The Palestra Building
London, England

Architectural Renderings compliments of Alsop Architects

Mechanical Systems Existing Conditions Report

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AE 481W, Fall 2005

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I. Executive Summary

The purpose of this report is to examine and summarize the existing mechanical systems designed for the Palestra Building in London, England. The design team's main objectives were to create an iconic office building in the south of London that was BREEAM Certifiable (The Building Research Environmental Assessment Method – the UK's equivalent to the LEED program) yet flexible enough in its design to accommodate its tenants both currently and in the future. The ability to maintain the desirability of the rentable office space is critical to the project's financial return to its investors and owners.

This report will elaborate on the design conditions (indoor and outdoor), the heating and cooling loads the systems were designed to meet, as well as the schedules and schematics of the main mechanical equipment.

The estimated heating demand of the building, including preheat and spare capacity, is 1796kW. The cooling load was calculated to be approximately 3871kW, including almost 20% spare capacity. Based on these calculations and the design criteria set by the project developer centralized chiller and boiler plants were installed in coordination with a 4 pipe fan coil system. The chiller plant consists of seven chiller units of equal size with the seventh serving as a reserve. The boiler plant consists of four gas-fired boilers of equal size with the fourth unit also serving as spare capacity.

In addition seven air handling units will be installed throughout the building servicing the office spaces, corridors, water closets, reception area, and plant rooms. This system has allowed for a significant percentage of growth to account for all equipment brought in by the tenant and the possibility of additional fan coil units being added.

Overall the mechanical systems are very well designed and have achieved a high level of flexibility, desirability, and redundancy. The choice to use gas heating versus electric also gained several additional 'Green' credits, allowing the project to go on to achieve a 'Very Good' BREEAM rating. The largest critique of the system would be the lack of humidity control. Due to the moderate climate found in London,

humidity levels are rarely a problem for three-fourths of the year. However, those levels can occasionally drop below 35% during the winter months. While there are accommodations to allow for the installation of humidifiers in the air handling system, there will be no direct control of these levels as currently designed. This could be an excellent opportunity to look into the feasibility of a Dedicated Outdoor Air System for the Palestra Building.

It is also important to note that the Palestra Building is still under construction, so all load calculations and energy rates are based on 'Good Practice.'

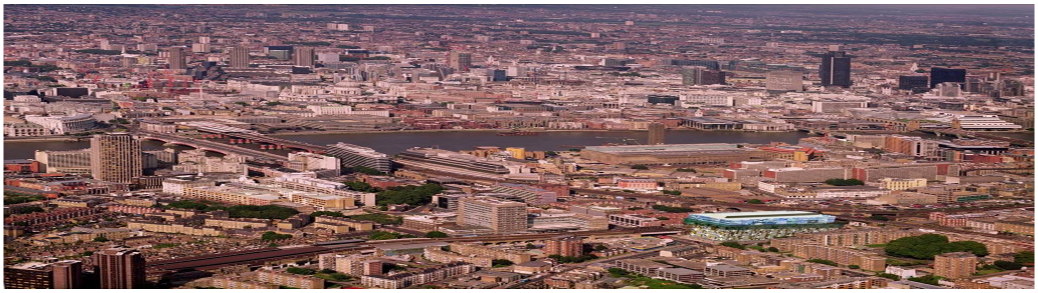
II. Design Objective and Requirements

Design Approach and Strategy

The Palestra Building is the result of a business collaboration between Insignia Richard Ellis Development and Blackfriars Investment. The team wanted to create an iconic landmark office building in southern London as an effort to spur regeneration in the area. In addition to an exciting and contemporary design, great efforts were made to develop the most efficient building from an engineering standpoint as well. With the complex structural systems incorporated throughout the building with the 'dancing columns' and 9 meter cantilever, careful integration of the building services distribution systems was imperative. Due to the 'glass box' nature of the design, a detailed solar shading study was completed to ensure system efficiency with minimal impact on the views from the office space.

Key Objectives

- At least 280,000 square feet of office space
- High Asset Value
- Flexible design to meet current and future business needs
- Design should comply with design specification set forth by Insignia Richard Ellis
- Flexible enough to allow for multi-tenant occupiers, up to four per floor
- Minimal impact on Building Services as office layouts are modified
- Cost Effective and Economic design
- Energy Efficient with Low Operating Costs



Occupied Environment

Temperature: The air and radiant temperatures shall meet the occupant's perception of their thermal environment comfort zone.

Air Movement: In order to meet the fresh air requirements for comfort while avoiding draughts the air velocity shall be limited to 0.15m/s in the winter and 0.25 during summer conditions.

Indoor Air Quality: To maintain appropriate contaminant levels (including C02) from office equipment and equipment the ventilation system shall be designed for 10-16L/s per person.

Humidity: Due to the moderate climate found in London, England the only critical season is winter when the humidity level can fall below 30%.

Acoustics: Too much background noise can be distracting, however a moderate amount has been proven to enhance concentration and disguise general conversations.

Lighting: Adequate levels of lighting must be provided throughout the building, yet it must be of the appropriate quality and also coordinate with the day lighting studies.

In addition to these specific strategies it is important to note that when utilizing air as the predominant means for heating and cooling internal spaces you will be able to satisfy up to 80% of the occupants. And through the fan coil unit layout chosen for the Palestra building limits the amount of humidity control the occupants will have, however the humidity levels should remain between 35-65% most of the year. Individual user controls will also be provided to account for the psychological aspect of how an occupant perceives his/her thermal environment.

Additional design criteria are summarized in Table 2.1.

Table 2.1 Design Criteria

Design Parameter					Comments
Outdoor temperature	Winter -4°C sat		Summer 29°C db, 20°C wb		
Internal temperature	Offices 22°C ± 2	Toilets & Stairs 18°C min (Winter)	22 ^{o}C ± 2	Toilets & Stairs uncontrolled (summer)	The internal temperatures specified are more onerous than the BCO recommendations and will increase the building maximum demand and year round energy consumption.

