727,800

After running the 25 year analysis it was determined that the CHP system would see a full return in just over 5 years.

Appendix C: Enthalpy Wheel

Enthalpy Wheel/Sensible and Latent Load Calculations:

The following section shows the calculations for the enthalpy wheel that was utilized to satisfy the latent load. Also presented are the sensible and latent load values for a typical office floor. The enthalpy wheel calculations were performed via the methods prescribed by the Berner Energy Recovery document found at www.bernerenergy.com. Below is a typical schematic of an enthalpy wheel that will be used to help perform the calculations.



Design Supply CFM:	17,000 CFM
Design Exhaust CFM:	17,000 CFM
CFM Ratio:	1.0
Base Efficiency:	75%

EFFICIENCY OF THE WHEEL AT WHEEL RATIO

Model No.	CFM	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
9617	16,000	0.75	0.80	0.83	0.86	0.88	0.91	0.93	0.94
	16,500	0.75	0.80	0.83	0.86	0.88	0.93	0.92	0.94
	17,000	0.75	0.80	0.83	0.86	0.88	0.90	0.92	0.95
	17,500	0.74	0.79	0.82	0.86	0.88	0.90	0.92	0.95
	18,000	0.73	0.78	0.83	0.85	0.87	0.90	0.93	0.95

Quantity	A (OA)	D (SA)	E (RA)	H (EX)
Dry Bulb	81	62	75	75
Wet Bulb	64	63	63	63
% Relative Humidity	39	-	50	50
Gr/lbs	63	62.7	66	66

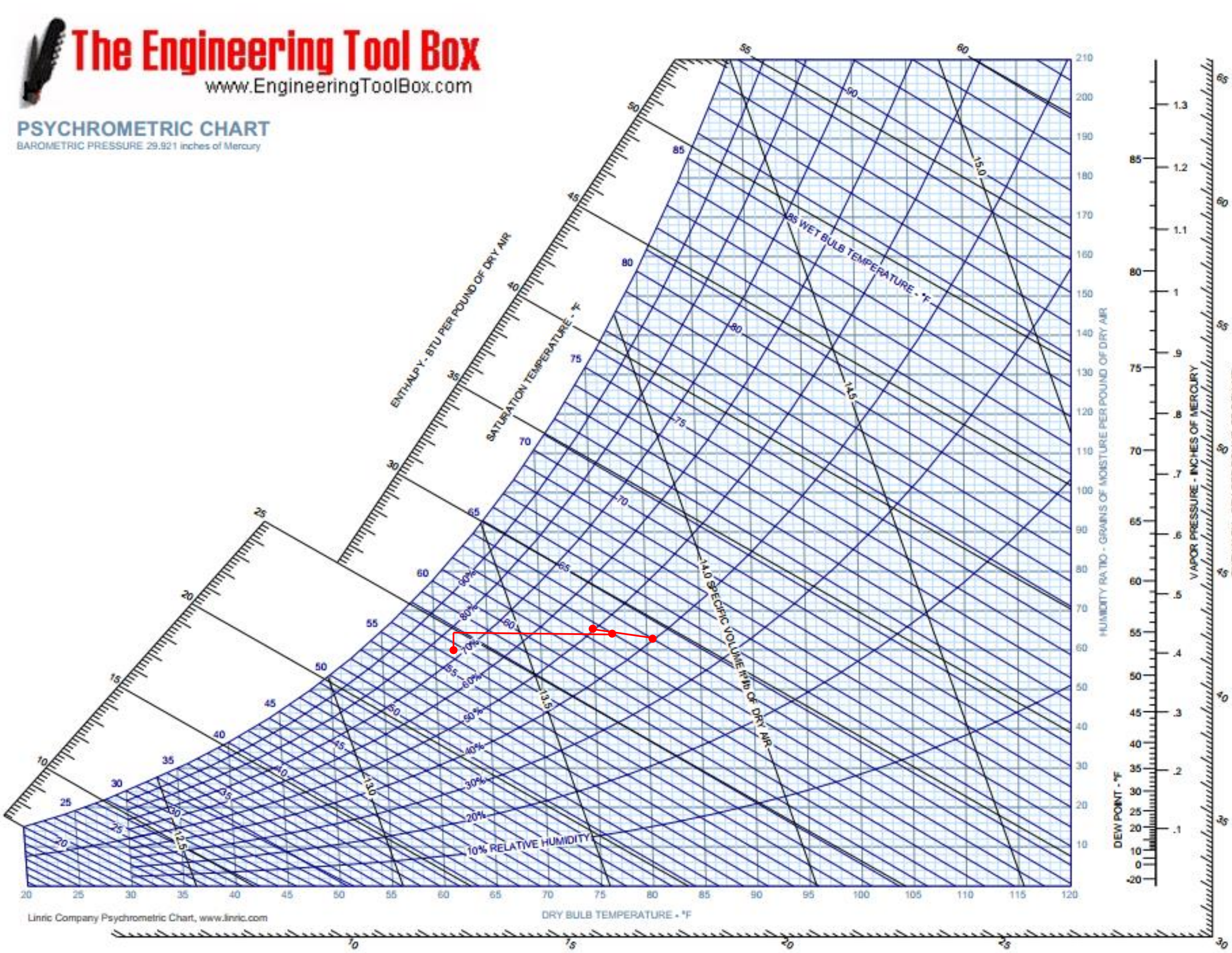
Enthalpy Wheel Capacity Procedure:

Formula 1 (Enthalpy wheel effect on DB): $\mathbf{OA_{DB} - RA_{DB} * eff_{Base}}$

4.5 ^{oF} = (81-75)*.75

Formula 2 (Enthalpy wheel effect on humidity ratio): $\mathbf{OA_{gr/lbs} - RA_{gr/lb} * eff_{Base}}$

2.3 gr/lbs = (63-66)*.75



$Q_{sensible}$	$=1.1*CFM*\triangle T$	Q_{latent}	$=.68*CFM*\triangle w$
$\mathbf{Q_{sensible,\ calculated}}$	**=242,000 Btu/hr.**	$\mathbf{Q_{latent,\ calculated}}$	**=27,000 Btu/hr.**
$Q_{sensible,system}$	=1.1*17,175*(75-62)	$Q_{latent,system}$	=.68*17,175*(66-62.7)
	=245,600 Btu/hr.		**=38,500 Btu/h**

Appendix D: Ventilation Calculations

Room Number	Room Name	Occupancy Categoery (ASHRAE 62.1)	Area A_z (sf)	Area Outdoor Air Rate R_a (Table 6.1)	Occupant Density P_z (#people)	People Outdoor Air Rate R_p (CFM/person)	Breathing Zone Outdoor Air Flow $V_{bz} = R_pP_z+R_aA_z$ (CFM)	Zone Air Distribution Effectiveness E_z (Table 6.2)	Zone Outdoor Air Flow $V_{oz}=V_{bz}/E_z$
B411	Elevator Lobby	Lobby	121	0.06	0.6	5	10	0.8	13
B409	Firemans Service Lobby	Lobby	191	0.06	1.0	5	16	0.8	20
B306	Elevator Lobby	Lobby	221	0.06	1.1	5	19	0.8	23
B300	Firemans Service Lobby	Lobby	191	0.06	1.0	5	16	0.8	20
B303	Service Lobby	Lobby	109	0.06	0.5	5	9	0.8	12
B206	Elevator Lobby	Lobby	221	0.06	1.1	5	19	0.8	23
B200	Firemans Service Lobby	Lobby	191	0.06	1.0	5	16	0.8	20
B203	Service Lobby	Lobby	109	0.06	0.5	5	9	0.8	12
B106	Elevator Lobby	Lobby	104	0.06	0.5	5	9	0.8	11
B100	Firemans Service Lobby	Lobby	187	0.06	0.9	5	16	0.8	20
B103	Service Lobby	Lobby	99	0.06	0.5	5	8	0.8	11
103	Service Lobby	Lobby	105	0.06	0.5	5	9	0.8	11
200	Firemans Service Lobby	Lobby	193	0.06	1.0	5	16	0.8	21
203	Service Lobby	Lobby	101	0.06	0.5	5	9	0.8	11
B112	Engineers Office	Office Space	500	0.06	3.0	5	45	0.8	56
B119	Valet Office	Office Space	90	0.06	1.0	5	10	0.8	13
110	Loading Dock Office	Office Space	100	0.06	1.0	5	11	0.8	14
101	Elevator Lobby	Lobby	350	0.06	1.8	5	30	0.8	37
111	Retail	Sales	400	0.12	6.0	7.5	93	0.8	116
100	Lobby	Main Entry Lobby	3600	0.06	36.0	5	396	0.8	495
113	Retail	Sales	625	0.12	9.4	7.5	145	0.8	182
215	Lobby	Lobby	1584	0.06	7.9	5	135	0.8	168
209	Restaurant	Restaurant dinning room	4330	0.18	303.1	7.5	3053	0.8	3816
208	Corridor	Corridor	450	0.06	0.0	0	27	0.8	34
508	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
509	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
510	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
511	Executive Office	Office Space	200	0.06	1.0	5	17	1.2	14
512	Copy Room	Occupiable Storage	100	0.06	1.0	5	11	1.2	9
513	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
514	Server Room	Media Center	100	0.12	0.0	5	12	1.2	10
515	Copy Room	Occupiable Storage	100	0.06	1.0	5	11	1.2	9
516	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
517	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
518	Executive Office	Office Space	200	0.06	1.0	5	17	1.2	14
519	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
520	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
521	Private Office	Office Space	100	0.06	1.0	5	11	1.2	9
522	Conference	Conference/Meeting	190	0.06	9.5	5	59	1.2	49
523	Conference	Conference/Meeting	190	0.06	9.5	5	59	1.2	49
501	Elevator Lobby	Lobby	350	0.06	1.8	5	30	1.2	25
500	Open Office	Office Space	10250	0.06	51.3	5	871	1.2	726

Note: Only Podium and 5th floor office is shown due to repetitiveness and space constraint.

Appendix E: Load Calculations

AHU-1 - LOBBY Cooling Loads — **Air Side Cooling**

Room Number	Room Name	Occupancy Category (ASHRAE 62.1)	Area A_z (sf)	Internal Cooling Load (BTU/hr)	Internal Cooling Load (TONS)	Room Air Set Point (F)	Supply Air Flow (CFM)	Supply Air Temperature (F)	Air Side Cooling Capacity (BTU/hr)	Capacity Satisfied
111	Retail	Retail - Sales	441	2,643	0.22	75	185	62	2643	Confirmed
113	Retail	Retail - Sales	743	17,000	1.42	75	1189	62	17000	Confirmed
100	Lobby	Lobby	9362	651,012	54.25	75	45525	62	651012	Confirmed
TOTAL			9,362	670,655	56	75	46,899	62	670,655	

AHU-2 -PODIUM Cooling Loads — **Air Side Cooling**

Room Number	Room Name	Occupancy Category (ASHRAE 62.1)	Area A_z (sf)	Internal Cooling Load (BTU/hr)	Internal Cooling Load (TONS)	Room Air Set Point (F)	Supply Air Flow (CFM)	Supply Air Temperature (F)	Air Side Cooling Capacity (BTU/hr)	Capacity Satisfied
B411	Womens Locker Room	Restroom	608	477	0.04	75	22	55	477	Confirmed
B415	Mens Locker Room	Restroom	612	323	0.03	75	15	55	323	Confirmed
B421A	Service Corridor	Corridor/ Transition	776	227	0.02	75	10	55	227	Confirmed
B411	Elevator Lobby	Lobby	121	3,825	0.32	75	174	55	3825	Confirmed
B409	Firemans Service Lobby	Lobby	191	6,349	0.53	75	289	55	6349	Confirmed
B306	Elevator Lobby	Lobby	221	6,586	0.55	75	299	55	6586	Confirmed
B300	Firemans Service Lobby	Lobby	191	6,123	0.51	75	278	55	6123	Confirmed
B303	Service Lobby	Lobby	109	2,894	0.24	75	132	55	2894	Confirmed
B206	Elevator Lobby	Lobby	221	6,612	0.55	75	301	55	6612	Confirmed
B200	Firemans Service Lobby	Lobby	191	6,125	0.51	75	278	55	6125	Confirmed
B203	Service Lobby	Lobby	109	3,016	0.25	75	137	55	3016	Confirmed
B119	Valet Office	Enclosed Office	87	174	0.01	75	8	55	174	Confirmed
B106	Elevator Lobby	Lobby	104	2,602	0.22	75	118	55	2602	Confirmed
B100	Firemans Service Lobby	Lobby	187	6,108	0.51	75	278	55	6108	Confirmed
B103	Service Lobby	Lobby	99	2,616	0.22	75	119	55	2616	Confirmed
B112	Engineers Office	Enclosed Office	639	1,151	0.10	75	52	55	1151	Confirmed
110	Loading Dock Office	Enclosed Office	97	185	0.02	75	8	55	185	Confirmed
103	Service Lobby	Lobby	105	2,952	0.25	75	134	55	2952	Confirmed
105	Electrical	Electrical/Mechanical	135	579	0.05	90	15	55	579	Confirmed
107	Exit Passageway	Corridor/ Transition	285	397	0.03	75	18	55	397	Confirmed
108	Exit Vestibule	Corridor/ Transition	62	85	0.01	75	4	55	85	Confirmed
M206	Mechanical Platform	Electrical/Mechanical	1,972	32,488	2.71	90	844	55	32488	Confirmed
208	Corridor	Corridor/ Transition	471	745	0.06	75	34	55	745	Confirmed
205	Electrical	Electrical/Mechanical	135	1,108	0.09	90	29	55	1108	Confirmed
200	Firemans Service Lobby	Lobby	193	7,394	0.62	75	336	55	7394	Confirmed
206	Mechanical Room	Electrical/Mechanical	272	1,592	0.13	90	41	55	1592	Confirmed
203	Service Lobby	Lobby	101	3,782	0.32	75	172	55	3782	Confirmed
TOTAL			5,243	73,099	6		4,145		73,099	

AHU-3 - RESTAURANT Cooling Loads | **Air Side Cooling**

Room Number	Room Name	Occupancy Category (ASHRAE 62.1)	Area A_z (sf)	Internal Cooling Load (BTU/hr)	Internal Cooling Load (TONS)	Room Air Set Point (F)	Supply Air Flow (CFM)	Supply Air Temperature (F)	Air Side Cooling Capacity (BTU/hr)	Capacity Satisfied
209A	Kitchen	Food Preperation	1300	23,844	1.99	80	867	55	23844	Confirmed
209	Restaurant	Dining Area - Family	3400	58,903	4.91	75	2677	55	58903	Confirmed
TOTAL			4,700	82,747	7		3,544		82,747	

AHU-4 - OFFICE Peripheral Cooling Loads | **Air Side Cooling**

Room Number	Room Name	Occupancy Category (ASHRAE 62.1)	Area A_z (sf)	Internal Cooling Load (BTU/hr)	Internal Cooling Load (TONS)	Room Air Set Point (F)	Supply Air Flow (CFM)	Supply Air Temperature (F)	Air Side Cooling Capacity (BTU/hr)	Capacity Satisfied
508	Private Office	Office Space	100	2,388	0.20	75	167	62	2,388	Confirmed
509	Private Office	Office Space	100	2,353	0.20	75	165	62	2,353	Confirmed
510	Private Office	Office Space	100	2,373	0.20	75	166	62	2,373	Confirmed
511	Executive Office	Office Space	200	4,784	0.40	75	335	62	4,784	Confirmed
512	Copy Room	Occupiable Storage	100	2,645	0.22	75	185	62	2,645	Confirmed
513	Private Office	Office Space	100	2,676	0.22	75	187	62	2,676	Confirmed
514	Server Room	Media Center	100	5,356	0.45	75	375	62	5,356	Confirmed
515	Copy Room	Occupiable Storage	100	2,646	0.22	75	185	62	2,646	Confirmed
516	Private Office	Office Space	100	2,639	0.22	75	185	62	2,639	Confirmed
517	Private Office	Office Space	100	2,679	0.22	75	187	62	2,679	Confirmed
518	Executive Office	Office Space	200	7,225	0.60	75	505	62	7,225	Confirmed
519	Private Office	Office Space	100	3,679	0.31	75	257	62	3,679	Confirmed
520	Private Office	Office Space	100	3,949	0.33	75	276	62	3,949	Confirmed
521	Private Office	Office Space	100	3,591	0.30	75	251	62	3,591	Confirmed
501B	Electrical	Electrical	100	800	0.07	90	26	62	800	Confirmed
501A	Telecomm	Electrical	100	800	0.07	90	26	62	800	Confirmed
500	Open Office	Office Space	2,563	40,046	3.34	75	2,800	62	40,046	Confirmed
TOTAL			4,363	90,629	8		6,278		90,629	

AHU-5 - OFFICE Core Cooling Loads | **Air Side Cooling**

Room Number	Room Name	Occupancy Category (ASHRAE 62.1)	Area A_z (sf)	Internal Cooling Load (BTU/hr)	Internal Cooling Load (TONS)	Room Air Set Point (F)	Supply Air Flow (CFM)	Supply Air Temperature (F)	Air Side Cooling Capacity (BTU/hr)	Capacity Satisfied
522	Conference	Conference/Meeting	200	4,200	0.35	75	294	62	4,200	Confirmed
523	Conference	Conference/Meeting	200	4,213	0.35	75	295	62	4,213	Confirmed
501	Elevator Lobby	Lobby	350	18,412	1.53	75	1,288	62	18,412	Confirmed
506A	Men's Restroom	Restroom	270	4,408	0.37	75	308	62	4,408	Confirmed
506B	Women's Restroom	Restroom	270	4,452	0.37	75	311	62	4,452	Confirmed
500	Open Office	Office Space	7,689	120,139	10.01	75	8,401	62	120,139	Confirmed
TOTAL			8,979	155,824	13		10,897		155,824	

Appendix F: Duct Sizing

			Room Airflow (CFM)	Duct Airflow (CFM)	Duct Length (ft)	Friction Loss	Duct Velocity	Duct Size
Duct A				**1407.9**	**140.0**	**0.28**	**1300**	**13x12**
	500	Perimeter Open Office	1,407.9					
Duct B				**1,398.2**	**70.0**	**0.15**	**1300**	**13x12**
	508	Private Office	167.9					
	509	Private Office	165.5					
	510	Private Office	166.8					
	511	Executive Office	336.6					
	512	Copy Room	188.5					
	513	Private Office	186.4					
	514	Server Room	186.5					
Duct C				**1,407.9**	**140.0**	**0.3**	**1300**	**13x12**
	500	Perimeter Open Office	1,407.9					
Duct D				**1,728.5**	**70.0**	**0.15**	**1300**	**13x12**
	519	Private Office	262.8					
	520	Private Office	257.4					
	521	Private Office	246.7					
	515	Copy Room	186.5					
	516	Private Office	186.0					
	517	Private Office	189.1					
	518	Executive Office	400.0					
Duct E				**2,005.7**	**65.0**	**0.11**	**1300**	**17x12**
	500	Open Office	500.0					
	501	Elevator Lobby	1,294.6					
	501A	Telecom	52.6					
	501B	Electrical	50.4					
	504	Stair 2	108.1					
Duct F				**1,302.5**	**110**	**0.25**	**1300**	**11x12**
	500	Open Office	500.0					
	502	Stair 1	94.5					
	502A	Stair 1 Vestibule	82.7					
	503	Service Lobby	31.7					
	522	Conference	296.7					
	523	Conference	296.9					
Direct Supply								
	500	Open Office	7,447.3					
	507	Fan Room	172.7					

The duct sizing was vital to clash detection and integration. The supply ducts could not be any taller than 13 inches because the raised access flooring is only 14 inches off of the slab. Therefore, the ducts needed to be wider in many cases, but still had to fit within the 24 inches between panels.

APPENDIX G: WATER USAGE

Level	Men's Toilets	Women's Toilets	Urinals	Faucets
B4	1	3	2	6
B3	0	0	0	0
B2	0	0	0	0
B1	0	0	0	0
L01	1	1	0	2
L02	1	1	0	0
L05-L30	50	100	50	100
TOTAL	**53**	**105**	**52**	**108**

Rain Water Collection

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (in)	4.50	4.61	3.26	1.46	0.70	0.16	0.00	0.06	0.21	1.12	3.16	4.56	**23.80**
Collection Capacity	**35,882**	**36,759**	**25,994**	**11,642**	**5,582**	**1,276**	**0**	**478**	**1,674**	**8,931**	**25,197**	**36,360**	**189,774**

Water Use (Baseline)

	# of Units	Gallons Per Flush	Building Occupants	Occupant Uses/Day	FTE		Yearly Use (Gal/Unit)	Total Use (Gal/Month)	Total Use (Gal/ Year)
Toilet - Men	53	1.6	712.5	1	712.5		1,140	5,035	60,420
Toilet - Women	105	1.6	712.5	3	2,137.5		3,420	29,925	359,100
Urinal	52	1.0	712.5	2	1425		1,425	6,175	74,100
Total Non-Potable								**41,135**	**493,620**
		Gallons Per Minute				**Total Uses (min)**			
Faucet	108	0.5	1425	3	4275	2137.5	1,069	9,619	115,425
TOTAL								**50,754**	**609,045**

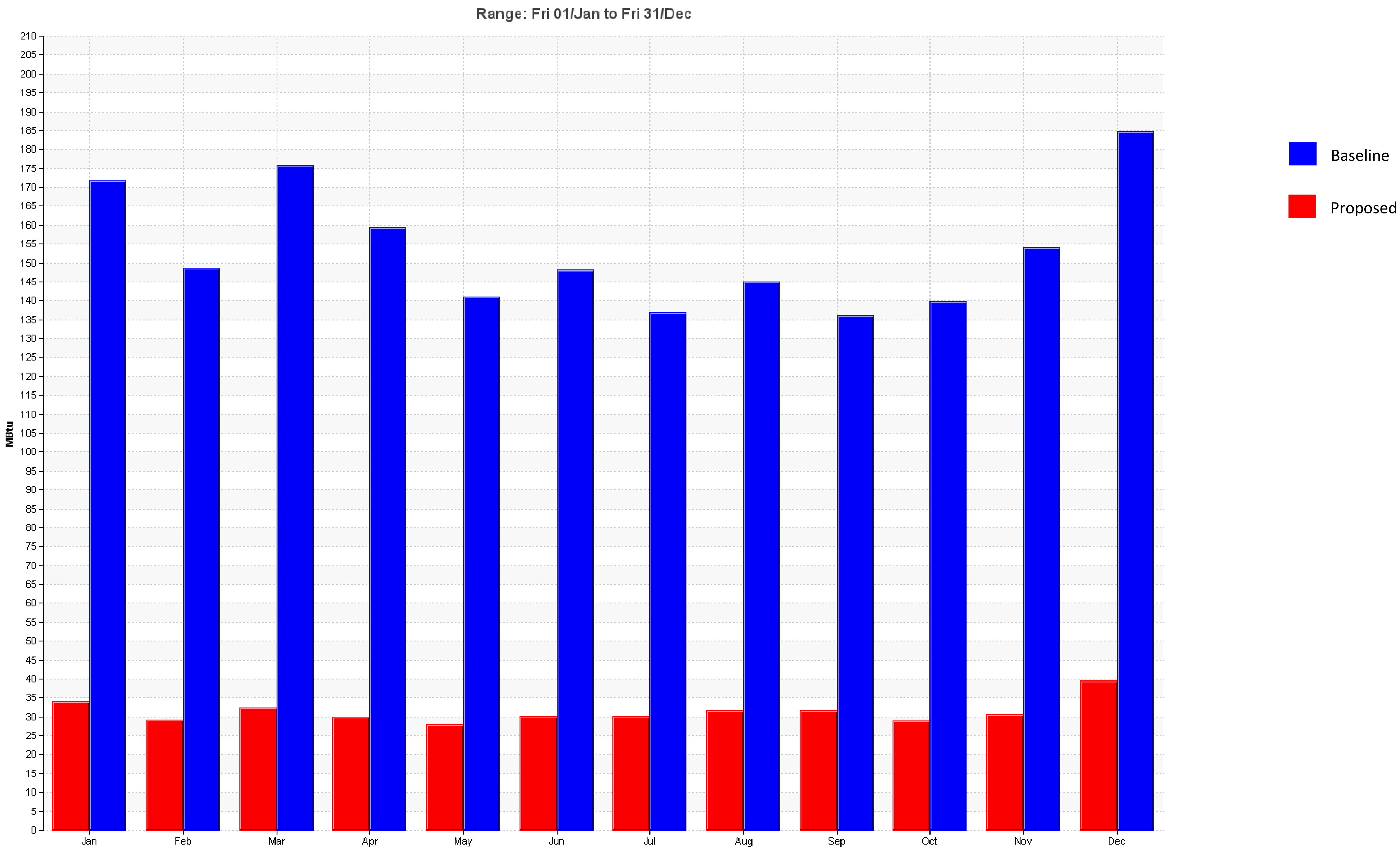
Water Use (Proposed)

	# of Units	Gallons Per Flush	Building Occupants	Occupant Uses/Day	FTE		Yearly Use (Gal/Unit)	Total Use (Gal/Month)	Total Use (Gal/ Year)
Toilet - Men	53	1.0	712.5	1	712.5		713	3,147	37,763
Toilet - Women	105	1.0	712.5	3	2,137.5		2,138	18,703	224,438
Urinal	52	1.0	712.5	2	1425		1,425	6,175	74,100
Total Non-Potable								**28,025**	**336,300**
		Gallons Per Minute				**Total Uses (min)**			
Faucet	108	0.5	1425	3	4275	2137.5	1,069	9,619	115,425
TOTAL								**37,644**	**451,725**

The water reduction calculations were based off of LEED 2009 water reduction guidelines. The baseline values were those set forth by the LEED guidelines, and the proposed values were taken from possible manufacturers' websites. A building full-time equivalent occupancy of 1,425 was assumed based on ASHRAE occupant density values.

The rainwater collection values were calculated based on a 15,990 sq ft. roof area. Monthly precipitation levels were found from the National Weather Service.

Appendix H: Energy Use



We modeled our building in IES and were able to calculate our energy use. As can be seen in the graph above, energy use decreased significantly from the baseline every month.

Appendix I: LEED

Water Efficiency 6/10

Prerequisite 1: Water Use Reduction

Water demand reduced by 26% (see Appendix G)

WE Credit 2: Innovative Wastewater Technologies **2 Points**

Option 1: Water use reduced by 56% (Appendix G and Table 9 in report) through rainwater collection and demand reduction

WE Credit 3: Water Use Reduction **4 Points**

Water use reduced by 56% (Appendix G and Table 9 in report)

Energy & Atmosphere 26/35

Prerequisite 1: Fundamental Commissioning of Building Energy Systems

Budgeted for a commissioning authority

Prerequisite 2: Minimum Energy Performance

Option 1: Whole Building Energy Simulation – Used IES to simulate and achieved a savings of 53% (see Table 7 in report)

Prerequisite 3: Fundamental Refrigerant Management

Designed chilled water system

EA Credit 1: Optimize Energy Performance **19 Points**

Achieved an overall energy use savings of 53% (see Table 7 in report)

EA Credit 4: Enhanced Refrigerant Management **2 Points**

Option 1: Did not use refrigerants

EA Credit 5: Measurement and Verification **3 Points**

Option 1: Budgeted for a measurement and verification plan

EA Credit 6: Green Power – 35% from renewable sources **2 Points**

Option 1: Determine Baseline Electricity Use – We used IES to determine the annual electricity demand of the site

Indoor Environmental Quality 4/15

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance

Met both Case 1 and Case 2 because our building utilizes both natural and mechanical ventilation

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Option 1: We are prohibiting smoking on the entire property, inside and outside

IEQ Credit 1: Outdoor Air Delivery Monitoring **1 Point**

Case 1 and Case 2: We have provided for CO_2 for all spaces

IEQ Credit 6.2: Controllability of Systems - Thermal Comfort **1 Point**

Because of our underfloor system, the occupants have control over the vent closest to their desks

IEQ Credit 7.1: Thermal Comfort – Design **1 Point**

Our HVAC system was designed using ASHRAE Standard 55-2004

IEQ Credit 7.2: Thermal Comfort – Verification **1 Point**

We budgeted for a monitoring system

Innovation in Design 5/6

ID Credit 1: Innovation in Design **5 Points**

Path 1: Innovations in Design – Cogeneration, algae bioreactors

Path 2: Exemplary Performance – two incremental increases in EA Credit 1 (2 pts.), three incremental increases in WE Credit 3 (1 pt.)

Total 41 Points

Appendix J: Design Tools

The design teams utilized a myriad of tool in order to analyze and develop the mechanical systems. The following tools are outlined below.

Autodesk Revit

- Duct Layout
- Visual System Modeling
- BIM

Integrated Environmental Solutions (IES)

- Load Calculation
- Energy Calculations
- System Analysis

Autodesk CAD

- System layouts

Microsoft Excel

- Design Calculations

Autodesk Inventor

- Visual System Modeling

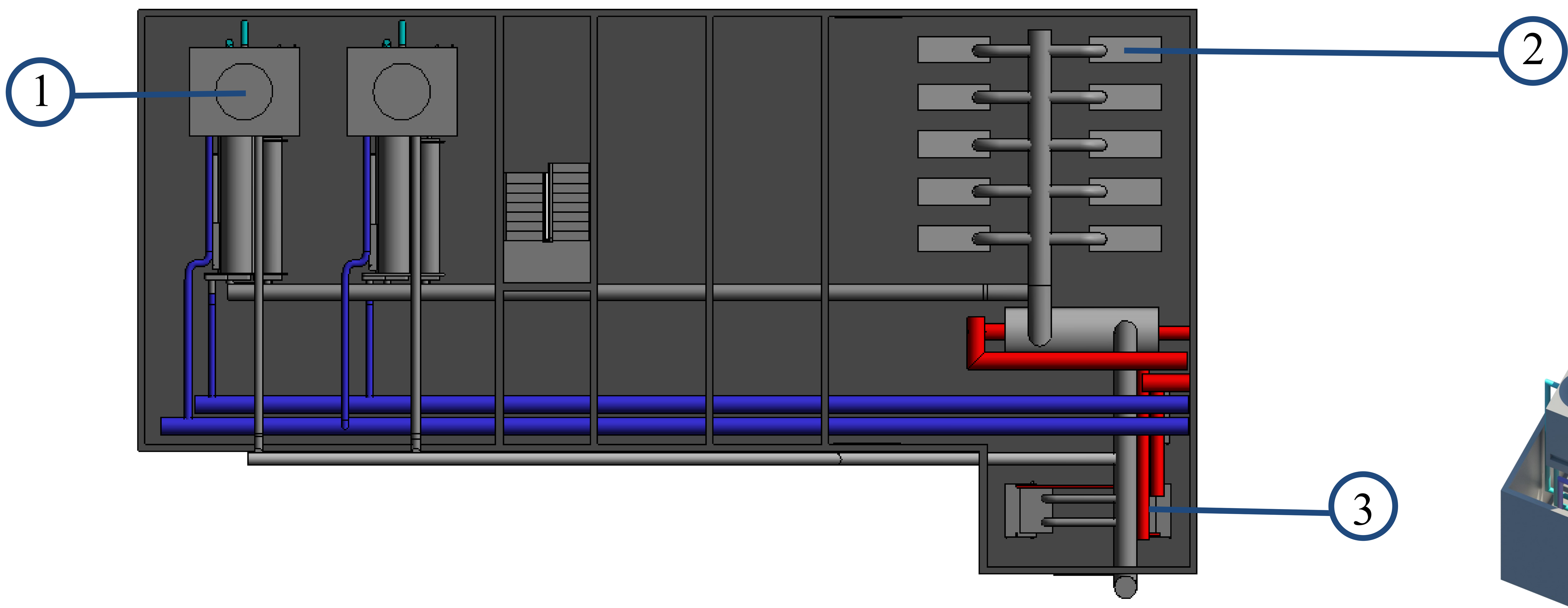
Autodesk Navisworks

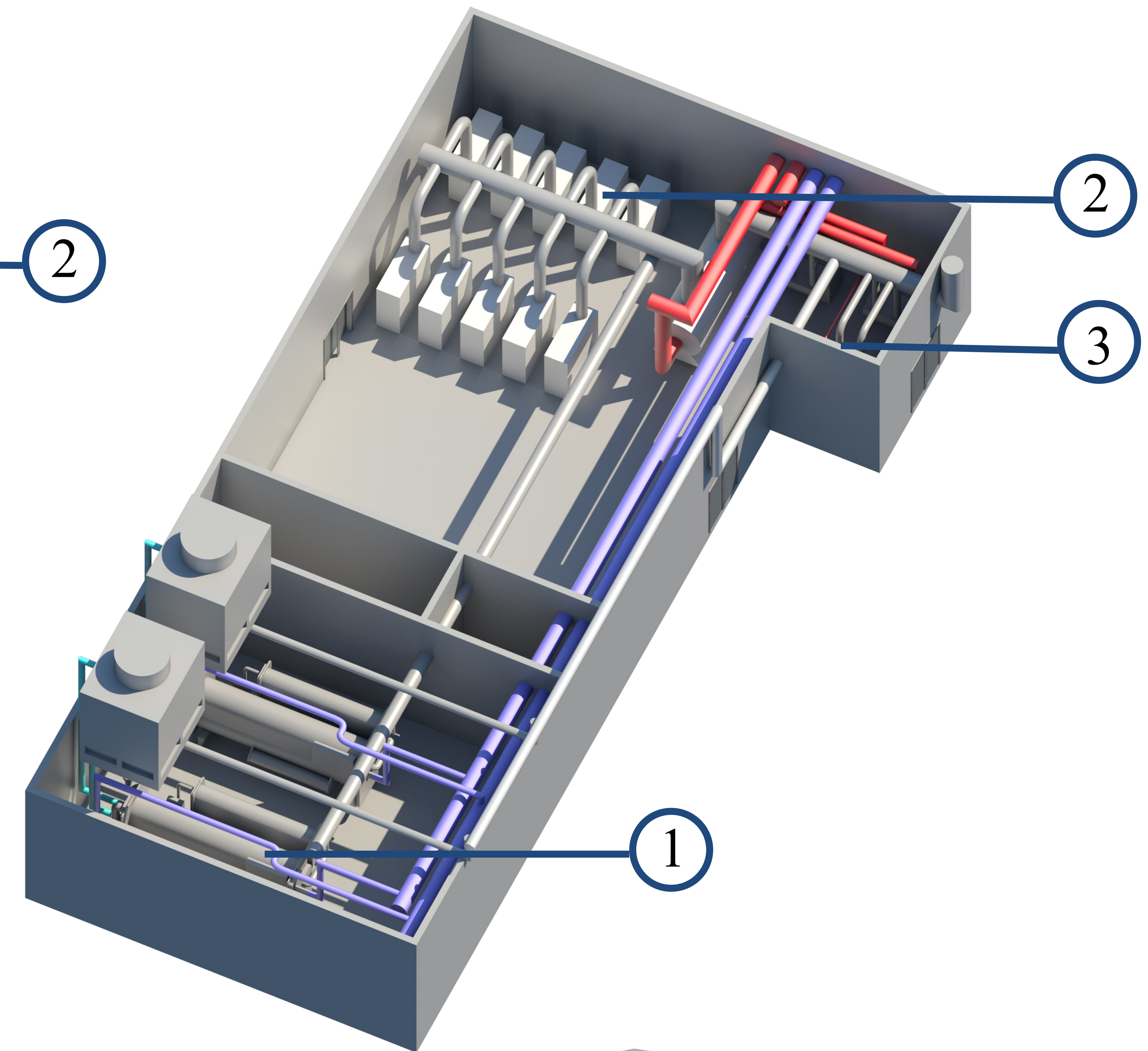
- BIM
- Clash Detection

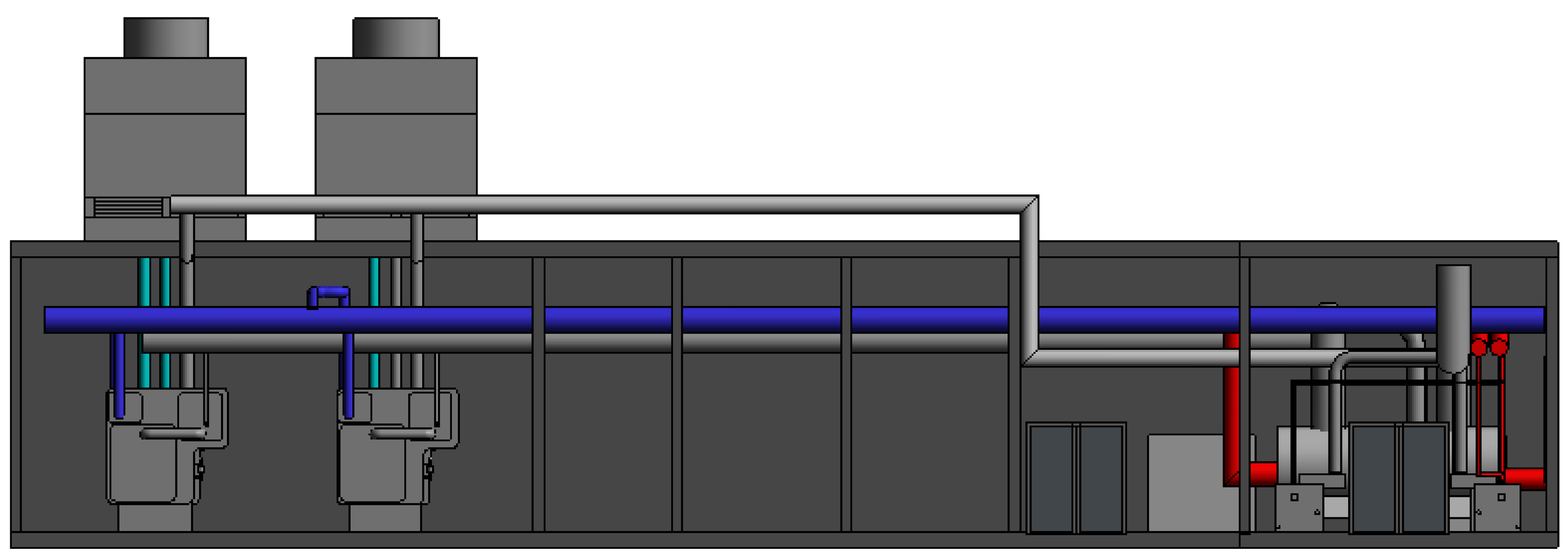
Google Sketch Up

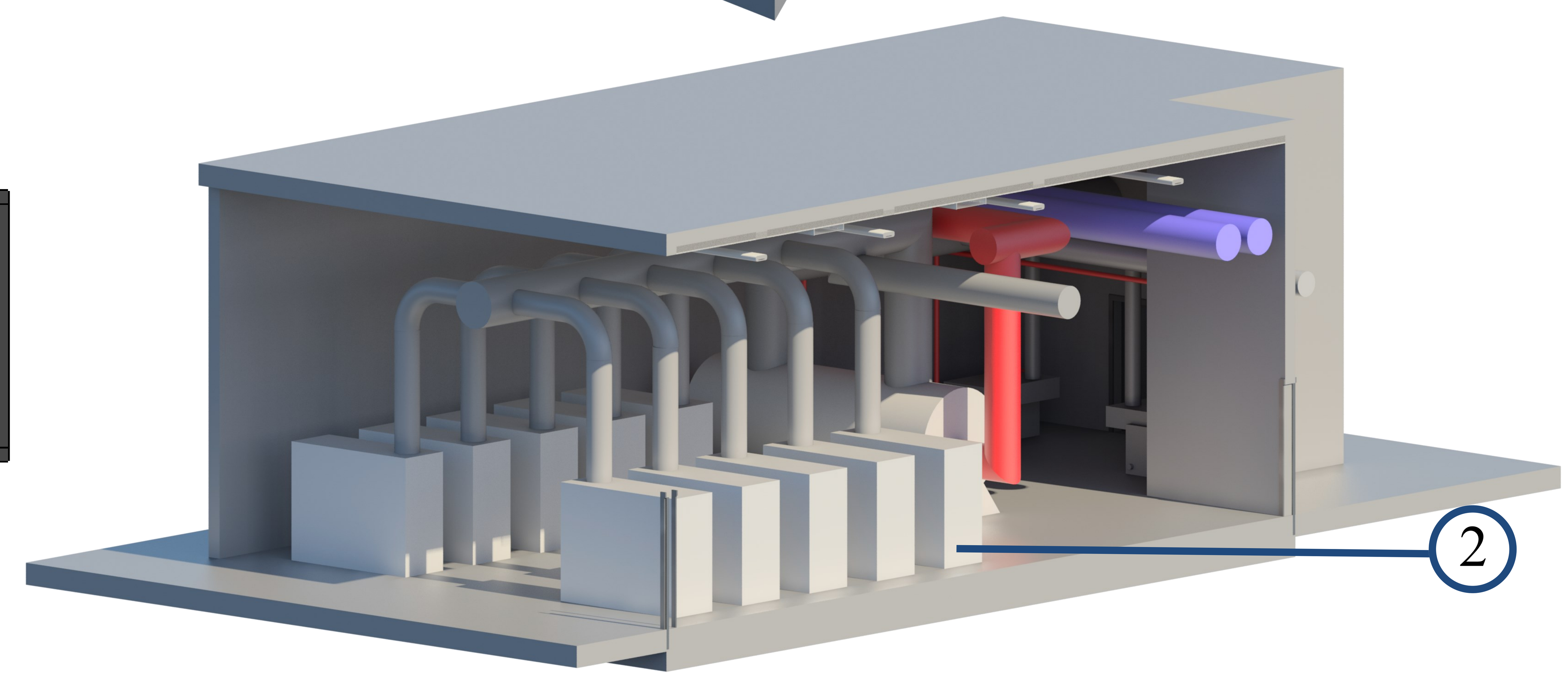
- Preliminary Design
- Model Creation Tool