Air Movement	Winter 0.15m/s max Summer 0.25m/s max		To avoid stratification when heating is required the 0.15 m/s criteria can be relaxed for systems supplying at high level.
Relative Humidity	35 – 65% areas conditioned by fancoil systems (expected levels – note the humidity levels are not controlled). Other areas no control.		Initial installation will not contain humidity control. Space shall be provided within the office area AHU on the roof for future tenant installation of humidification system.
Internal Services Noise	Open plan offices Private offices Toilets, Reception Stairs Plantrooms	NR 38 NR 35 NR 40 NR 45 NR 50	Complies with CIBSE criteria. Care taken to ensure building is not too quiet and privacy is maintained.
Vibration	All plant to be designed to minimise transmission of noticeable vibration through the structure to occupied areas.		
Fresh Air	Offices: 16 l/s per person, 1 person / 12m^2 (average) (= 1.33 l/s m2).	Toilets 10 air changes/hour extract, 8 air changes/hour supply.	The outside air rate specified is generally in line with the BCO recommendations.
Heat Gains	Small power 30 W/m^2 Lighting 15W/m^2 for 450 lux. Occupancy 80W per person sensible heat 60 W per person latent. Local occupancy based on 1 person/8m^2. Central plant diversified load based on one person/10m^2.		Tenant plant areas have been identified for supplementary plant to serve special 24 hour areas; dedicated systems; higher load departments; on-floor IT rooms etc.
Fabric Leakage	Fabric to be constructed to allow no more than 2.5 m^3/hr per m^2 of permeable envelope, at a maintained pressure of 50 Pa.		This specification is as BCO and building regulations recommendations. Air tightness standard equates to an allowance of 0.25 air changes per hour uncontrolled infiltration. To be verified by leakage testing. (Refer to facades report) This specification to be further developed with the façade engineers.
Energy Target	225kWhr/m^2 of treated floor area, per annum (standard = "Good Practice") or 18.5 kg of CO$_2$/m^2.annum whichever the greater		Based upon criteria given in Energy consumption guide 19 (DETR Publication). Building type 3 – (Office. air conditioned – standard). 18.5 kg of CO$_2$/m^2.annum is a requirement of Part L2, 2000 of the Building Regulations. Refer to specific section of the report.
Resilience	Avoid dependency upon single systems where possible so that if one equipment fails the building can continue to operate albeit at reduced capacity. Ensure that systems are designed and installed to facilitate ease of		Spare capacity in the plant means that if one plant fails the other plant should be able to maintain the building operational, albeit with inferior conditions.

	maintenance Chiller Plant – Modular chillers providing 100% of the load (6 No) with one unit as spare (Total 7 no.) Heating / Cooling pipework etc. 20% spare capacity. Heating Plant – Modular boilers providing 100% of the load (3 No.) with one unit as spare (total 4 No.)		
Flexibility	Ceiling services to respect 1500mm partition grid. Flexibility required for 3m wide x 4.5m deep cellular offices at the perimeter, adaptable to 6m deep. Cost plan only allows for a fancoil per 7.5m grid at perimeter. (Cat A fitout for open plan) Internal zones – provide one terminal unit per 6m x 7.5m zone		
Lighting	Offices	450 lux average, Glare index 19. with cat 2 louvres as CIBSE LG3	Uniformity better than 0.8
	Reception	300 lux	
	Stairs and corridors	200 lux	
	Toilets	150 lux	
	Plant rooms	150 lux	
	Car park	100 lux	
Passenger Lifts	Waiting time	<30 second	Based on 1 person /14 m^2, absence rate 15% as BCO and CIBSE Recommendations.
	5 minute handling capacity	<15% of building population	
		Lift for capacity <= 80%	

Maintenance and access to equipment was also very important at the beginning of the design process in order to coordinate these spaces in such a way to minimize lost rentable space, and maximize the possibility for natural ventilation to keep costs low. The provision of plant space in the basement was arranged so that large equipment such as the boilers may be easily replaced in the future. This room is also naturally ventilated with backup mechanical ventilation and sprinkler system in the event of a fire. The plant space located on the roof for the chillers and air handling units is accessible through the internal staircase, and replacement units can be lifted on the roof by a crane. In addition to these two mechanical spaces there is a small provision of space on 1st level for the fan coil units and local hot water heaters accessible through lift off panels.

Achieving a ‘Very Good’ rating on the BREEAM scale was another main objective for the design team. BREEAM (The Building Research Environmental Assessment Method) is the UK’s equivalent of the LEED rating for sustainable building design. The

incorporation of these methods assured the commitment of the team to minimize the impact of the Palestra Building on its surroundings. Achieving such a prestigious rating as ‘Very Good’ would also increase the appeal of the office space within Palestra, thus improving the bottom line for the owners and developers.

III. Energy Sources and Rates for Site

The Palestra Building is being construction on site that previously had a structure of similar size and scope. Therefore the same utilities will be used and increased if needed in order to keep connection costs low. Due to this the design team was given little choice in the selection of the utilities and competitive rates. Transco will provide the gas supply, 24Seven Utility Network Limited (now owned under EDF Energy) will provide the electrical supply as well as a new substation, and Thames Water will provide the water supply and sewage access.

Water Supply Rates: Thames Water, London
Water: 38.88 pence per pound
Waste: 18.24 pence per pound
*These rates exclude the Annual Charge for both the Water and Waste services. These charges will be calculated according to the actual utility usage of the building.
Predicted Annual Cost: £30,000

Gas Supply Rates: Transco, London
Rate: 2.95 pence/kWh
Provision: £138.12 per annum
Installation/Maintenance: £52.28 per annum
Predicted Annual Cost: £11,513

Electricity Supply Rates: 24Seven Utility Network Limited, London

Month	Day Charges
April to October day time	4.48 p/kW.h
April to October night time	3.15 p/kW.h
Novembre to March (8am-4pm and 7pm-8am)	6.69 p/kW.h
November, February and March (4pm-7pm)	22.68 p/kW.h
December and January (4pm-7pm)	33.5 p/kW.h
Standing charges	112.60 £/month
Standing charges / kV.A	1.46 p/kV.A

Predicted Annual Cost: £690,000

*Chart 3.1 shows an annual electric cost profile typical in London on projects of similar size and scope as the Palestra Building.

It is important to note that because the Palestra Building is still under construction, these energy rates are not based on actual data, but rather ‘Good Practice.’ Additional savings from the utility providers could be attained depending on the quantity of each utility consumed.