Penthouse Mechanical Room Layout



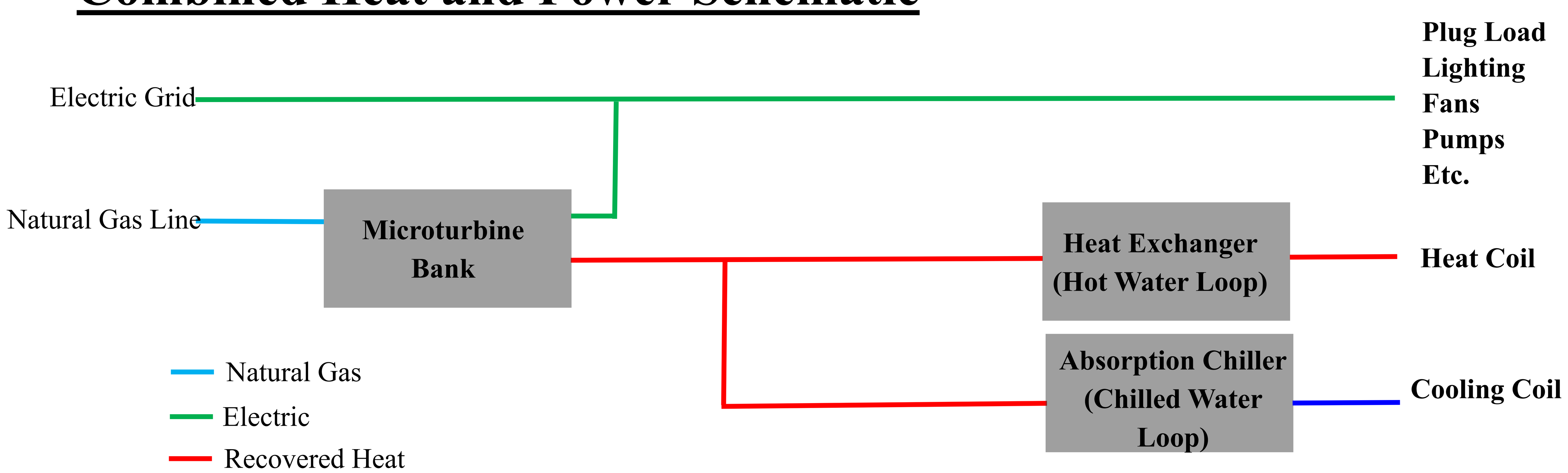






1. Two 450 Ton Absorption Chillers
2. Ten 65 kW Microturbines (CHP System)
3. Three 750 MBH Natural Gas fired Boilers

Combined Heat and Power Schematic



Code

IBC 2009: Section 1015.3 Boiler Room:

In order to comply with the above code we had to ensure that "two exit access doorways" were placed in the Mechanical Penthouse Room. The exit doors are located on the north and south wall of the room along the western corridor.

Mechanical

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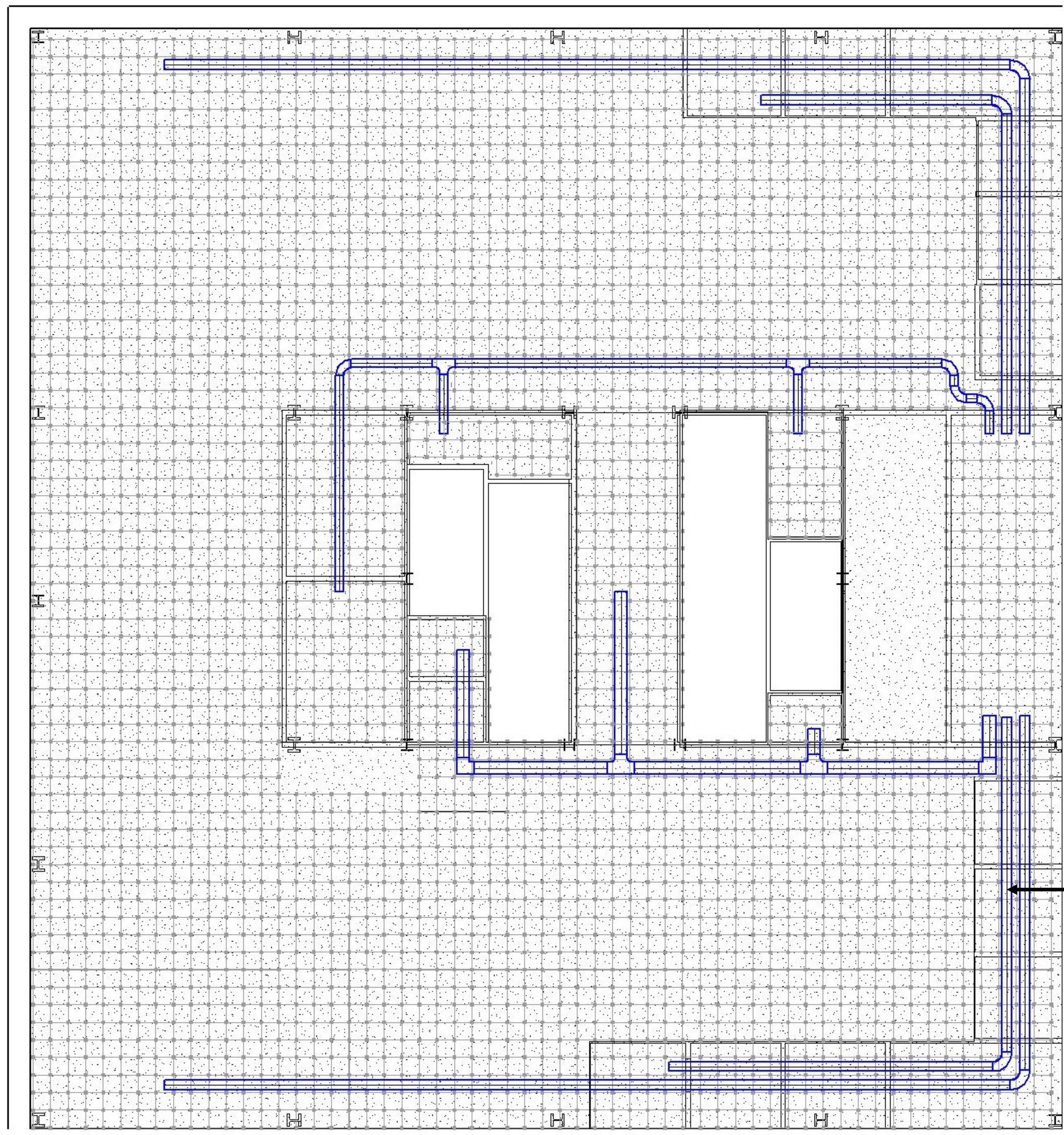
No.	Description	Date

AEI Team Number
05-2014

Penthouse Mechanical Room

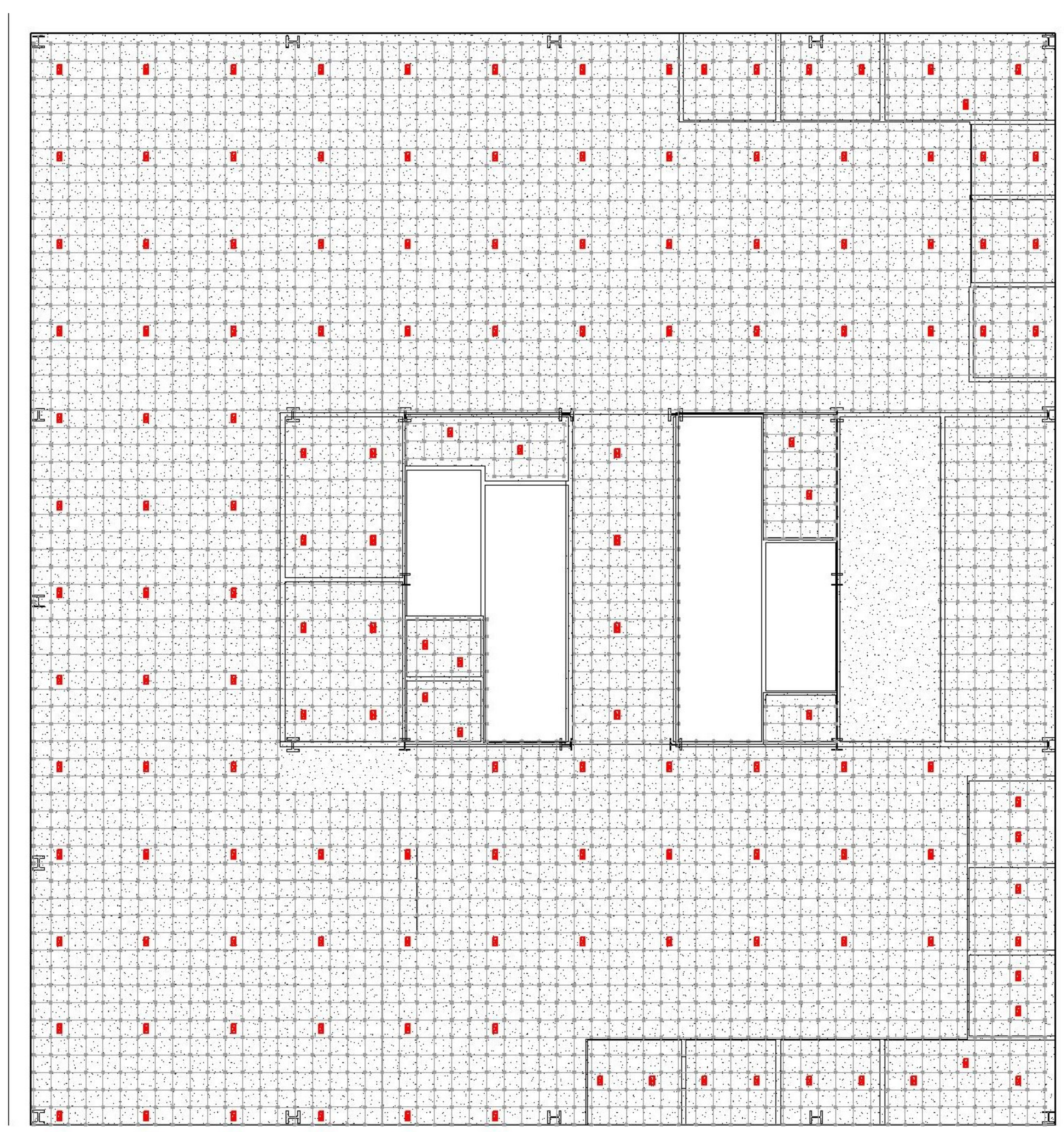
M-101

Air Side Distribution Plan



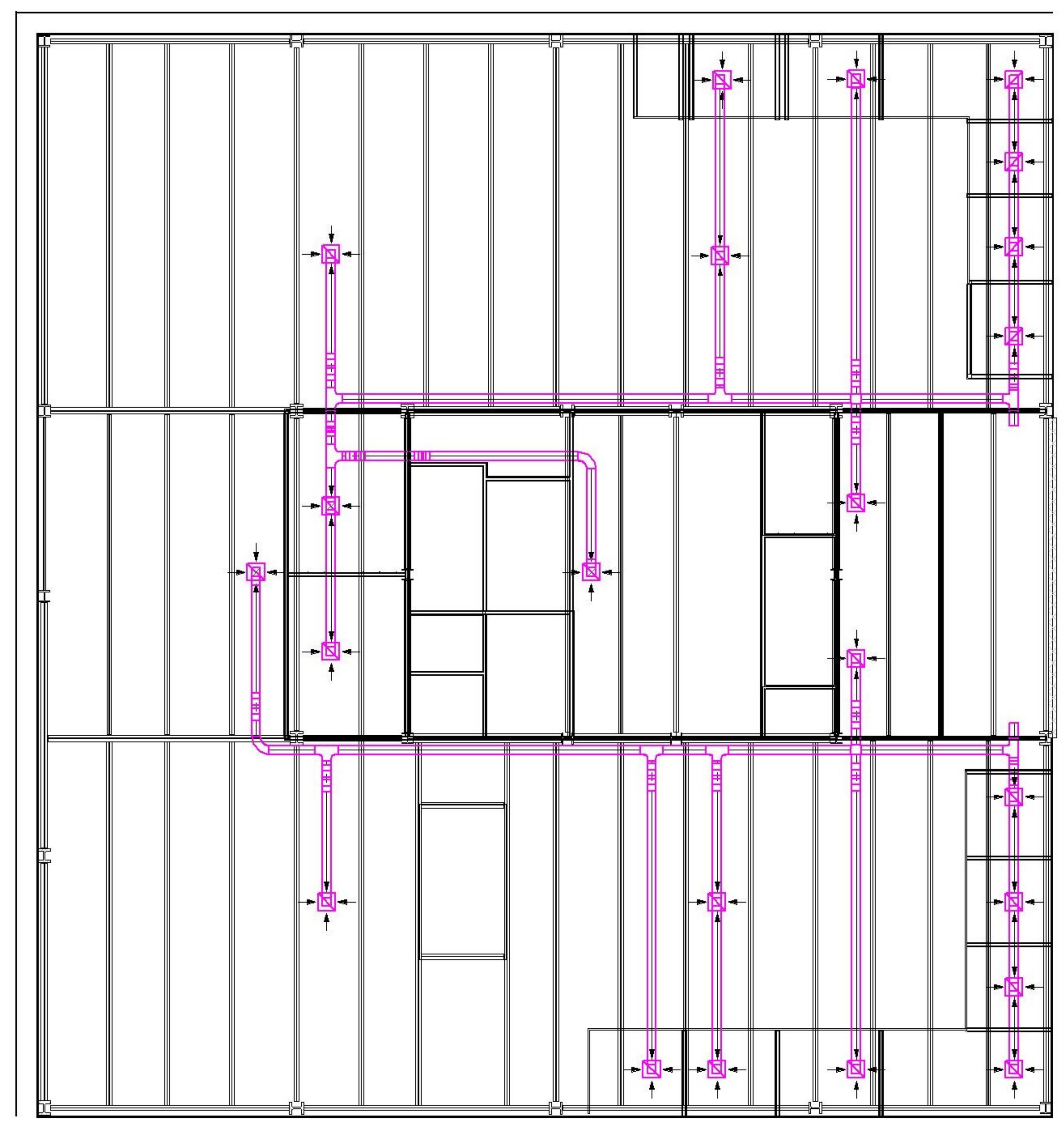
Supply Duct Plan

Mechanical Room



Floor Diffusers

Return Duct Plan



AEI

ASCE

Mechanical

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No.	Description	Date

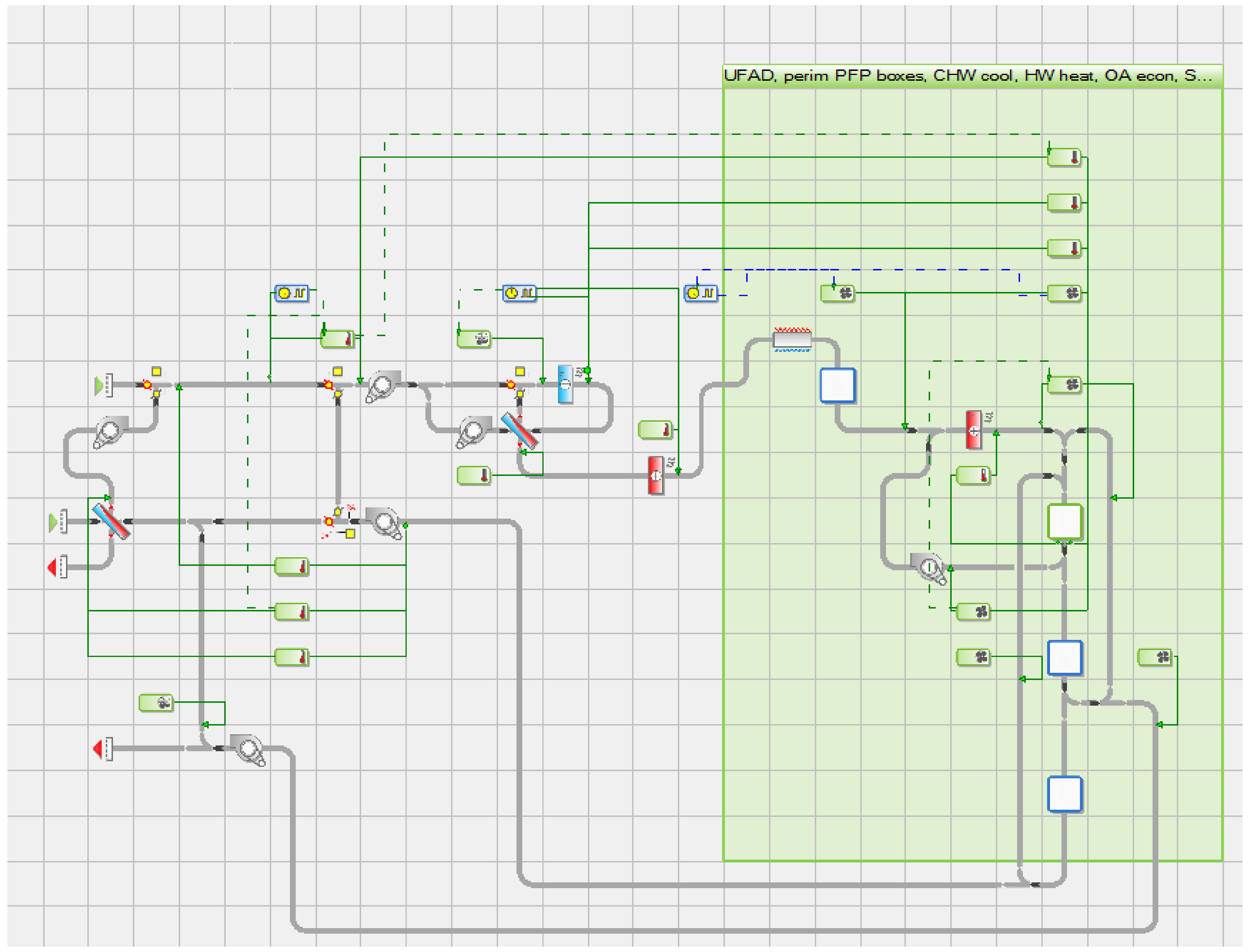
AEI Team Number
05-2014

Air Side Distribution Plan

M-102

Air Distribution and Hot/Chilled Water Loops

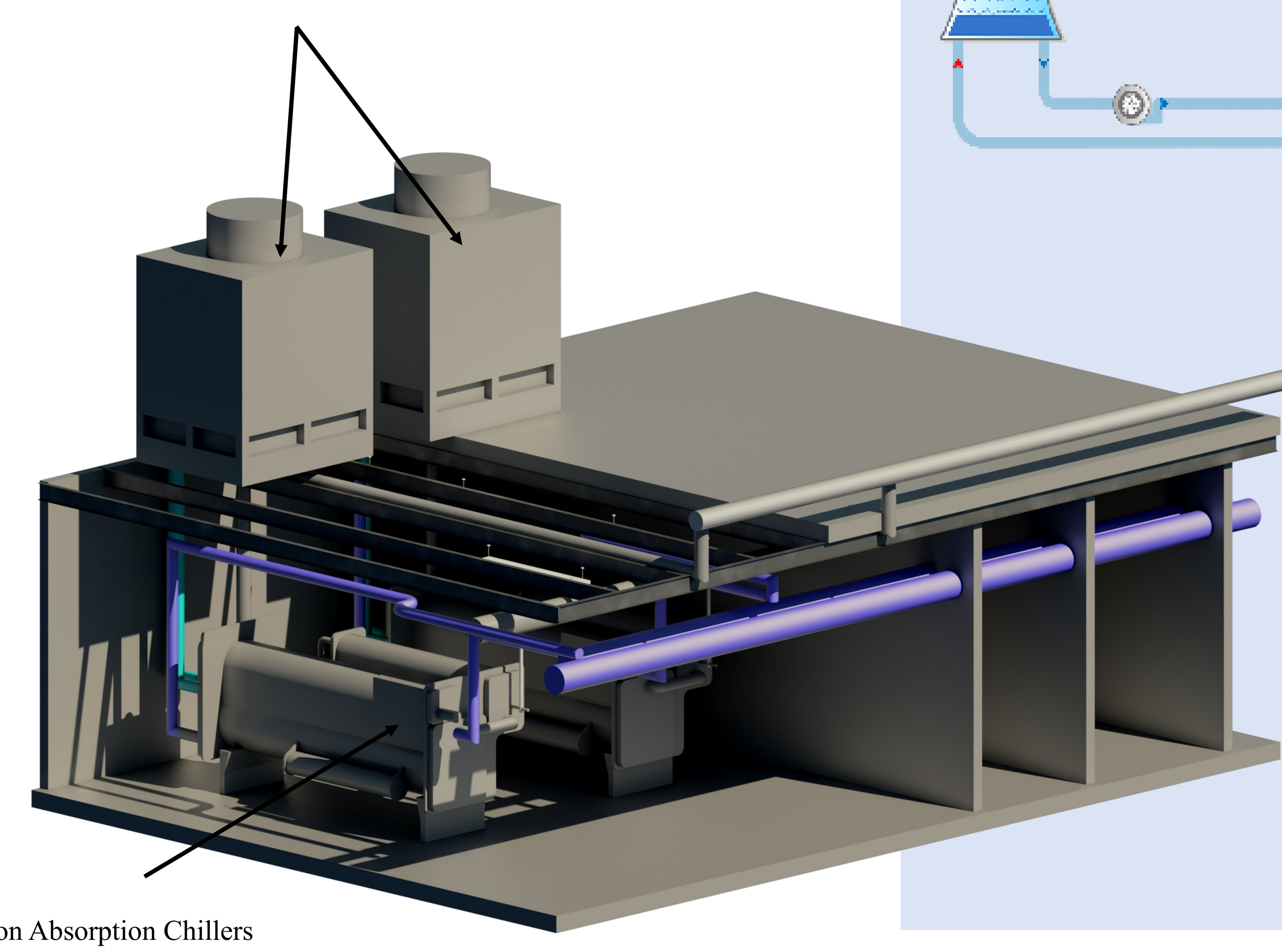
Underfloor Air Distribution System (UFAD)



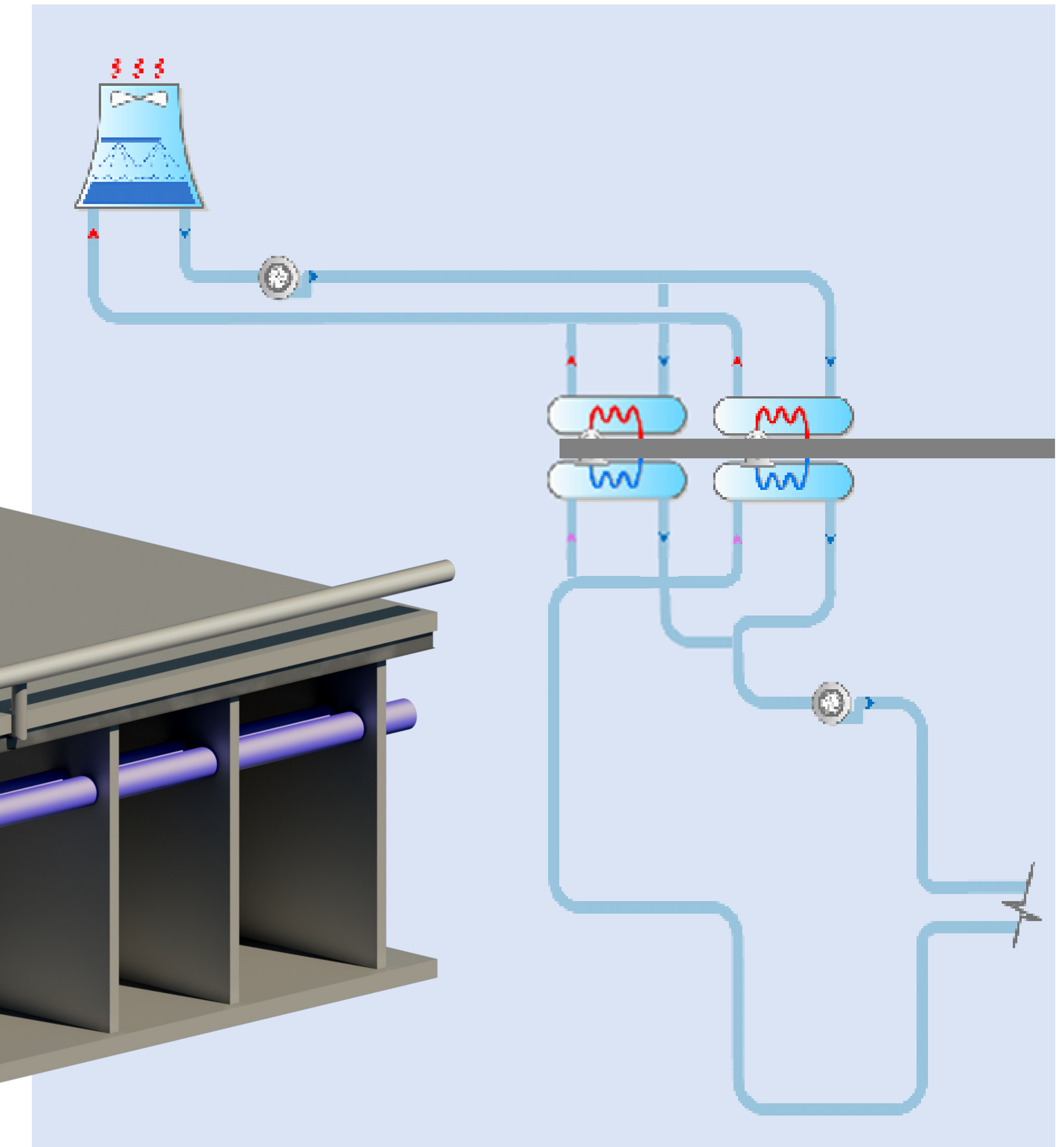
UFAD: UFAD supply air plenum; parallel fan-powered reheat boxes; occupied and stratified zones; re-mixing path and control to de-stratify zone when stirred by fan-powered reheat box. Enthalpy wheel to help with humidity control.

Chilled Water Loop

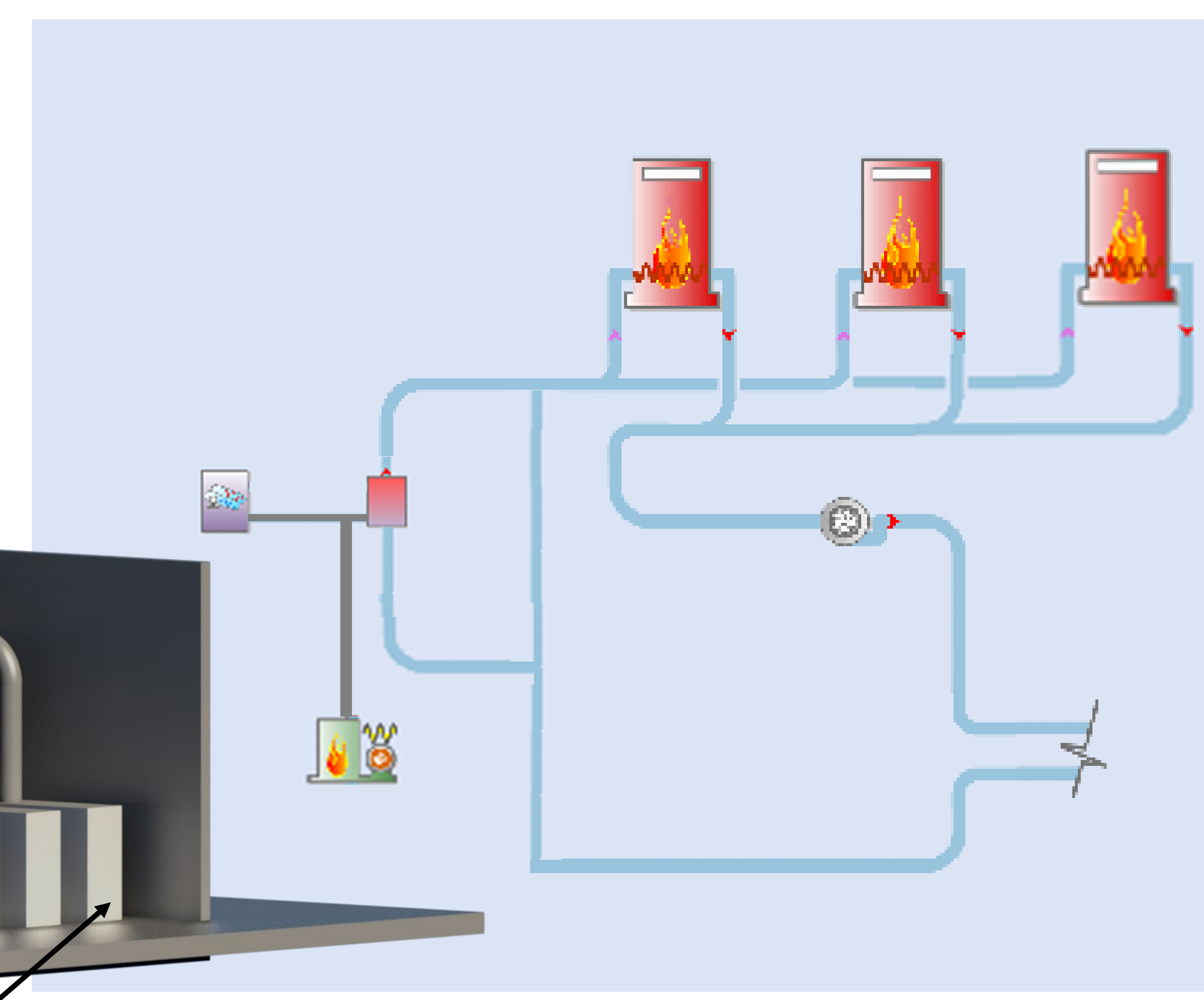
700 Ton Cooling Tower

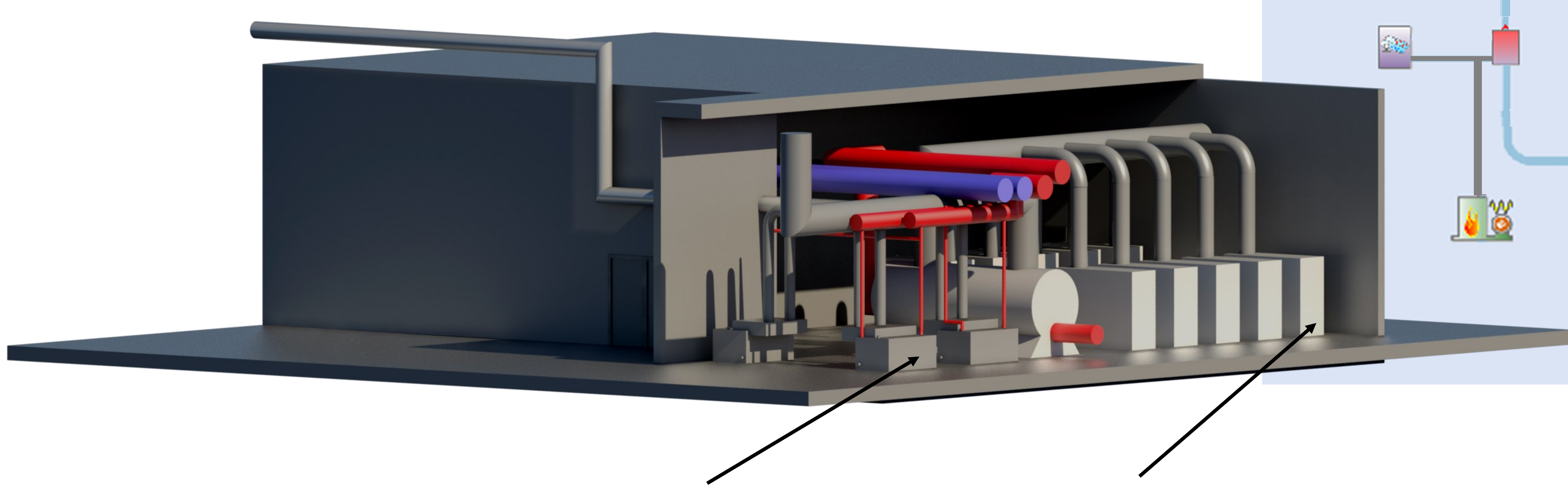


450 Ton Absorption Chillers



Hot Water Loop





750 MBH Natural Gas Boilers

65 kW Capstone Microturbines

Images for the hot water and chilled water loop were taken from IES's Apache HVAC Systems Simulation Interface.

Mechanical

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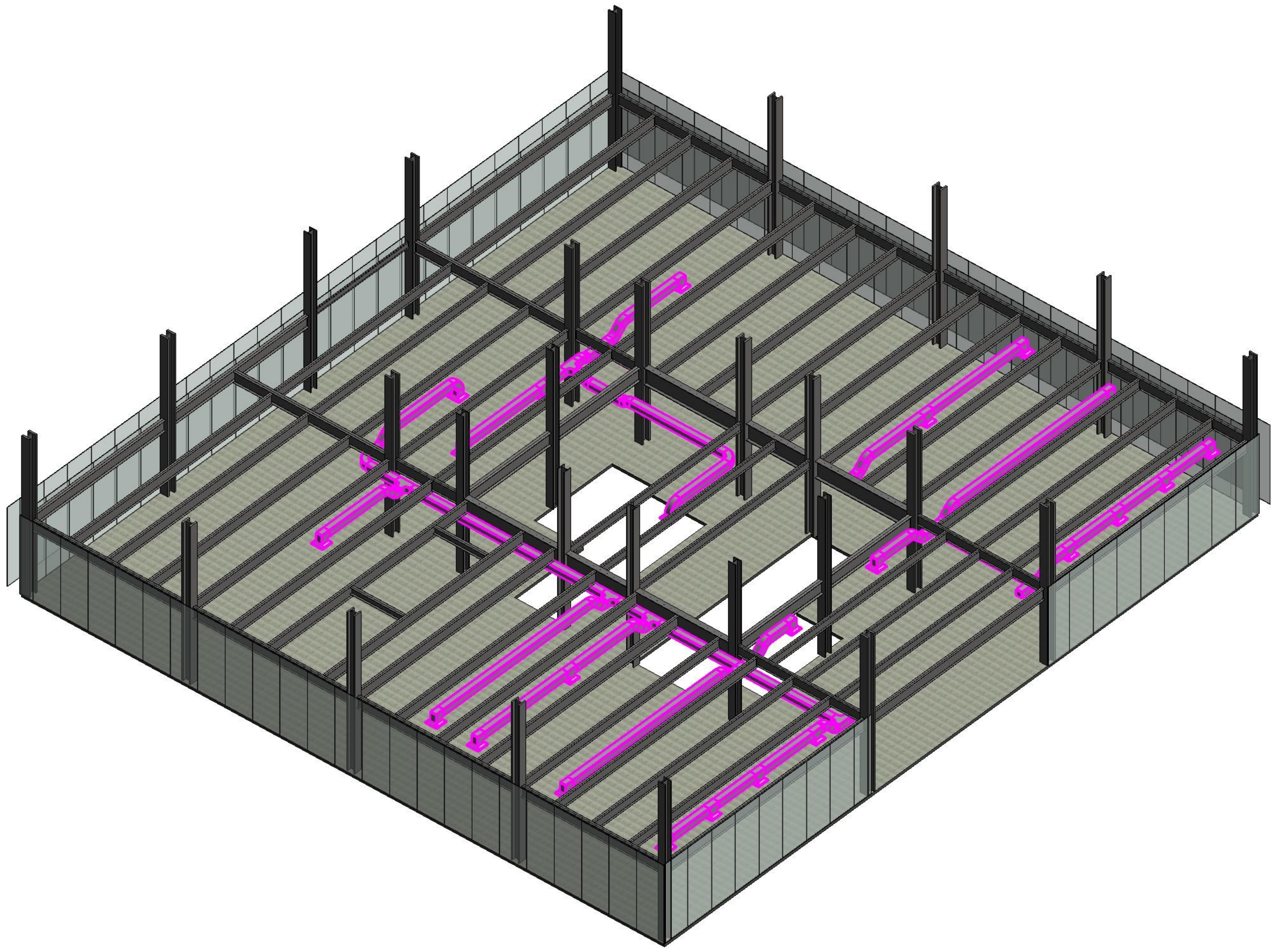
No.	Description	Date