Chart 3.1 Typical Electric Cost Profile

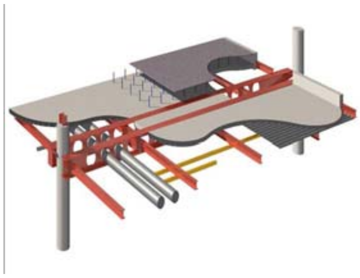
Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
01:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
02:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
03:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
04:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
05:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
06:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
07:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
08:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
09:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
10:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
11:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
12:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
13:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
14:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
15:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
16:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	6.69	6.69
17:00	33.50	22.68	22.68	4.48	4.48	4.48	4.48	4.48	4.48	4.48	22.68	33.50
18:00	33.50	22.68	22.68	4.48	4.48	4.48	4.48	4.48	4.48	4.48	22.68	33.50
19:00	33.50	22.68	22.68	4.48	4.48	4.48	4.48	4.48	4.48	4.48	22.68	33.50
20:00	33.50	22.68	22.68	4.48	4.48	4.48	4.48	4.48	4.48	4.48	22.68	33.50
21:00	6.69	6.69	6.69	4.48	4.48	4.48	4.48	4.48	4.48	4.48	22.68	33.50
22:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69
23:00	6.69	6.69	6.69	3.15	3.15	3.15	3.15	3.15	3.15	3.15	6.69	6.69

IV. Cost Factors

The primary concern for developers and owners of large iconic buildings such as Palestra is the same: maximize profit and produce a positive return on their investment as quickly as possible. Table 4.1 summarizes the mechanical systems’ first costs of over £9,000,000 which accounts for 14.6% of the project’s £68 million budget.

This is a rather large percentage of the budget as compared to other projects of similar size and scope. However, due to the need for a fully mechanical ventilation system the costs are all significantly higher than buildings with completely passive means of ventilation. The increase in the value of the rentable space due to the increased acoustic and thermal comfort was deemed enough to offset all of the additional first costs.

The same mentality used to decide on the ventilation methods was also used to finance the means needed to achieve a high BREEAM rating. Additional funds had to be budgeted for public health, recycling, and emissions testing in order to gain BREEAM certification. But with the BREEAM recognition more businesses will be willing to look into Palestra’s office space.



In addition the design team also faced the large challenge of making the extreme structures of the building possible, efficient and within the budget. This required some additional costs to be invested in the front-end of the design stage, which usually doesn’t see as high paybacks. This investment allowed the engineers to utilize several unique technologies and steel products, as well as integrating the building systems within the structural frame to maximize interior space. These costs were in line with the original intent of the building to be an iconic office building in London, and the final design is quite striking.

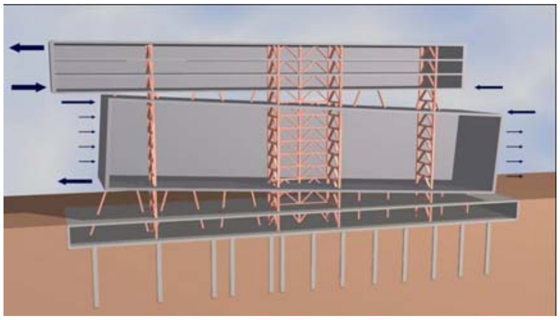
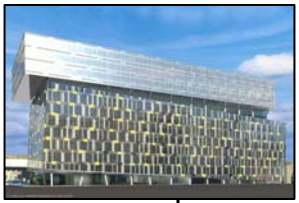


Table 4.1 First Costs

Mechanical Firsts Costs

Equipment	Quantity	Cost
HEATING SYSTEMS		
Gas Supply	37,394 m^3	£1,037,744.00
700kw Gas-Fired Boiler	4	£46,600.00
Boiler Flue System	1	£27,780.00
LTHW Pumps	1	£11,715.00
Primary Distribution - Heating	37,394 m^2	£299,152.00
Secondary Distribution - Heating	26,904 m^2	£591,888.00
COOLING SYSTEMS		
553kw Air-Colled Chiller Package	7	£359,240.00
CHW Pumps	1	£18,165.00
Primary Distribution - Cooling	37,394 m^2	£373,940.00
Secondary Distribution - Cooling	26,904 m^2	£1,022,352.00
Fan Coil Units		
Size 15 - Perimeter Office Areas	343	£303,554.00
Size 9 - Internal Office Areas	394	£292,741.00
Size 6 – Lobbies	22	£16,346.00
Carrier 30RH - 39 heat pumps (Lobby)	1	£11,700.00
Fan Coils	6	£5,310.00
AIR SYSTEMS		
AHUs – Office	2	£170,000.00
Toilet Extract Fans	37,394 m^2	£74,788.00
Supply/Extract Ductwork	37,394 m^2	£373,940.00
Constant Volume Box	176	£80,960.00
Secondary Ductwork to Fan Coils	26,904 m^2	£1,022,352.00
Basement Car Park Ventilation	1,227 m^2	£50,307.00
Plant Room Ventilation	1,235 m^2	£56,810.00
1500x1000mm motorised damper and grille for smoke clearance	98	£171,500.00
CONTROLS		



Control Installation to Mech Systems with Interface	1	£603,860.00
TRANSPORTATION		
1600kg/21 Person passenger lift @ 1.6m/s serving 13 levels	6	£1,440,000.00
1600kg/21 Person passenger lift @ 1.6m/s serving 14 levels	1	£260,000.00
3000kg/40 person goods lift@1.6m/s serving 14 levels	1	£170,000.00
630kg/8 person fire fighting lift @ 1m/s serving 14 levels	2	£350,000.00
LABOUR		£660,996.00

TOTAL **£9,903,740.00**

V. Site Factors Influencing Design Decisions

The Palestra Building is located in the heart of London and just 500 meters from the Southwark tube station. The proximity to such massive public transit systems as well as the urban nature of the area, noise and air pollution were two of the major site concerns. Therefore full reliance on passive ventilation methods was deemed unattainable and mechanical conditioning systems were pursued.