AEI Team Number
05-2014

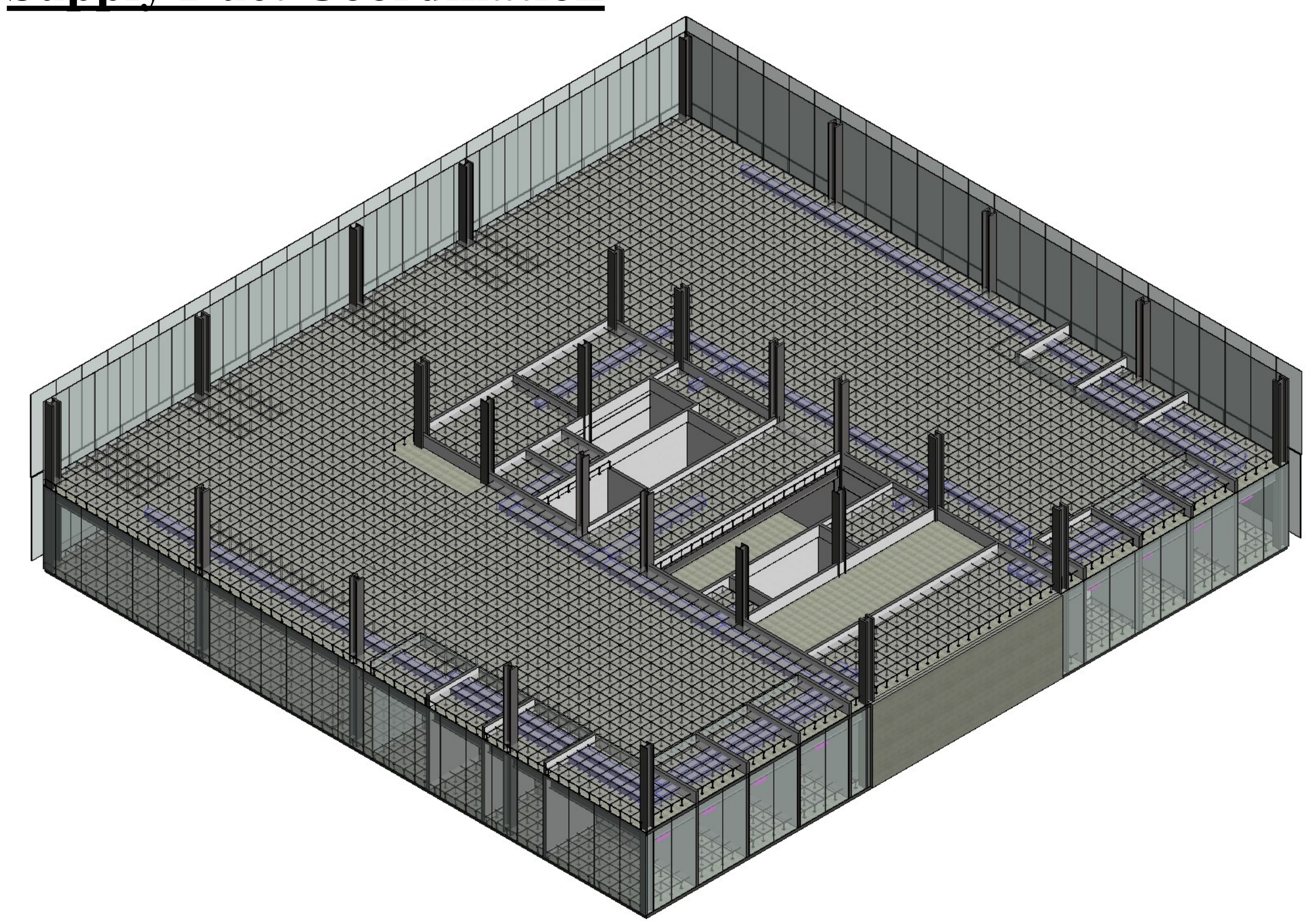
Air Distribution and Water Loops

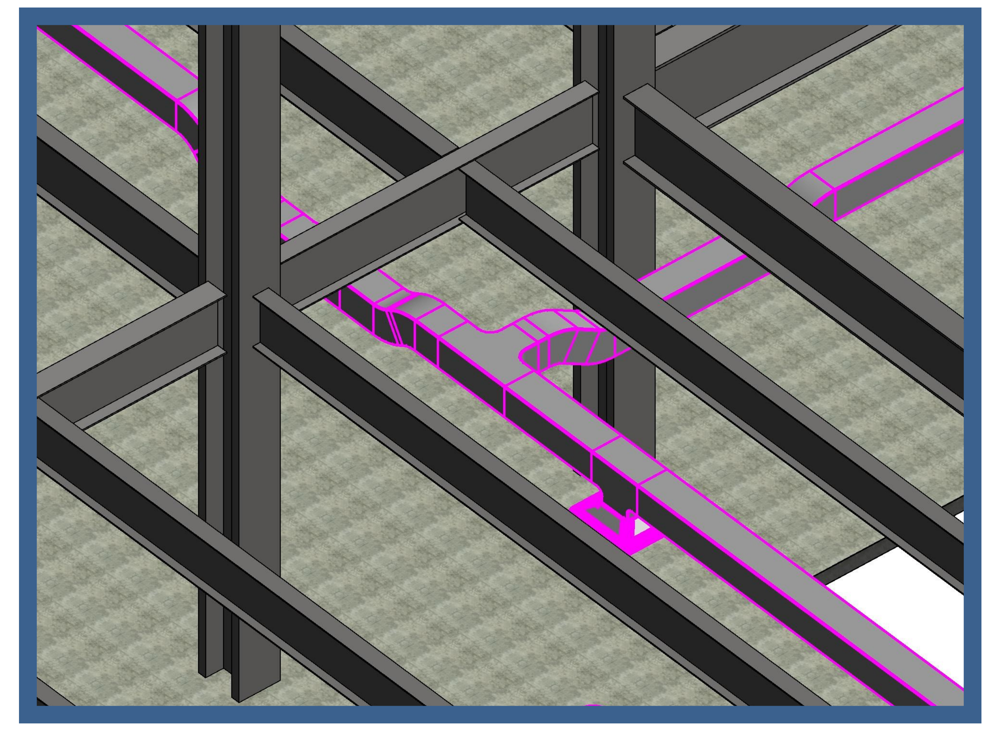
M-103

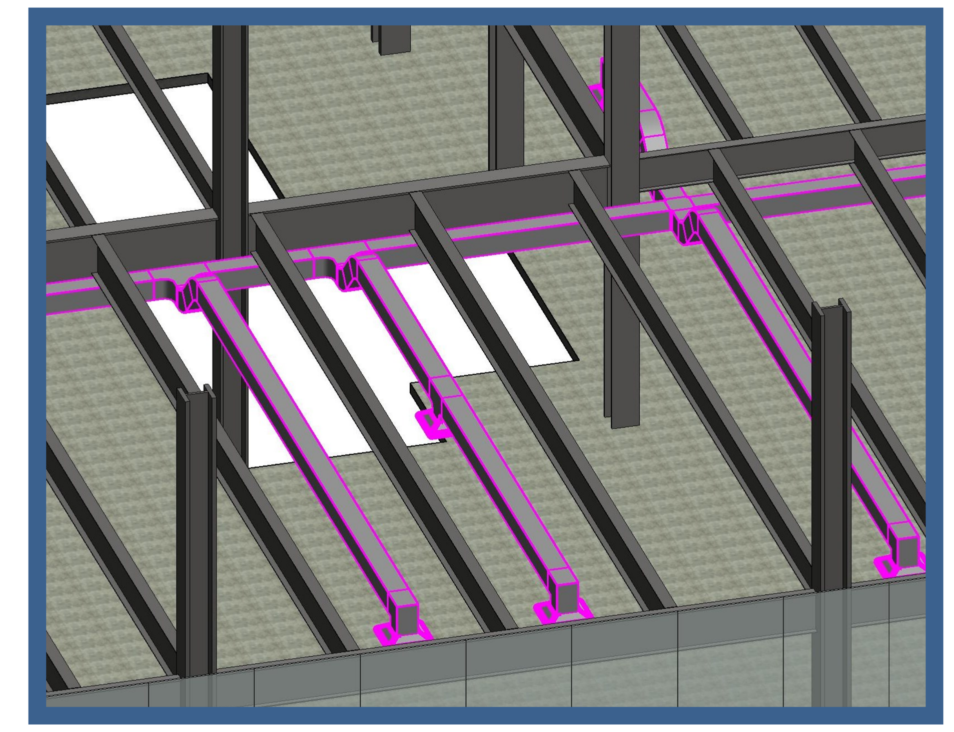
Return Duct Coordination



Supply Duct Coordination

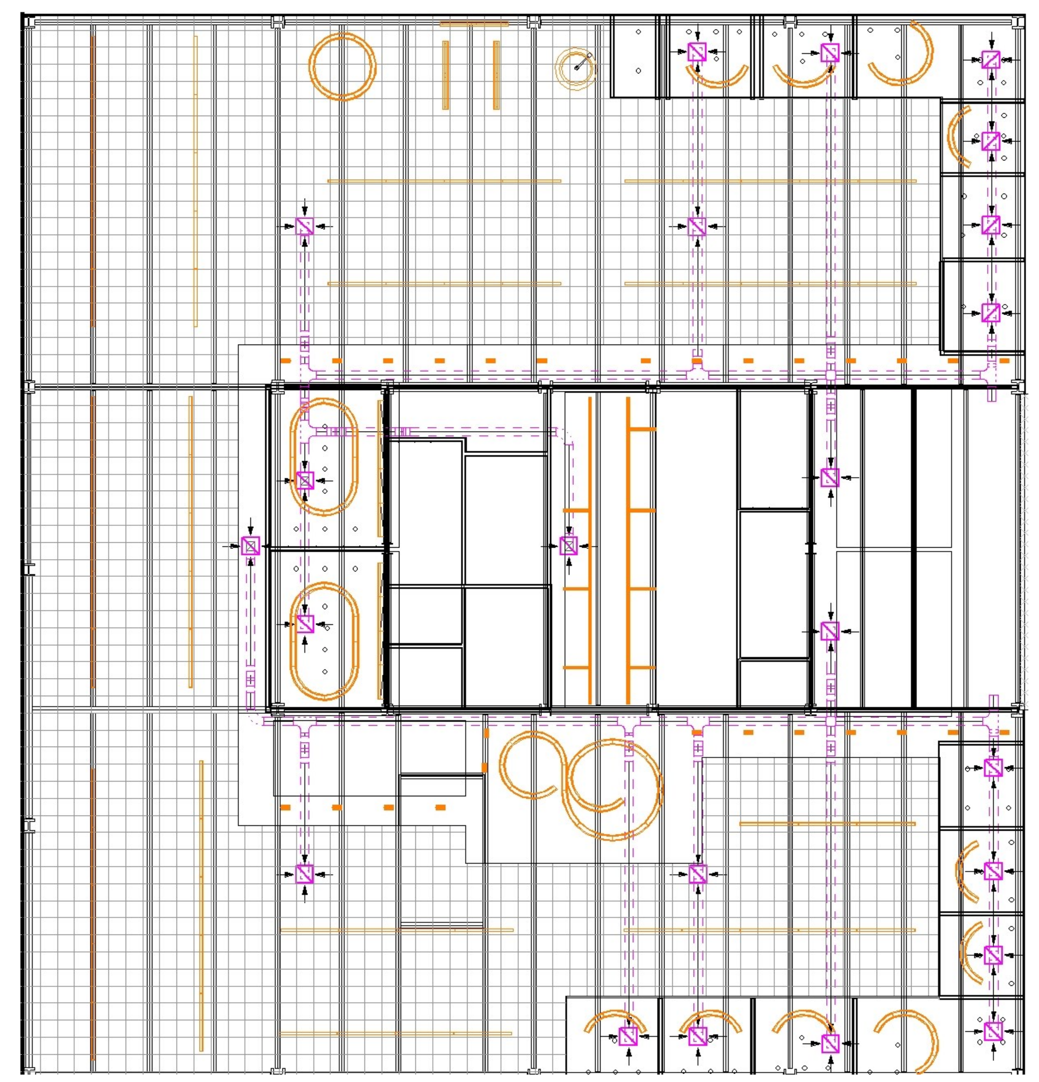






Structural Members

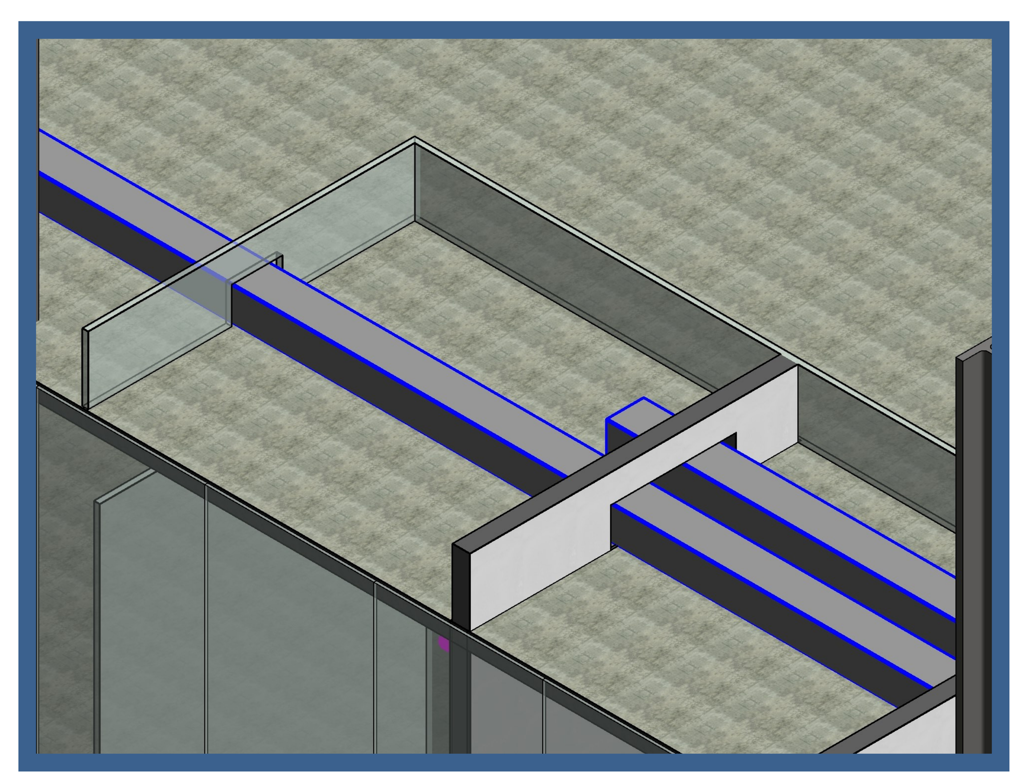
Because we do not have a drop ceiling in the majority of the space, most of the duct had to be run between beams as seen in the image to the left. This also meant that in some areas the duct did need to be dropped below the beams (and hidden with a bulkhead) so a great deal of time and consideration went into choosing the correct locations and coordinating transitions as can be seen above.



Return Diffuser Coordination

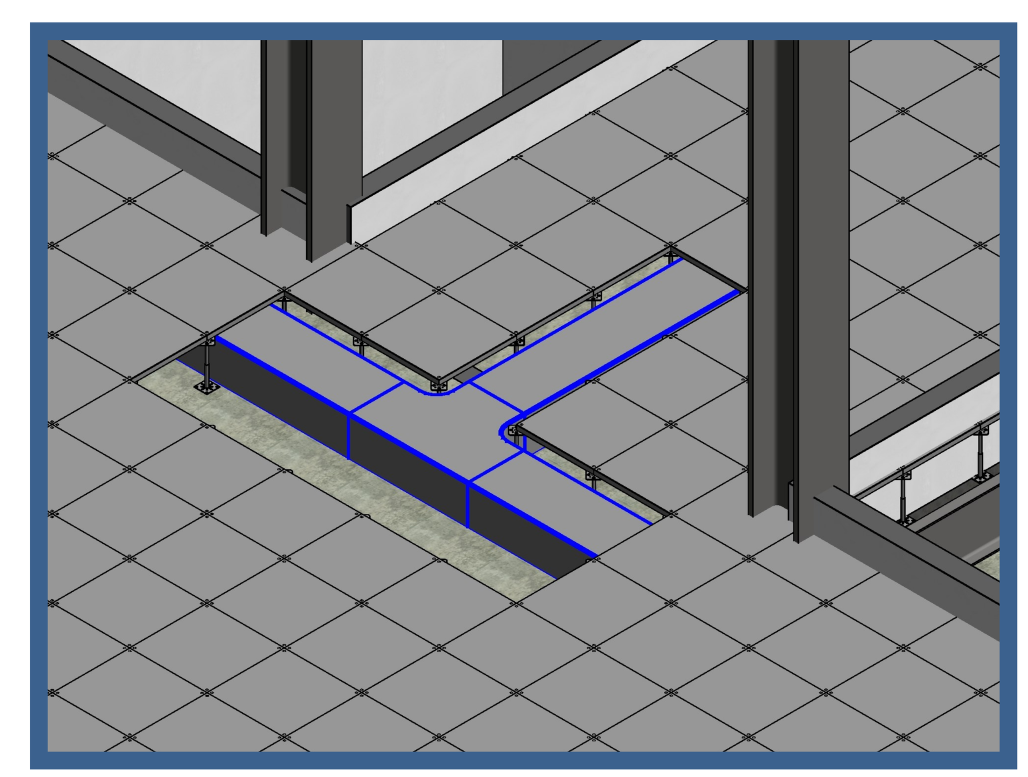
The diffusers needed to be placed in such a pattern that they did not clash with any of the lighting in the space. In addition, we placed the diffusers in the middle of acoustical tiles to ensure a consistent look across the space. The duct was not a concern because it was above the ceiling.

- Lighting
- Diffusers



Wall Cutouts

Because the duct needed to run from room to room and the walls extend down to the slab, cutouts were added to walls where needed to allow for the duct.



Raised Access Floor

When designing the duct system, we needed to make sure that all duct fit within the 24" x 24" x 14" space created by each panel of the raised access flooring.

Mechanical

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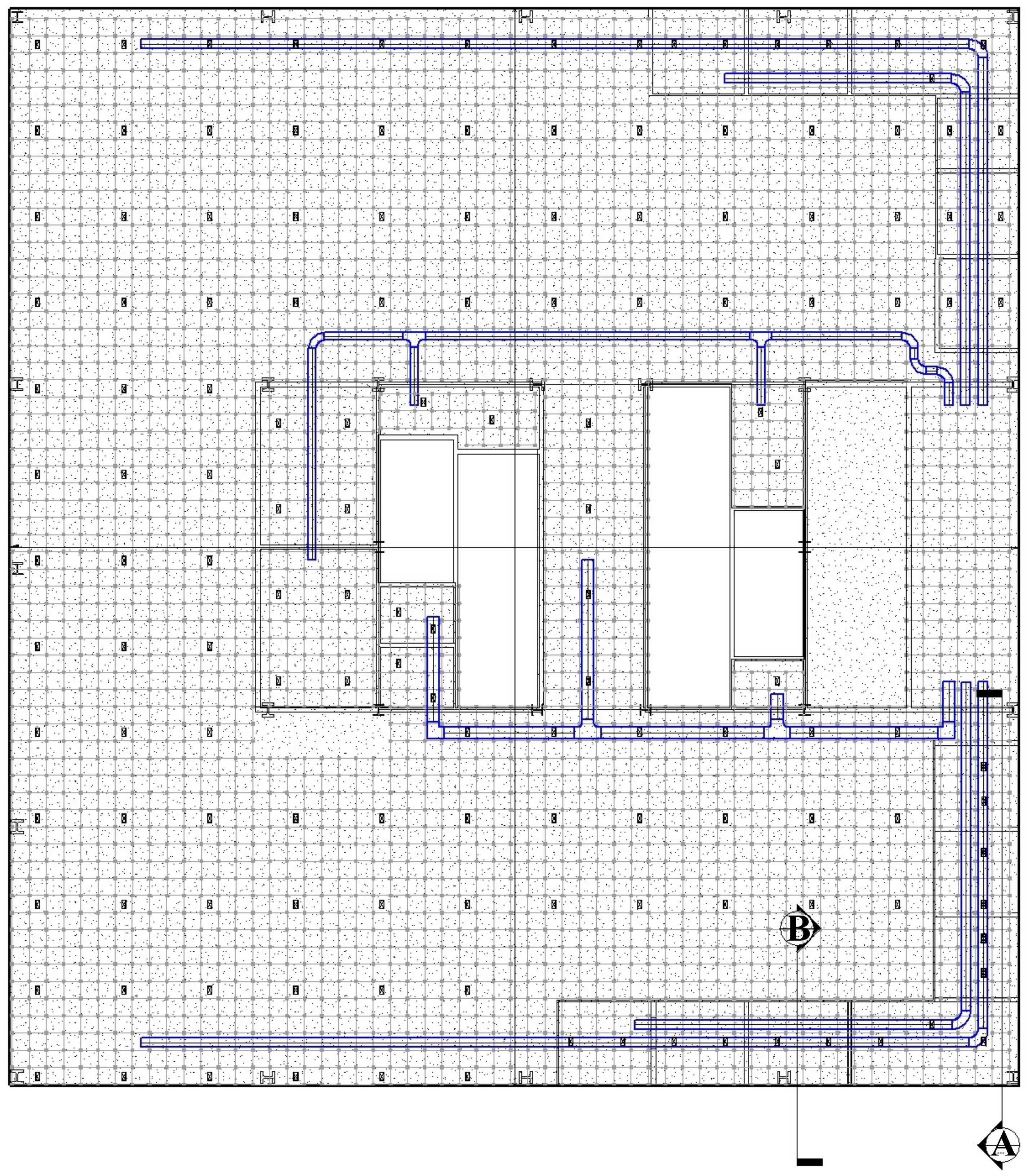
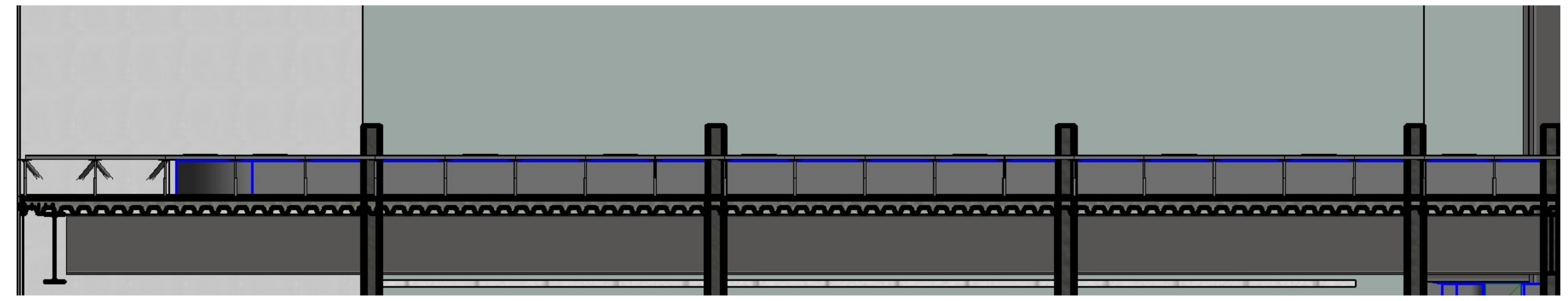
3D Duct Coordination