Site Analysis

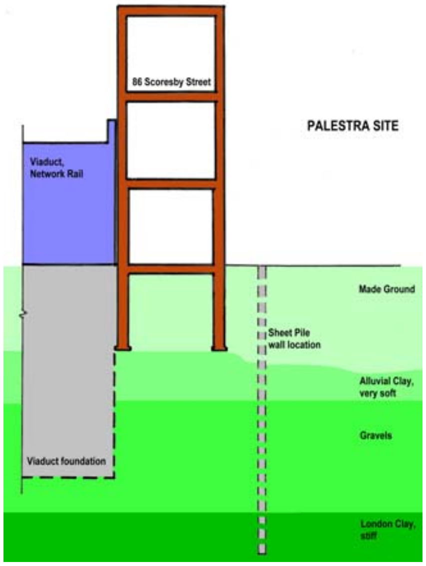
Noise: Adjacent rail lines on the north side of the site, and automobile traffic on the south side will require special acoustic treatments to the façade.

Vibration: A vibration study was completed to completely understand the impact that the above-ground and underground rail lines will have on the Palestra Building's structure.

Solar Gain: To meet the building regulations section 4.3 the solar gain and glare affecting the site's location and orientation were investigated due to the long south-facing façade.

Air Quality: The urban location of the Palestra Building with the high volume of traffic around the site will require an additional filtration system for all outdoor air supplies. All outdoor air shall be brought in through the roof units to ensure the highest quality air attainable.

The close proximity of the Palestra Building to both the underground and above ground rail lines was a major obstacle facing its construction process. Any crane over 8.5 ton is deemed a 'controlled lift' requiring special supervision from National Rail, so every effort was made to remain below this weight. The result was composite steel beams that were structurally efficient as well as light-weight and east to assemble on site. In addition all below grade structures had to be careful not to interfere with of National Rail's existing structures.



VI. Outdoor and Indoor Design Conditions

Outdoor Design Conditions

The Climatic Design Conditions for London, England are taken from ASHRAE Fundamentals. In this case the design weather data listed in British standards are equivalent to those in ASHRAE.

Summer Conditions (ASHRAE 1% @ Atmospheric Pressure in London, England)
Dry Bulb Temperature: 29°C
Wet Bulb Temperature: 20°C
Summer Daily Range: 9°C

Winter Conditions (ASHRAE 99% @ Atmospheric Pressure in London, England)
Dry Bulb Temperature: -1°C
Wet Bulb Temperature: -4°C

Indoor Design Conditions

This set of design criteria was set by Insignia Richard Ellis Development's specifications for the Palestra Building.

Summer Conditions
Dry Bulb Temperature-Offices: 22°C +/- 2
Dry Bulb Temperature-Toilets/Stairs: uncontrolled
Relative Humidity: 35-65% (uncontrolled)

Winter Conditions
Dry Bulb Temperature-Offices: 22°C +/- 2
Dry Bulb Temperature-Toilets/Stairs: 18°C min
Relative Humidity: 35-65% (uncontrolled)

VII. Design Heating and Cooling Loads

The heating and cooling loads for the Palestra Building were calculated based on Stage D design documents produced by Buro Happold Engineers. Those calculations are summarized in Tables 7.1 and 7.2.

Table 7.1

Fabric Heating Load				
Total Fabric insulation (from Appendix H)	17014	W/K		
External temperature	-3	deg.C		
Internal temperature (Assume identical throughout)	22	deg.C		
Total Fabric load	**425351**	W		
Infiltration Heating Load				
Total Façade area	10800	m^2		
Infiltration rate	2.5	m^3/hr/m2		
temperature difference (as above)	25	K	Indexes	
Volume of infiltration	7.5	m^3/s	Building Floor height	3.6
Thermal capacity of air	1200	J/m3.K	Air changes per hour	0.23
Total Infiltration load	**225000**	**W**		
Mechanical Ventilation Heating Load				
Total floor area	26677	m^2		
Occupancy	12	m^2/occupant		
Ventilation Flow rate	16	l/s/occupant		
Air tempered to	22	deg.C		
External air	-3	deg.C		
Thermal Efficiency of ventilation plant	50	%		
Temperature difference	12.5	K		
Ventilation Flow rate	35.6	m^3/s		
Air thermal Capacity	1200.0	J/m^3.K		
System losses	10%			
Ventilation heat load	586894	W		
Total Heating Load				
Total Heating Load	**1,237**	**kW**	Indexes	
Spare capacity	10%			
Pre-heat period	32%		Building Floor	26677

Installed Heating Load	**1,796**	**kW**	area Load per m2 (W/m^2)	67.3

Table 7.2

Breakdown of cooling loads		
	BH proposed Brief	
Internal Cooling Load		
Persons	10 W/m2	m^2/occupant
Light	15 W/m2	W/m^2
Equip	30 W/m2	W/m^2
Fan Coil units	6 W/m2	W/m^2
total – Internal	**61 W/m2**	W/m^2
Environmental Cooling Load		
Room Temperature	22	deg.C
Outdoor temperature	29	deg.C
Difference	7	deg.C
Solar cooling load	25	W/m^2 (estimate) *
Fabric cooling load	5	W/m^2 (estimate) *
Infiltration cooling load	1.9	W/m^2 (estimate) *
Total Environmental	**32 W/m2**	
Mechanical Ventilation Cooling Load		
Total floor area	26677	m^2
Occupancy	12	m^2/occupant
Ventilation Flow rate	16	l/s/occupant
Air tempered to	22	deg.C
External air	29	deg.C
Thermal Efficiency of ventilation plant	50	% (estimate) *
Temperature difference	-3.5	K
Ventilation Flow rate	35.6	m^3/s
Air thermal Capacity	1200.0	$J/m^3.K$
Ventilation cooling load	149391	W (estimate) *
Ventilation cooling load	5.6	W/m^2 (estimate) *
Total		
total W/m2	99	W/m^2
Area	26416	m^2
Total Cooling Load	2602	W
Sensible Heat Ratio	15%	

System Losses	10%
Total	**3,291 kW**

Proposed chillers	Capacity	Spare
6 x 0.553 MW	**3,318 kW**	**0.81%**
7 x 0.553 MW	**3,871 kW**	**17.61%**

Table 7.3 Summary of Loads

	Client Brief	BH proposed Brief	BCO Brief
COOLING			
Persons	10 W/m2	10 W/m2	10 W/m2
Light	15 W/m2	12 W/m2	12 W/m2
Equip	30 W/m2	25 W/m2	15 W/m2
spare capacity	3 W/m2		10 W/m2
total - occupants	**58 W/m2**	**47 W/m2**	**47 W/m2**
Room Temperature	22 deg.C	23 deg.C	24 deg.C
Outdoor temperature	29 deg.C	29 deg.C	29 deg.C
Difference	7 deg. C	6 deg. C	5 deg. C
Solar cooling load	35 W/m2	30 W/m2	26 W/m2
Fabric cooling load	9 W/m2	8 W/m2	7 W/m2
Infiltration	0.5 Ac/hr	0.25 Ac/hr	0.5 Ac/hr
Infiltration cooling load	14 W/m2	6 W/m2	10 W/m2
Total Environmental	**58 W/m2**	**44 W/m2**	**43 W/m2**
total W/m2	**116 W/m2**	**91 W/m2**	90 W/m2
Area	35,000 m2	35,000 m2	35,000 m2
Total Cooling Load	**4,060 kW**	**3,185 kW**	**3,133 kW**
Spare capacity	20%		
Total	**4,872 kW**	**3,185 kW**	**3,133 kW**
	153%	100%	98%
Proposed chillers	*4 x 1.2 MW*	*3 x 1.1 MW*	
Area allocation on roof	*220 m2*	*150 m2*	
Fan Coil units			
Cellular layout	60 per floor	60 per floor	
Open Plan layout	60 per floor	48 per floor	
	125%	100%	
HEATING			
Total Heating load	61.0 W/m2	61.0 W/m2	

Area	35,000 m2	35,000 m2	
Heating load	2,135 kW	2,135 kW	
Morning Cold Start	32%	32%	
Spare Capacity	20%	0%	
Heating Capacity	**3,382 kW**	**2,818 kW**	
	120%	100%	

VENTILATION

ventilation rate	10 m2/occupant 16 l/s/occupants	12 m2/occupant 12 l/s/occupants	12-14 m2/occupant 8-12 l/s/occupants
Ventilation / m2	1.6 l/m2	1 l/m2	0.6 - 1 l/m2
Spare Capacity	10%		
Total	**1.76 l/m2**	**1.0 l/m2**	**0.6 - 1 l/m2**
	176%	100%	
	Risers on upper levels will have to be enlarged to accommodate this air rate..		

ELECTRICAL POWER

Lighting	15 W/m2	12 W/m2	15 W/m2
Small Power	30 W/m2	25 W/m2	15 W/m2
Spare Capacity	3 W/m2		10 W/m2
General Mechanical Loads	40 W/m2	30 W/m2	30 W/m2
Cooling	46 W/m2	30 W/m2	26 W/m2
Misc.	10 W/m2	10 W/m2	10 W/m2
Sub-Total	**144 W/m2**	**107 W/m2**	**106 W/m2**
Area	35,000 m2	35,000 m2	35,000 m2
Electrical Load	5,040 kW	3,745 kW	3,714 kW
Spare Capacity	20%	20%	
Total	**6,048 kW**	**4,494 kW**	**3,714 kW**
	135%	100%	
Transformers	*4 x 1500 kVA*	*3 x 1500 kVA*	*3 x 1250 kVA*

VIII. Schedule for Major Equipment

Cooling

Cooling is provided through a chiller plant located on the roof and consisting of seven packaged air-cooled chiller units, six of which run at full load daily, while the seventh serves as a backup unit. These units run the building's chilled water system fed to the fan coil units and cooling coils in the air handling plant. The primary and secondary constant temperature pumps and circuits are located on the room next to the chiller units.

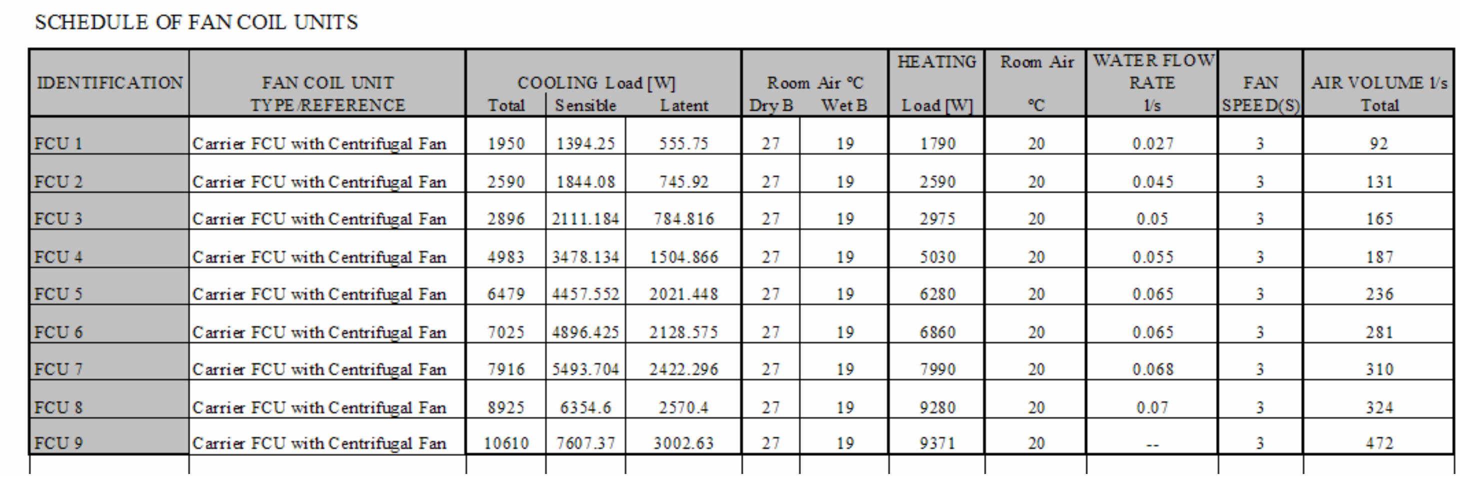
These chillers were specified as York YAES-SD 0625 Air-cooled package units. The fan coil units specified are Carrier Fan Coil Units with Direct Expansion coils for the reception area and Centrifugal fans. Table 8.1 and 8.2 summarize the design data for the chiller and Fan Coil Units.