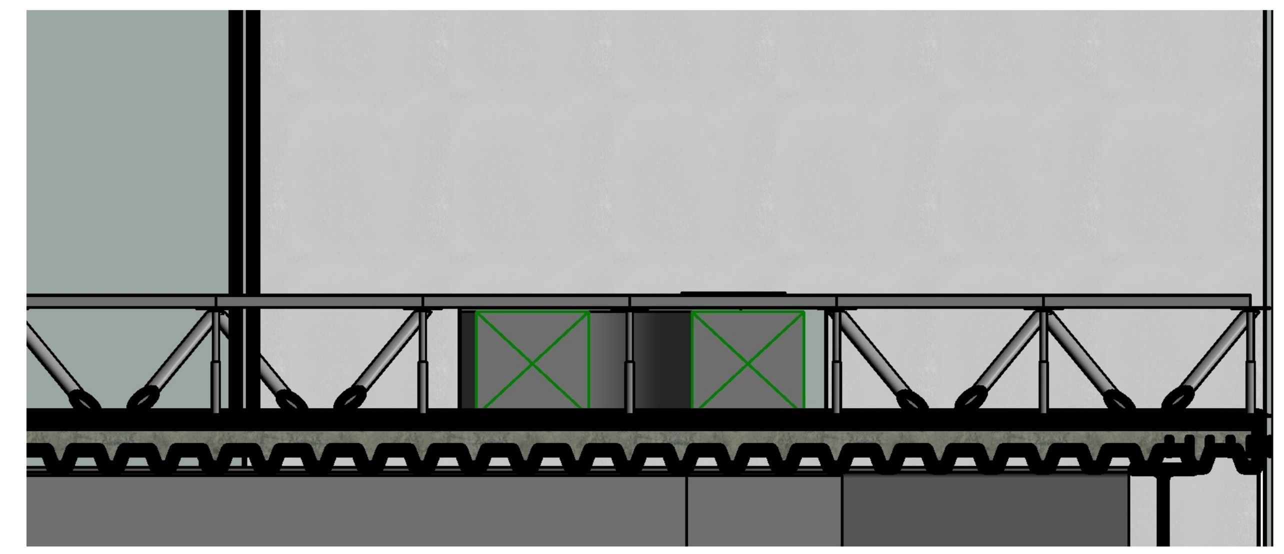
M-104

Supply Duct Sections



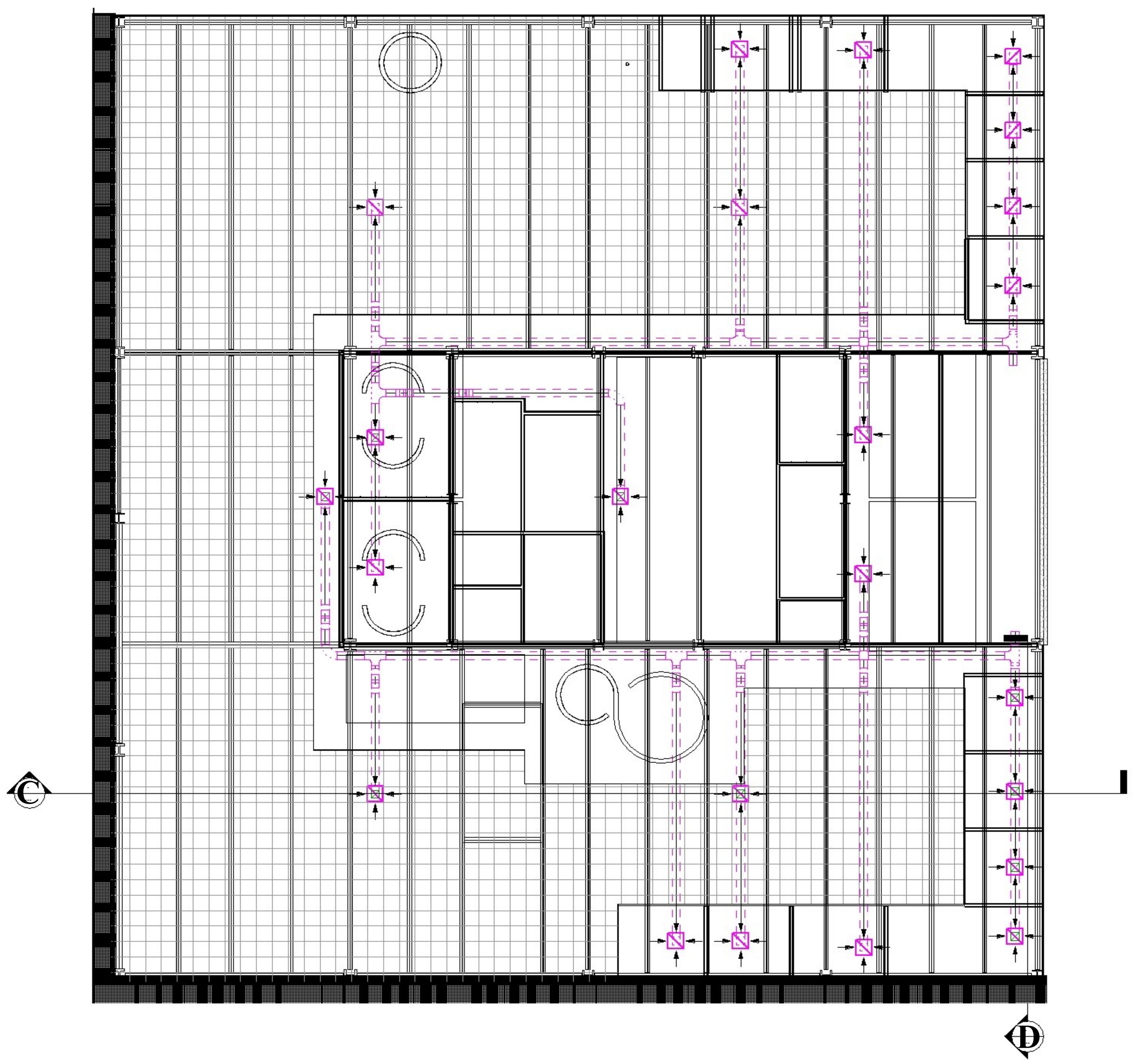


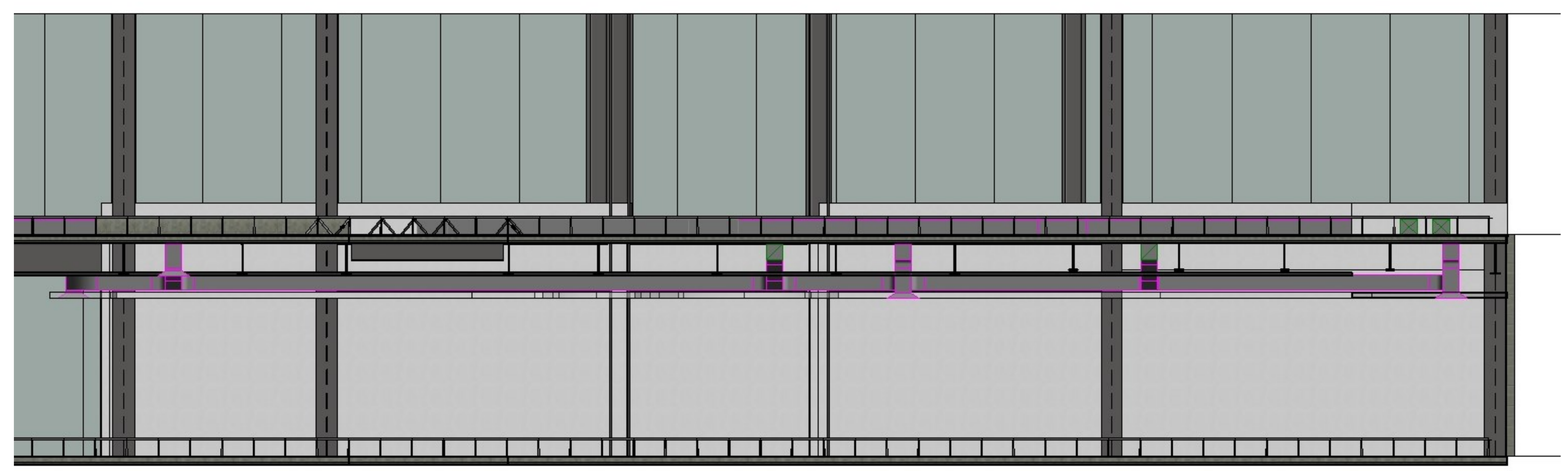
Section A



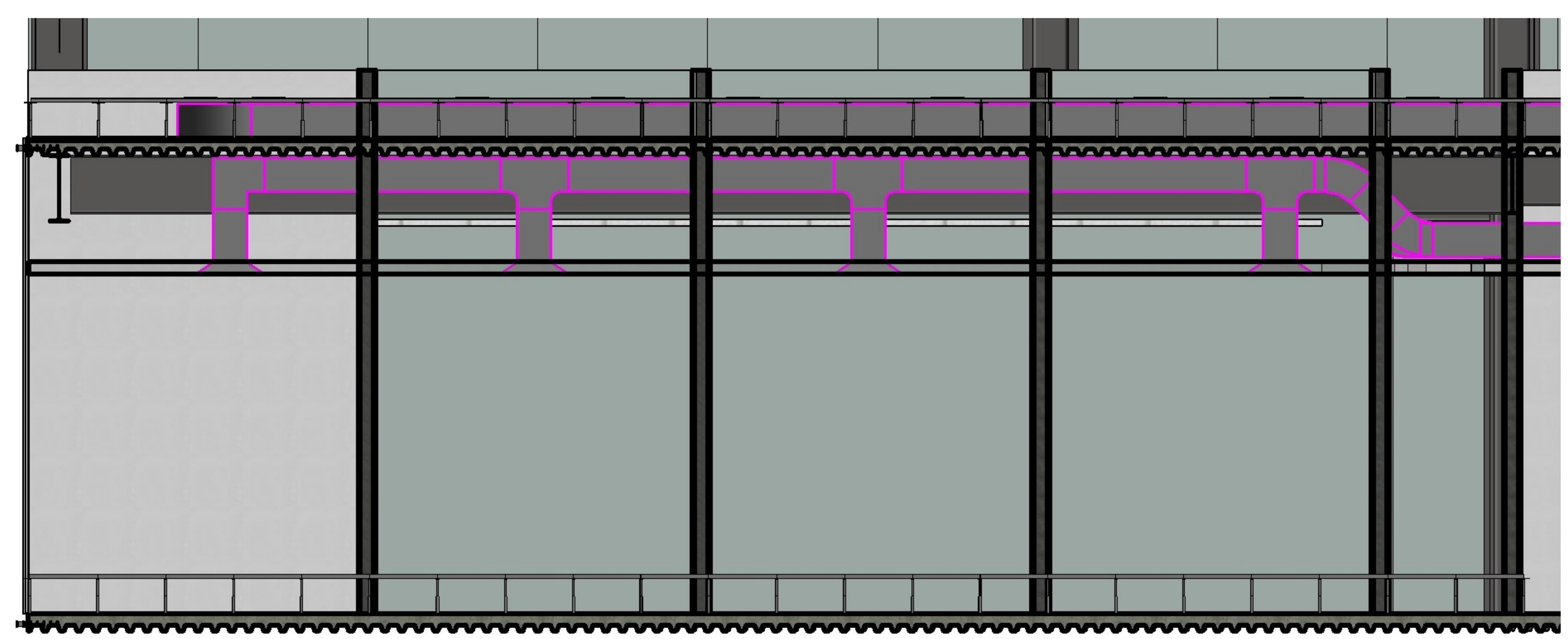
Section B

Return Duct Sections





Section C



Section D

AEI

ASCE

Mechanical

2014 Charles Pankow Foundation Annual Architectural Engineering Student Design Competition

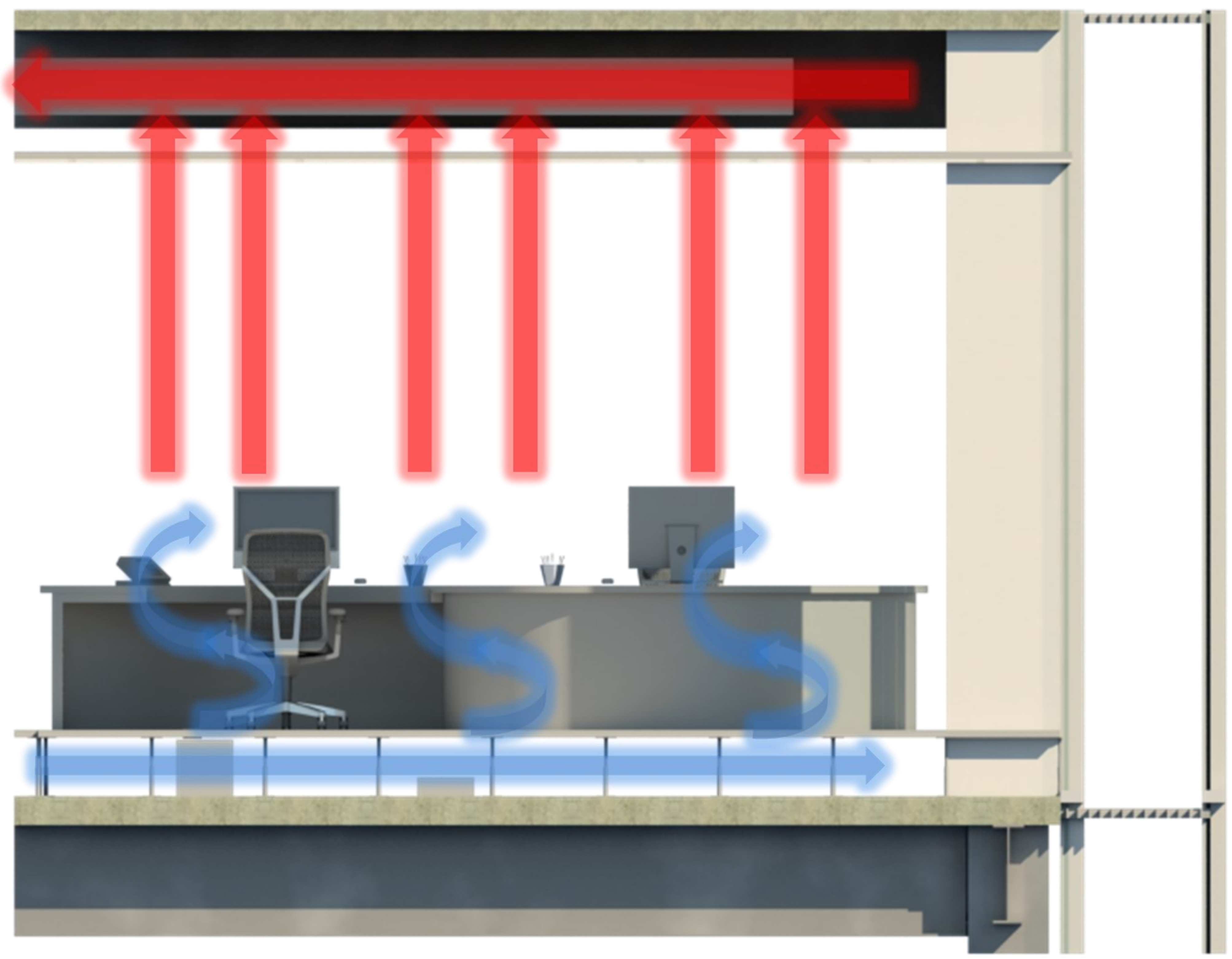
No.	Description	Date

AEI Team Number
05-2014

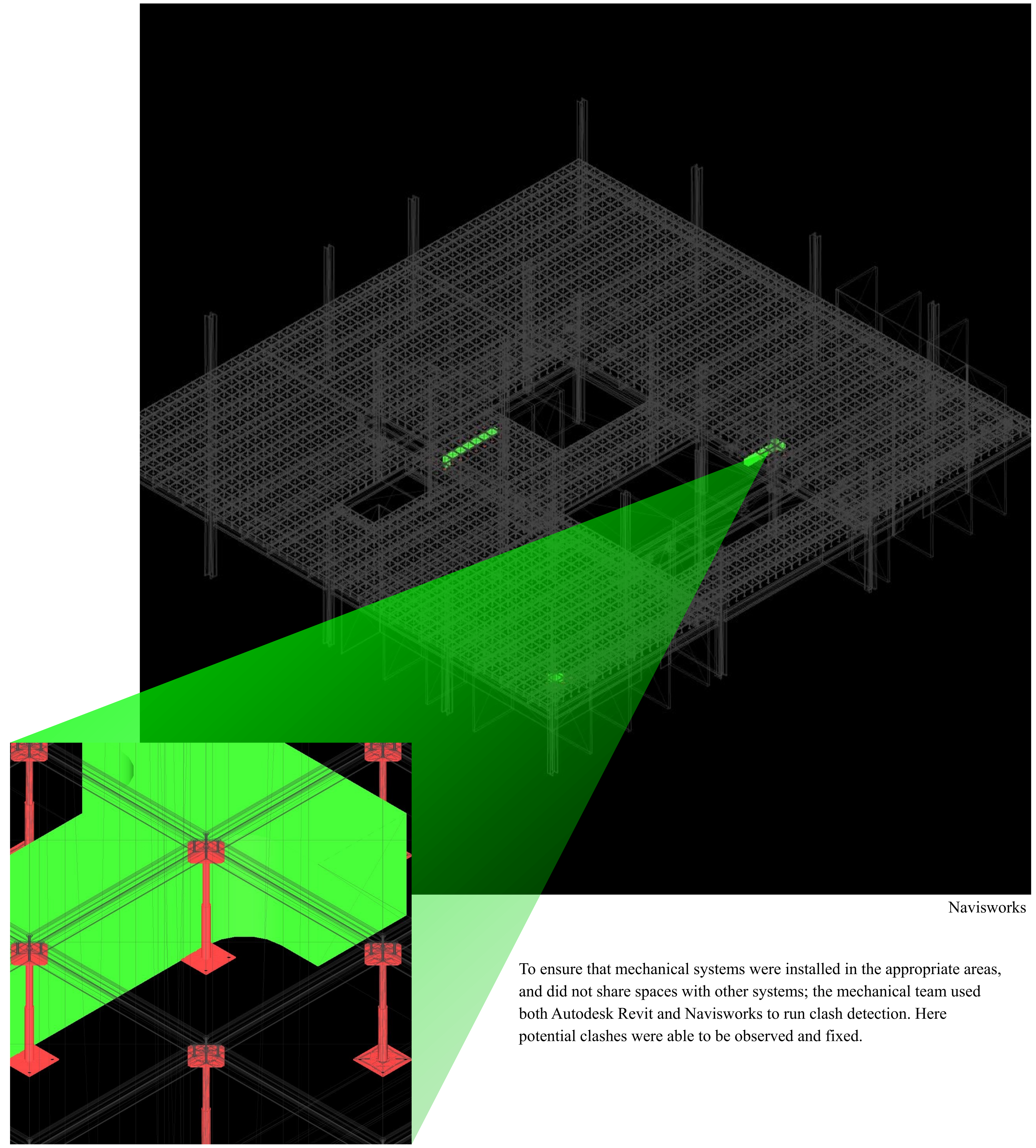
Duct Sections

M-105

Underfloor Air Distribution Schematics

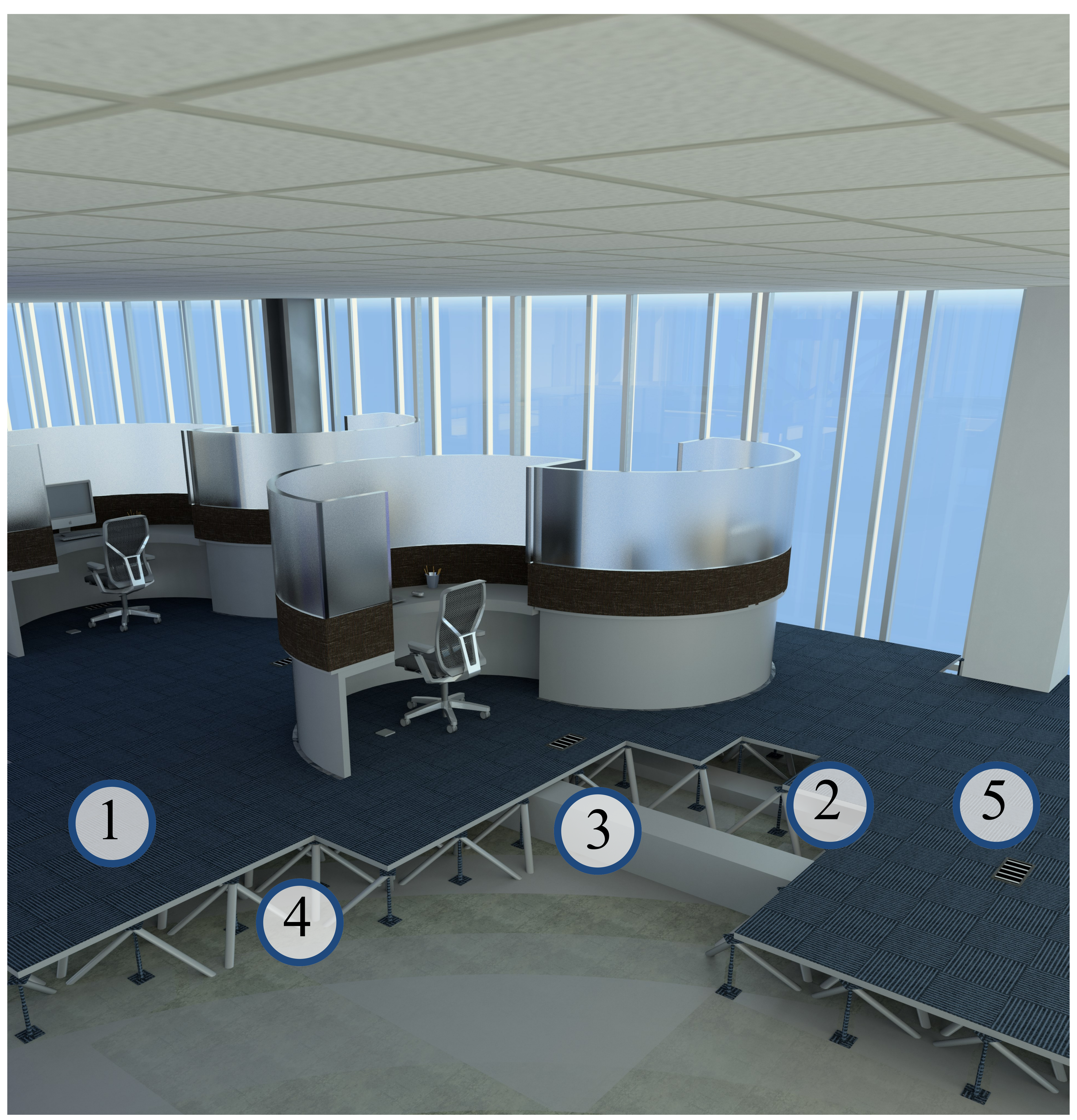


Underfloor Air Distribution Clash Detection



Navisworks

To ensure that mechanical systems were installed in the appropriate areas, and did not share spaces with other systems; the mechanical team used both Autodesk Revit and Navisworks to run clash detection. Here potential clashes were able to be observed and fixed.