Table 8.1 SCHEDULE OF CHILLERS

REFERENCE		CH-1	CH-2	CH-3	CH-4	CH-5	CH-6	CH-7
No. OFF								
MODEL REFERENCE		York YAES-SD 0625	York YAES-SD 0625	York YAES-SD 0625	York YAES-SD 0625	York YAES-SD 0625	York YAES-SD 0625	York YAES-SD 0625
TYPE		Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled
PERFORMANCE								
Cooling duty	kW	578	578	578	578	578	578	578
Leaving CHW temperature	ºC	5 to 13	5 to 13	5 to 13	5 to 13	5 to 13	5 to 13	5 to 13
Entering CHW temperature	ºC							
CHW flow rate	l/sec	33	33	33	33	33	33	33
Evaporator pressure drop	kPa	43.5	43.5	43.5	43.5	43.5	43.5	43.5
Evaporator fouling factor	m^2 ºC/kW	0.044	0.044	0.044	0.044	0.044	0.044	0.044
Design ambient temperature	ºC	35	35	35	35	35	35	35
Maximum ambient temperature	ºC	52	52	52	52	52	52	52
Minimum ambient temperature	ºC	-18	-18	-18	-18	-18	-18	-18
REFRIGERANT		Gylcol	Gylcol	Gylcol	Gylcol	Gylcol	Gylcol	Gylcol
REFRIGERANT CIRCUITS		2	2	2	2	2	2	2
CONDENSER CONSTRUCTION								
ELECTRICAL SUPPLY								
Absorbed power at design	kW	189.1	189.1	189.1	189.1	189.1	189.1	189.1
No. of compressors		2	2	2	2	2	2	2

Starter type								
Compressor start current (each)	A	487	487	487	487	487	487	487
No. of fans		8	8	8	8	8	8	8
Fan speed	rpm	715	715	715	715	715	715	715
Total fan power	kW	108.8	108.8	108.8	108.8	108.8	108.8	108.8
Maximum chiller current	A	408	408	408	408	408	408	408
Power factor		0.94	0.94	0.94	0.94	0.94	0.94	0.94
Capacity control steps		20-100%	20-100%	20-100%	20-100%	20-100%	20-100%	20-100%
SOUND PRESSURE LEVELS	63 Hz	66.2	66.2	66.2	66.2	66.2	66.2	66.2
	125 Hz	76.2	76.2	76.2	76.2	76.2	76.2	76.2
	250 Hz	83.6	83.6	83.6	83.6	83.6	83.6	83.6
	500 Hz	88.4	88.4	88.4	88.4	88.4	88.4	88.4
	1 kHz	88.8	88.8	88.8	88.8	88.8	88.8	88.8
	2 kHz	86.5	86.5	86.5	86.5	86.5	86.5	86.5
	4 kHz	80.6	80.6	80.6	80.6	80.6	80.6	80.6
	8 kHz	72.6	72.6	72.6	72.6	72.6	72.6	72.6
DIMENSIONS								
Length	mm	5983	5983	5983	5983	5983	5983	5983
Width	mm	2242	2242	2242	2242	2242	2242	2242
Height	mm	2478	2478	2478	2478	2478	2478	2478
Weight	kg	5713	5713	5713	5713	5713	5713	5713

Table 8.2



SCHEDULE OF FAN COIL UNITS

IDENTIFICATION	FAN COIL UNIT TYPE/REFERENCE	COOLING Load [W]			Room Air °C		HEATING Load [W]	Room Air °C	WATER FLOW RATE 1/s	FAN SPEED(S)	AIR VOLUME 1/s Total
		Total	Sensible	Latent	Dry B	Wet B					
FCU 1	Carrier FCU with Centrifugal Fan	1950	1394.25	555.75	27	19	1790	20	0.027	3	92
FCU 2	Carrier FCU with Centrifugal Fan	2590	1844.08	745.92	27	19	2590	20	0.045	3	131
FCU 3	Carrier FCU with Centrifugal Fan	2896	2111.184	784.816	27	19	2975	20	0.05	3	165
FCU 4	Carrier FCU with Centrifugal Fan	4983	3478.134	1504.866	27	19	5030	20	0.055	3	187
FCU 5	Carrier FCU with Centrifugal Fan	6479	4457.552	2021.448	27	19	6280	20	0.065	3	236
FCU 6	Carrier FCU with Centrifugal Fan	7025	4896.425	2128.575	27	19	6860	20	0.065	3	281
FCU 7	Carrier FCU with Centrifugal Fan	7916	5493.704	2422.296	27	19	7990	20	0.068	3	310
FCU 8	Carrier FCU with Centrifugal Fan	8925	6354.6	2570.4	27	19	9280	20	0.07	3	324
FCU 9	Carrier FCU with Centrifugal Fan	10610	7607.37	3002.63	27	19	9371	20	--	3	472

Heating

Heating is provided through a natural gas-fired central boiler system. The boiler room is located in the basement, and runs on four boilers, three of which run at 100% to meet the daily demands while the fourth is a backup during times of maintenance or it can be used as a 'booster boiler' to generate the morning warm-up. These boilers serve a low temperature hot water system fed to AHU ventilation systems, fan coil units, and heater batteries.

The boilers were specified by the engineers to be Hamworthy, Lulworth Model L7 high efficiency steel boilers. The design data for these units is summarized in Table 8.3.

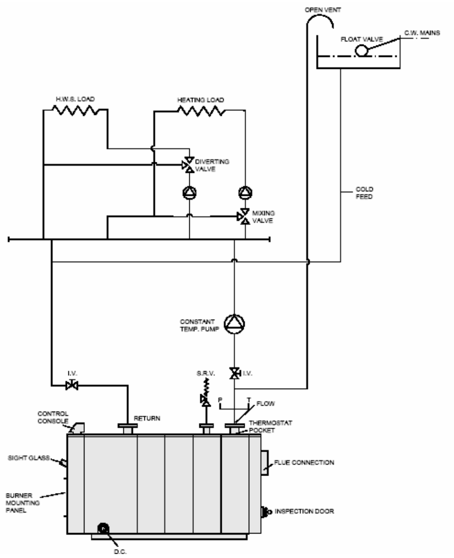


Table 8.3 SCHEDULE OF BOILERS

REFERENCE		B-1	B-2	B-3	B-4	
No. OFF						
MODEL/TYPE		Lulworth Model L7 Steel Boiler	Lulworth Model L7 Steel Boiler	Lulworth Model L7 Steel Boiler	Lulworth Model L7 Steel Boiler	
OUTPUT REQUIRED	Kw	700	700	700	700	
CONSTRUCTION						
WATER						
Flow	ºC	30	30	30	30	Delta T = 15C
Return	ºC	15	15	15	15	
Flow rate (at design temperature)	l/min	668.2	668.2	668.2	668.2	
Pressure drop	in/wg	14.1	14.1	14.1	14.1	
Maximum static head	bar	5	5	5	5	
CONNECTIONS						
Flow		100	100	100	100	Flanged to BS4504 Pt. 1 table 6/3
Return		100	100	100	100	
Gas		Y	Y	Y	Y	
Oil		Y	Y	Y	Y	
FLUE						
Size	mm	350	350	350	350	

Flue gas volume	m^3/hr	1033	1033	1033	1033	
BURNER						
Type						
No. of stages						
FUEL						
Gas:						
Gas flow rate	m^3/hr	80.7	80.7	80.7	80.7	
Gas pressure	mbar	to suit burner selection	to suit burner selection	to suit burner selection	to suit burner selection	
Oil:						
Oil flow rate	l/h	77.8	77.8	77.8	77.8	
Oil grade		Class D Oil 35 sec	Class D Oil 35 sec	Class D Oil 35 sec	Class D Oil 35 sec	
ELECTRICAL SUPPLY	ph	3	3	3	3	1 phase/230V/50Hz -- Boiler Panel
	V	415	415	415	415	
	Hz	50	50	50	50	

Air Handling Units

There are seven air handling units included in the Palestra Building. Two of the air handling units are located in the Basement Plant Room, four on the roof, and one on the Ground Floor servicing all of the office spaces, water closets, plant room, boiler room, and ground level reception/lobby.

Air Handling Units 1 and 2 are located on the roof and supply air to 16107m^2 of open plan office space disbursed evenly throughout the twelve levels (variable volume). Each AHU maintains a negative pressure of 400 Pa, and includes a heat exchanger in the form of a heat wheel, a cooling coil, a heating coil, a panel filter of grade G4, and a variable frequency drive supply and extract fan.

Air Handling Units 3 and 4 service the building's water closets and are also located in the roof ventilation plant. Unit 3 supplies air to 498m2 of toilets on the west side of the building, and Unit 4 supplies ventilation to 627m2 of toilet space on the east side. These are constant volume systems, and each includes a frost coil, cooling coil, heating coil, as well as supply and extract fans. These units were also over-sized by 60% in order to accommodate the future loads added by tenants.

Air Handling Units 5 and 6 are located in the basement plant room. Unit 5 services the sprinkler plant and includes only a panel filter of grade G4, a cooling coil, and a heating coil. Unit 6 services the boiler rooms and also includes a panel filter of grade G4, a cooling coil, and a heating coil. Units 5 and 6 were designed to provide adequate smoke clearance to these vital mechanical spaces. Approved Document F requires a minimum of 12 m/s face velocity for ventilation extract in the case of fire. Because Units 5 and 6 do not service occupied spaces, nor do they carry any of the daily load therefore they will be excluded from this study.

Air Handling Unit 7 is located in the Ground Floor mechanical room and solely supplies air to the reception area, 772m2, at a constant volume. This unit contains a heating coil, cooling coil, a panel filter of grade G4, as well as, supply and extract fans.

The air handling units for the Palestra Building’s office space were specified as Carrier’s Rooftop packages AHU model 39 FD 0625 with a flexible modular construction to allow for expansion of the unit with additional coils as needed. The data for these units is summarized in Table 8.4.

Table 8.4
SCHEDULE OF AIR HANDLING UNITS

REFERENCE		AHU 1	AHU 2	AHU 3
APPLICATION		Office Supply	Office Supply	WC Supply
LOCATION		Roof	Roof	Roof
System Served		Office Supply	Office Supply	WC supply
Supply Components				
Inlet Section				
Access Section				
Frost Coil		None	None	None
Duty	kW			
Air on/off	ºC			-4 / 0
LTHW on/off	ºC			n/a
Water flow rate	l/sec			n/a
Water Dp	kPa			n/a
Electrical Supply	V/ph/Hz			415/3/50
Panel Filter	Grade	G4	G4	G4
Bag Filter	Grade	EU7	EU7	EU7
Heat Exchanger	Type	Heat Wheel	Heat Wheel	None
Air on	ºcdb/ºcwb	-3/-3	-3/-3	
Air off	ºcdb/ºcwb	14.4/9.5	14.4/9.5	
Efficiency	%	70 (Latent) 64 (sens)	70 (Latent) 64 (sens)	
Cooling Coil Section				

Entering air condition	°cdb/°cwb	26/18.6	26/18.6	29/21.5
Leaving air condition	°cdb/°cwb	18/15.1	18/15.1	18/16.5
Chilled water temperature on/off	°C	6/12	6/12	6/12
Chilled water flow rate	l/sec	7300	7300	
Access Section		YES	YES	YES
Heating Coil Section				
Air temperature on/off	°C	14.4/22	14.4/22	-3/22
LTHW temperature on/off	°C	85/65	85/65	85/65
Supply Fan Section				
Duty volume	m³/s	18.318	17.805	
External static pressure	Pa			1.44
Volume control		Inverter	Inverter	None
Electrical supply	V/ph/Hz	415/3/50	415/3/50	415/3/50
Motor rating	kW	18	18	

Extract Fans Section				
Duty volume	m³/s	18.318	17.805	1.44
Unit Dimension Overall				
Length	mm	3830		
Width	mm	2255		
Height	mm	1625		

SCHEDULE OF AIR HANDLING UNITS

REFERENCE		AHU 4	AHU 5	AHU 6
APPLICATION		WC Supply	Plantroom	Boiler room
LOCATION		Roof	Basement	Basement
System Served		WC supply	Sprinkler plant	Boiler Rooms
Supply Components				
Inlet Section				
Access Section				
Frost Coil				
Air on/off	°C	-4 / 0		
LTHW on/off	°C	n/a		
Water flow rate	l/sec	n/a		
Water Dp	kPa	n/a		
Electrical Supply	V/ph/Hz	415/3/50		
Panel Filter	Grade	G4	G4	G4
Bag Filter	Grade	EU7	EU4	EU4