Autodesk Revit

1. Raised Access Floor (RAF)
2. Data Cable Tray
3. Supply Air Duct
4. Seismic Bracing
5. Supply Diffuser

Mechanical

2014 Charles Pankow Foundation Annual Architectural Engineering Student Design Competition

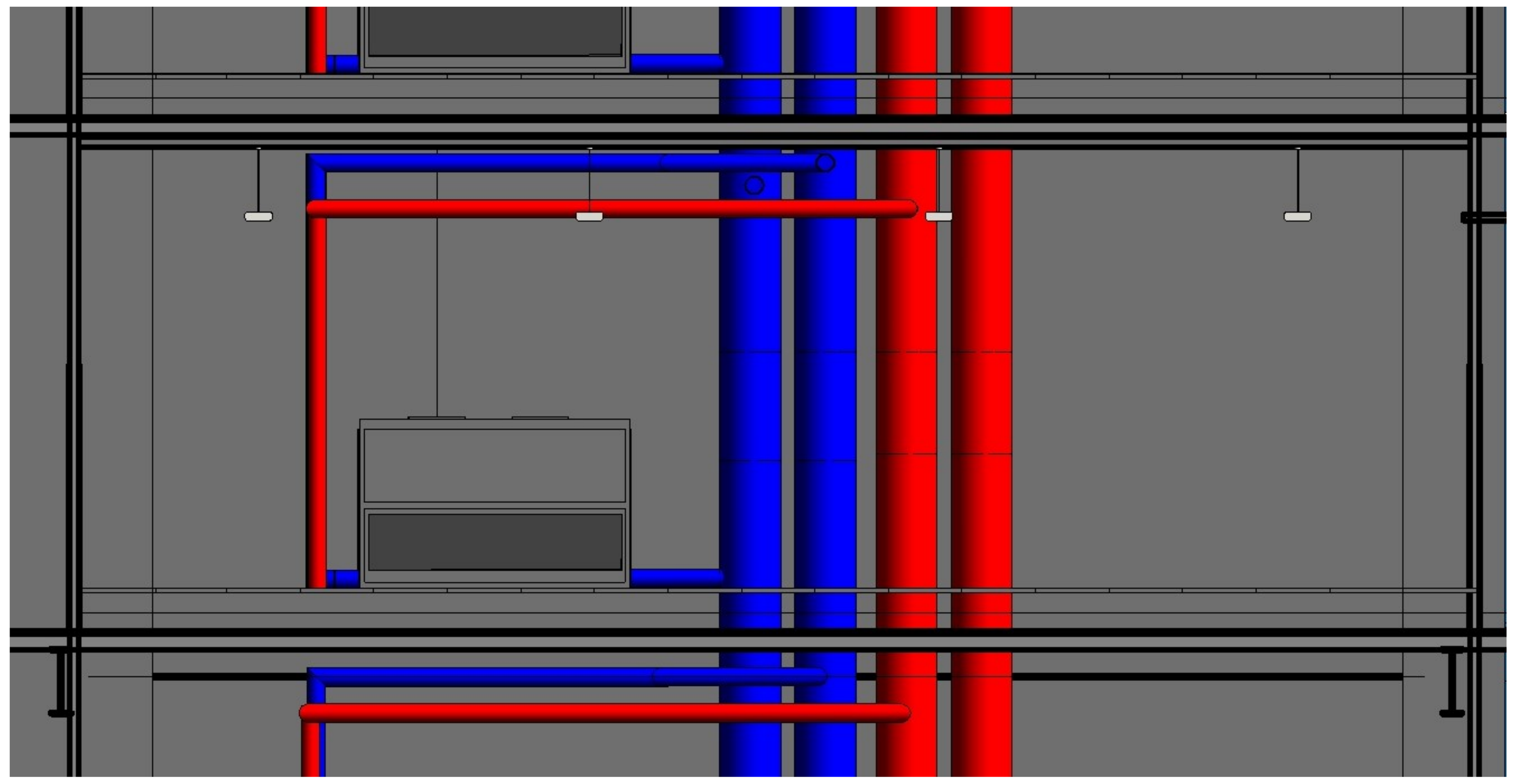
No.	Description	Date

AEI Team Number
05-2014

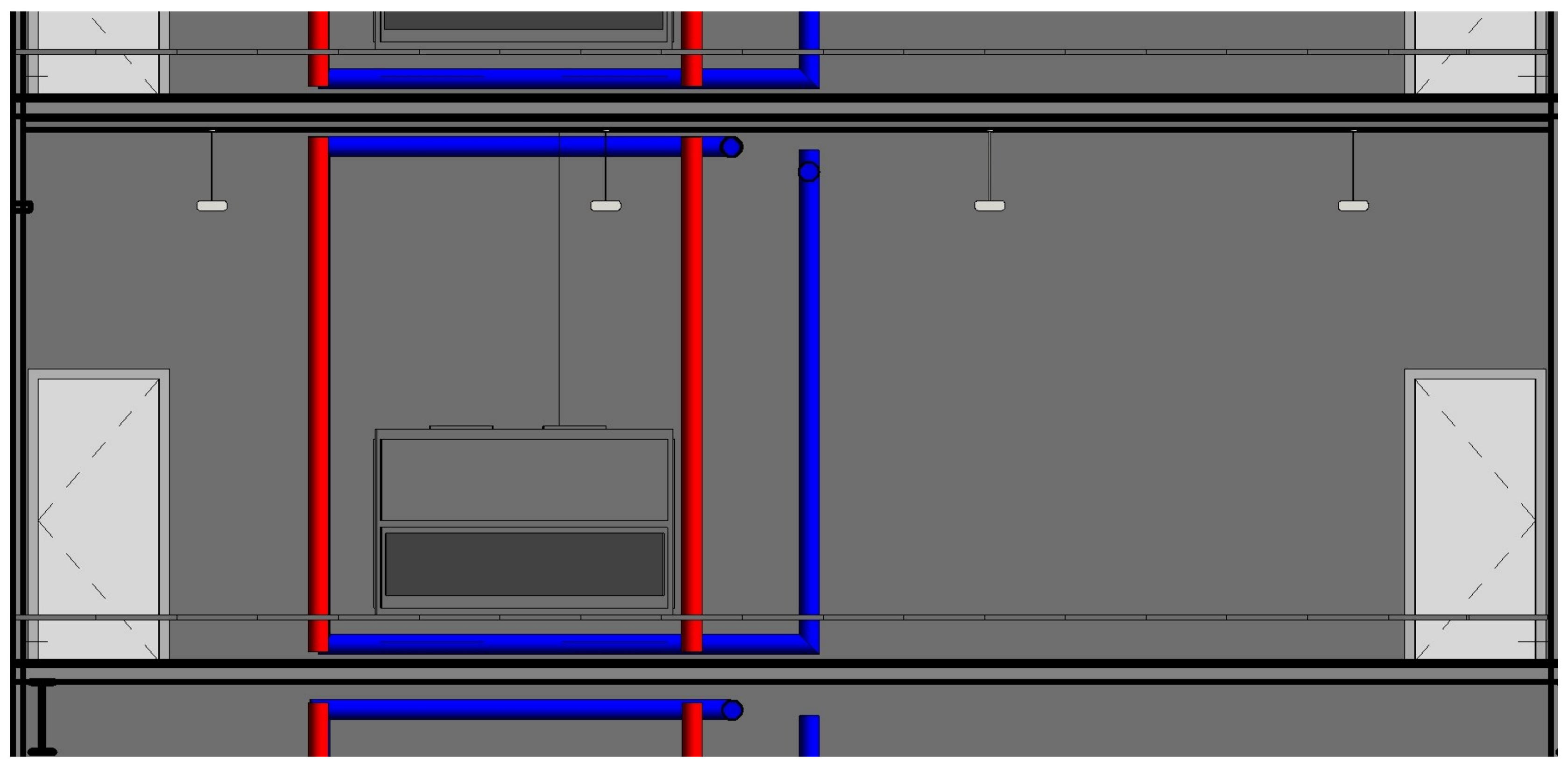
Underfloor Air Distribution

M-106

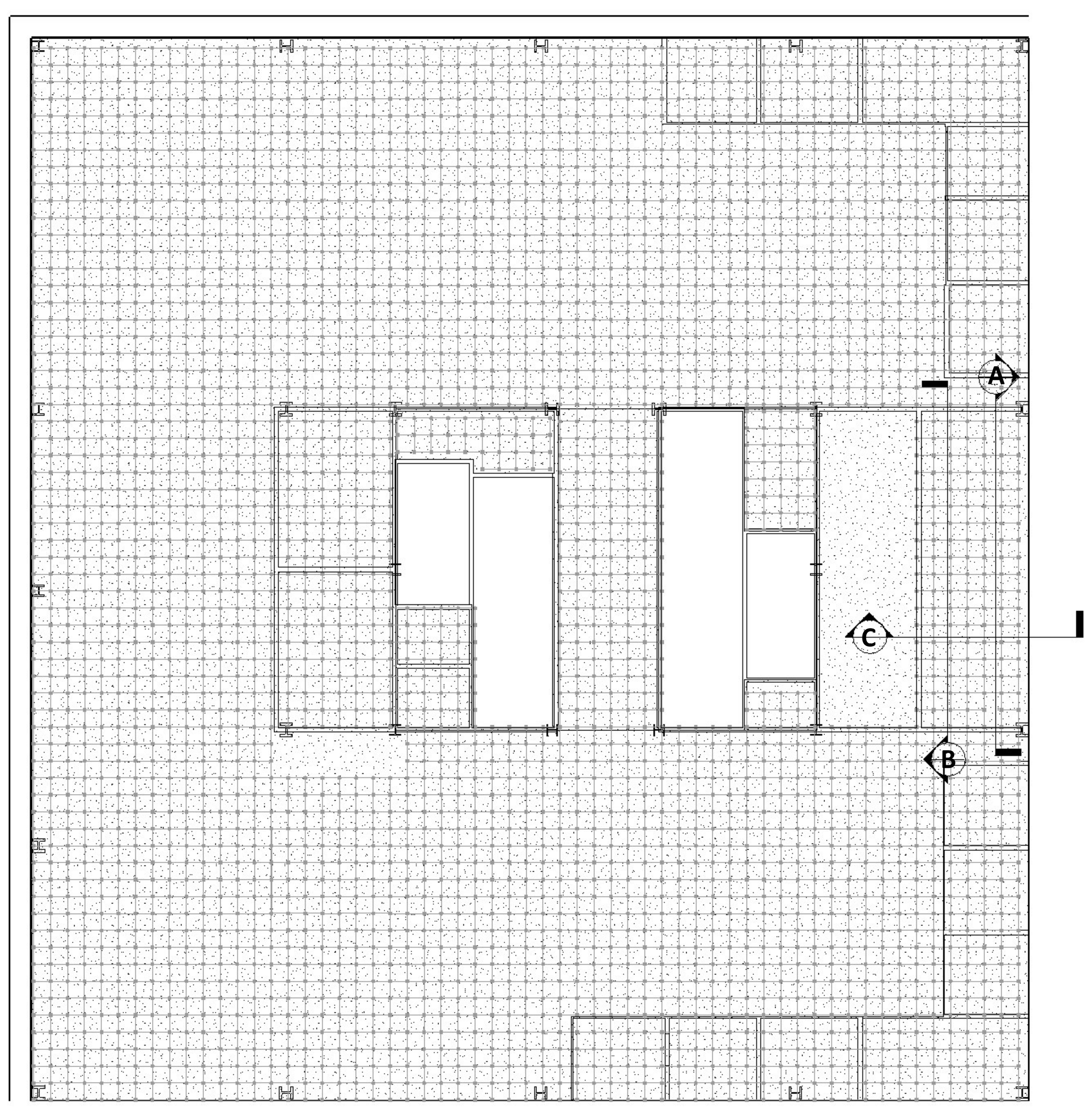
Mechanical Room

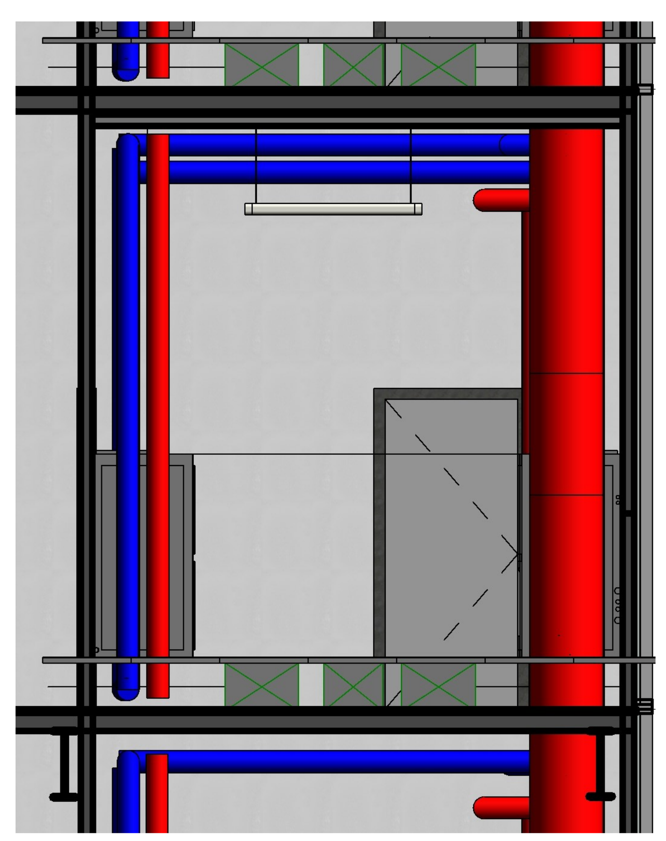


Section A



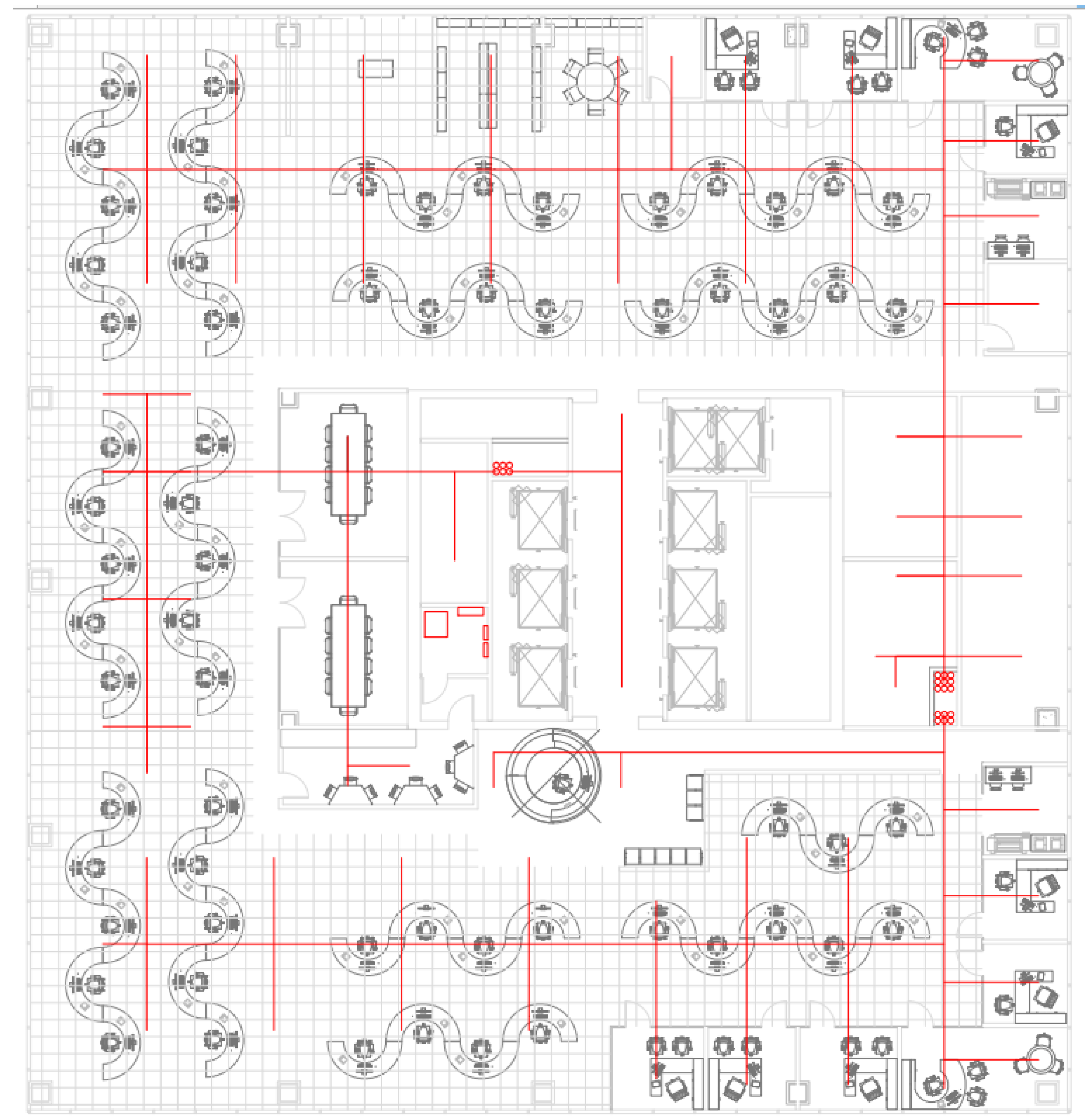
Section B





Section C

Fire Protection Plan



We chose a gaseous fire suppression system to help achieve our goal of immediate occupancy. A gaseous fire suppression system does not cause the damage to electronics and other materials that a traditional water fire suppression system would. Not only does this save on replacement costs, but also eliminates the repair time usually needed after a sprinkler system is activated.

Mechanical

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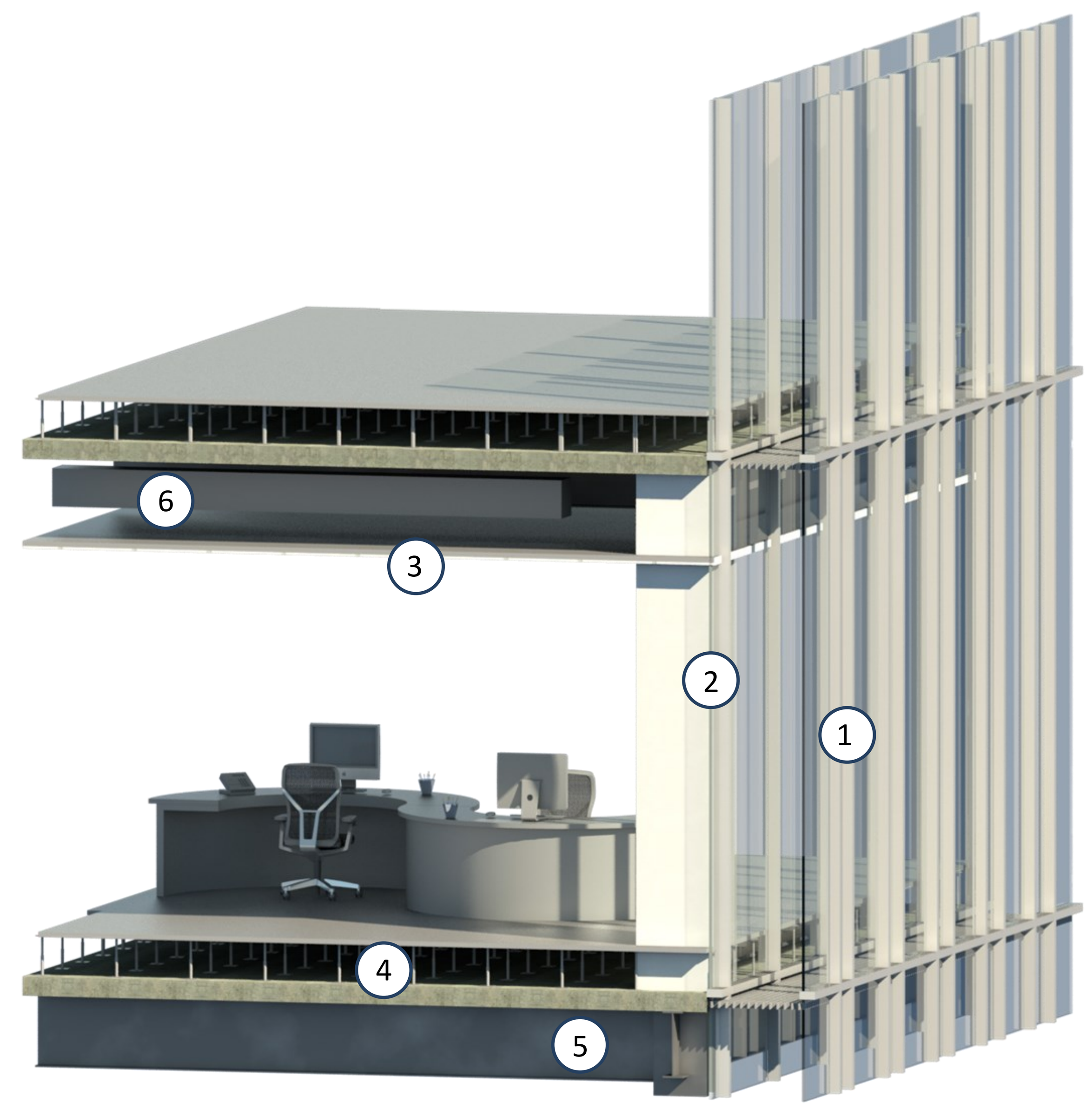
No.	Description	Date

AEI Team Number
05-2014

Piping

M-107

Double Facade



1. Double Façade System (DFS)
2. Daylight Control Retractable Shading
3. Daylight Dimming
4. Underfloor Ducts and Data Cables
5. Structural System
6. Return Duct

Collaboration:

To ensure that all goals were satisfied, the disciplines had to confirm that all systems worked integrally with each other

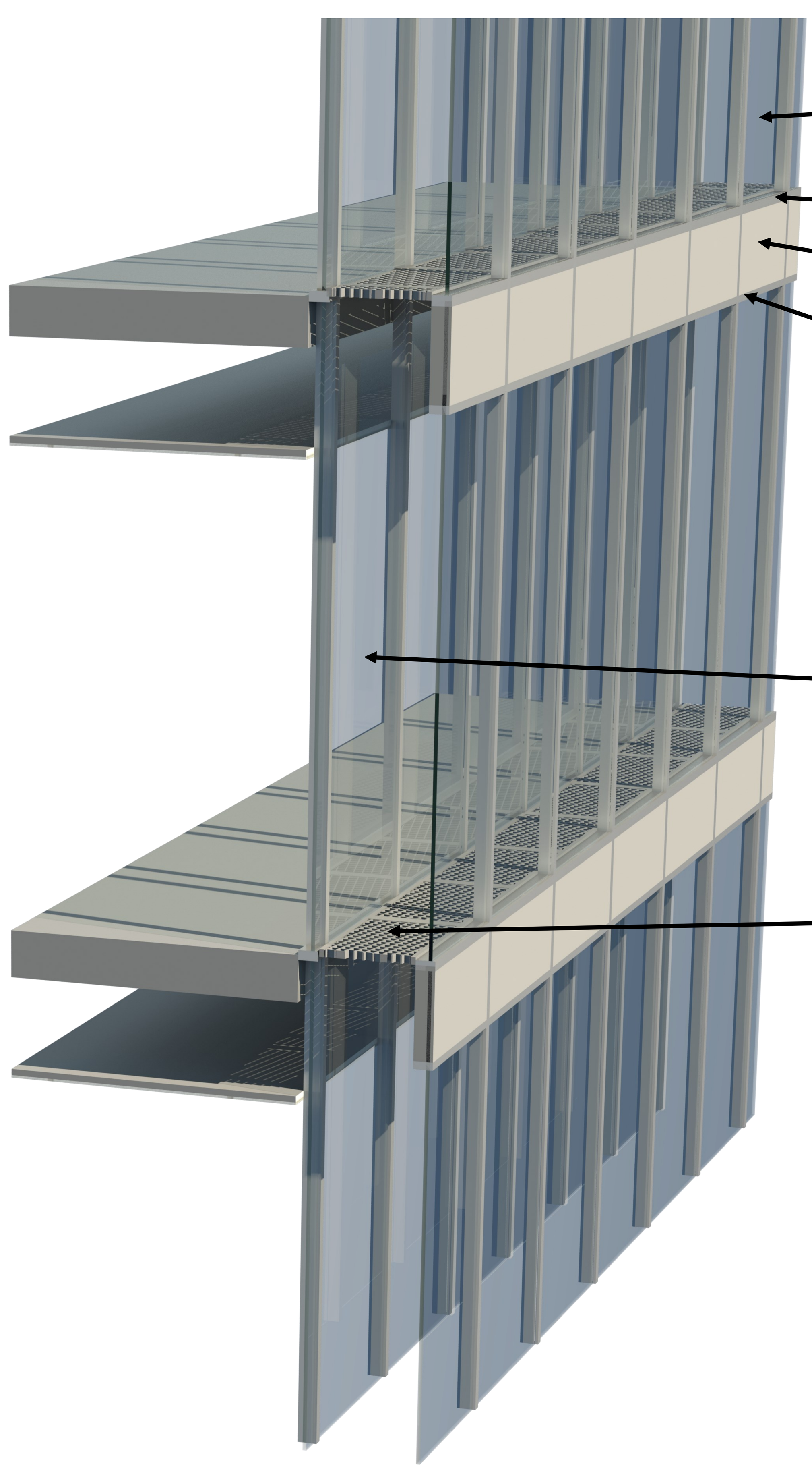
DFS
Mechanical: Energy Savings
Electrical: Light Control
Structural: Additional Imposed Weight

Retractable Shading
Mechanical: Effects Space Loads
Electrical: Effects Surface Lighting Levels

Daylight Dimming
Mechanical: Effects Space Loads
Construction: Additional Sensor Costs

Raised Access Floor
Mechanical: Coordinate with Electrical for Clash
Electrical: Coordinate with Mechanical for Clash

Structural System
Mechanical: Coordinate with Structural for Clash
Structural: Coordinate with all Disciplines for Loads
Structural: Coordinated with System Clash



Exterior Glass - Clear 6mm glass

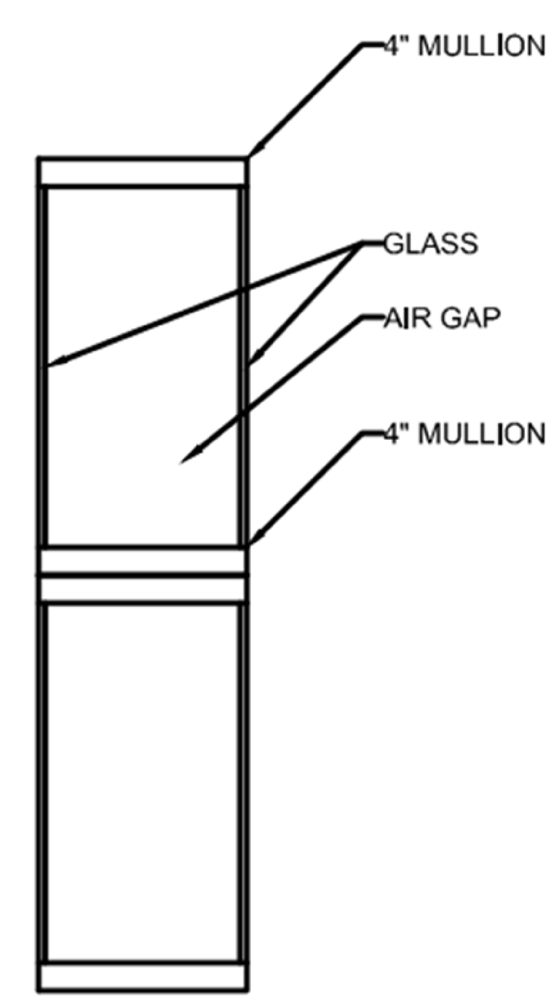
4” Mullion

Louver

8” Mullion

Interior Glass – Based off of PPG SOLARBAD product. U-value: 0.32, ½” argon-fill space, VLT: 64%, and SHGC: 0.36

Steel grates



Mechanical

2014 Charles Pankow Foundation Annual Architectural Engineering Student Design Competition

No.	Description	Date

AEI Team Number 05-2014

Double Facade

M-108

Equipment Schedules

AIR HANDLING UNIT SCHEDULE

TAG	LOCATION	AREA SERVED	COOLING CAPACITY (TONS)	HEATING CAPACITY (MBH)	SUPPLY FAN			ELECTRICAL DATA			BASIS OF DESIGN	
					AIR FLOW (CFM)	OA (CFM)	MOTOR HP	VOLTS/ PHASE/ HERTZ	FLA	MOP	MANUF	MODEL
AHU-1	Mechanical Platform	Lobby	60		24,000	845	2 @ 15	460-3-60	158.7	175.0	Carrier	50BVU-064
AHU-2	Podium	Podium	10		4,500	4,145	5	460-3-60	29.2	35	Carrier	50BRN-014
AHU-3	Mechancial Platform	Restaurant	10		4,000	3,761	3	460-3-60	25.6	30	Carrier	50BRN-012
AHU-4	Fan Room	Level 5 Office Peripheral	10		5,700	321	4.1	460-3-60	5.9	15	Stulz	CCU-300-CWE
AHU-5	Fan Room	Level 5 Office Core	20		11,500	668	4.1	460-3-60	10.1	15	Stulz	CCU-600-CWE
|	|	|	|	|	|	|	|	|	|	|	|	|
AHU-52	Fan Room	Level 30 Office Peripheral	10		5,700	321	4.1	460-3-60	5.9	15	Stulz	CCU-300-CWE
AHU-53	Fan Room	Level 30 Office Core	20		11,500	668	4.1	460-3-60	10.1	15	Stulz	CCU-600-CWE

NOTES:

COOLING TOWER SCHEDULE

TAG	COOLING CAPACITY (TONS)	WATER DATA			ELECTRICAL		BASIS OF DESIGN	
		RANGE (°F)	APPROACH (°F)	FLOW (GPM)	VOLT/ PHASE/ HERTZ	MOTOR HP	MANUF	MODEL
CT-1	696	10	22	2100	480-3-60	2 @25	Evapco	AT-29-824

NOTES:

DIFFUSER, REGISTER AND GRILLE SCHEDULE

TAG	CFM	Quantity/ Floor	SERVICE	TYPE	SIZE (INCHES)		MOUNT	MAX NC	BASIS OF DESIGN	
					FACE	NECK			MANUF	MODEL
NFD-5	100	120	Floor	Floor Diffuser	8"	-	Floor	15	Nailor	NFD
NFD-6	100	120	Floor	Floor Diffuser	8"	-	Floor	15	Nailor	NFD
|	|	|	|	|	|	|	|	|	|	|
NFD-29	100	120	Floor	Floor Diffuser	8"	-	Floor	15	Nailor	NFD
NFD-30	100	120	Floor	Floor Diffuser	8"	-	Floor	15	Nailor	NFD

NOTES:

HOT WATER BOILER SCHEDULE

TAG	TYPE	MAX INPUT (MBH)	MAX OUTPUT (MBH)	WATER DATA		ELECTRICAL	BASIS OF DESIGN	
				EWT (°F)	LWT (°F)	VOLT/ PHASE/ HERTZ	MANUF	MODEL
B-1	Natural Gas	750	720	150	180		Cleaver-Brooks	CFC-750
B-2	Natural Gas	750	720	150	180		Cleaver-Brooks	CFC-750
B-3	Natural Gas	750	720	150	180		Cleaver-Brooks	CFC-750

NOTES:

WATER COOLED ABSORPTION CHILLER SCHEDULE

TAG	TYPE	Capacity (TONS)	WATER DATA		ELECTRICAL	BASIS OF DESIGN	
			EWT (°F)	LWT (°F)	VOLT/ PHASE/ HERTZ	MANUF	MODEL
CH-1	Absorption	450	56	44	460-3-60	Carrier	16-DF-045
CH-2	Absorption	450	56	44	460-3-60	Carrier	16-DF-045

NOTES:

AEI ASCE

Mechanical

2014 Charles Pankow Foundation Annual Architectural Engineering Student Design Competition

No.	Description	Date

AEI Team Number 05-2014

Equipment Schedule

M-109