Heat Exchanger	Type	None	None	None
Access Section		None	None	None
Cooling Coil Section				
Entering air condition	ºcdb/ºcwb	29/21.5	29/21.5	29/21.5
Leaving air condition	ºcdb/ºcwb	18/16.5	18/16.5	18/16.5
Chilled water temperature on/off	ºC	6/12	6/12	6/12
Access Section		YES	YES	YES
Heating Coil Section				
Duty	kW			
Air temperature on/off	ºC	-3/22	-3/22	-3/22
LTHW temperature on/off	ºC	85/65	85/65	85/65
Supply Fan Section				
Duty volume	m³/s			
External static pressure	Pa	1.65		
Volume control		None	None	None
Electrical supply	V/ph/Hz	415/3/50	415/3/50	415/3/50
Access Section		None		
Extract Fans Section				
Duty volume	m³/s	1.65	0	0

SCHEDULE OF AIR HANDLING UNITS

REFERENCE		AHU 7
APPLICATION		Reception
LOCATION		Ground Floor
System Served		Reception area supply
Supply Components		
Inlet Section		
Access Section		
Panel Filter	Grade	G4
Bag Filter	Grade	EU7
Heat Exchanger	Type	None
Air on	ºcdb/ºcwb	
Air off	ºcdb/ºcwb	
Efficiency	%	
Access Section		None
Cooling Coil Section		
Entering air condition	ºcdb/ºcwb	29/21.5
Leaving air condition	ºcdb/ºcwb	18/16.5

Chilled water temperature on/off	ºC	6/12
Access Section		YES
Heating Coil Section		
LTHW temperature on/off	ºC	85/65
Supply Fan Section		
Duty volume	m^3/s	
External static pressure	Pa	1.65
Volume control		None
Electrical supply	V/ph/Hz	415/3/50
Access Section		None
Extract Fans Section		
Duty volume	m^3/s	1.65

*This data is based on preliminary scheduling for the mechanical equipment. The most recent data will be used as it becomes available as the construction process finalizes all designs.

IX. Schematic Drawing of Existing Mechanical Systems

See Appendix A.

X. Description of System Operation

Schedule of Operation

The Palestra Building, while innovative in its design as an architectural icon, will function as a multi-tenant office building. Therefore the occupancy schedule was critical to the design of its mechanical systems. The systems were designed to meet full load at the following times.

Monday-Friday 7am-7pm
Saturday 11am-5pm
Sunday/Holiday 12pm-3pm

However, it is important to note that the reception area's design schedule of operation was based on the assumption that it would be open and available 24/7. Therefore, to avoid running costly chiller and boiler systems to service such a small space, all of the mechanical systems for the reception are stand alone. AHU-7 provided dedicated service to the lobby, while the fan coil units depend on heating and cooling provided by heat pumps.

Centralized Boiler Plant

The boiler plant consists of four gas-fired boilers of equal size with the fourth installed for redundancy. These units are responsible for meeting the hot water demands of the building. The Low Temperature Hot Water produced services the Air Handling Units and the Fan Coil Units located on each level. In addition there are local heaters located on each level as well to reheat the water to meet higher demands. All of this equipment is wired into the Building Management System (BMS) which coordinates the building's systems proportional to the occupancy levels/operation schedule and feedback from temperature sensors (inside and outside) in order to maximize the efficiency of the system and adjust temperature set points as necessary.

The boilers are installed in parallel to one another and are staged according to the heating demand of the building. Each chiller is sized to accommodate one-third of the building's peak heating demand as estimated previously in Table 7.1. This creates redundancy allowing one boiler to be offline for repairs or maintenance while not sacrificing the system's ability to meet peak demand. In addition to the four boilers there are also four pumps in parallel that echo the redundancy.

When the outdoor air temperature falls below the set point of 18°C the boilers will come online one at a time as the demand increases past the full capacity of the first and second boilers. The system pumps coordinate with the boilers function in a similar manner as well, taking advantage of their parallel layout to stage them for maximum efficiency.

Air Handling Unit Operation

The air-side of the Palestra Building's design is comprised of 7 air handling units located throughout the building (as noted in Section 8). These units are responsible for providing all of the occupied spaces in the building with 20-24°C air, while also meeting the design standards for fresh air supply requirements. However this system relies on the individual fan coil units installed throughout the building to meet the local comfort needs of the occupants.

Each air handling unit is equipped with variable speed driven fans in order for the ventilation systems to appropriately respond to the occupancy levels as noted through the BMS. Two-speed constant volume boxes will be installed at the entrance/exit of each zone to more accurately meet the needs of each space. The intent of the design is for this fan to run at full capacity during normal daytime operating hours, at half load during evening/night hours, and off when the spaces are not occupied or tenantless.

As the BMS monitors the occupancy level of the spaces it will regulate the air handling units accordingly. Each unit is also equipped with an outdoor air damper controlled by the economizer to provide the fresh air needed throughout the building. This damper will modulate between 100% outdoor air and the minimum allowed fresh air rate to maintain the correct supply temperature from the unit. The higher the occupancy level the more fresh air that will be required and the more open the damper. This is the most common use of the damper and economizer in London due to its mild climate. However if the outdoor air temperature is higher than the set point temperature the damper will close so that the system can meet the cooling load.

Centralized Chilled Water Plant

The chiller plant consists of seven equally sized air-cooled package chiller units including an acoustic package. The seventh unit serves as redundancy during times of failure or maintenance on this primary/secondary design. These units are responsible for providing 6°C chilled water to the fan coil units and cooling coils in the Air Handling Units with a designed return flow at 12°C.

The four pipe fan coil system is how thermal comfort is maintained through out the office spaces. Each fan coil unit is equipped with temperature sensors in the return air path to allow the BMS to control the space temperature; however each occupant will also have some control as well. The heating and chilled water circuits feeding each unit will be installed with a variable speed pump to increase system efficiency during off-peak hours. The units are also set up on a 7.5 meter bay grid providing

sufficient cooling for an open space floor plan. If a cellular office plan is desired by the tenant, additional fan coil units can easily be installed within these bays.

Drafts through the office space were also a design concern due to the ‘glass box’ design of the building. The team designed a combination of highly insulated glazing conditioned with a jet of warm air in the winter to eliminate this common problem during the winter.

The chillers and fan coil units within the Palestra Building are also integrated into the BMS which utilizes its data feedback from temperature and humidity sensors to appropriately control the operating capacities/set points of these units, and minimize human error and waste.

Accessibility was an important concern in the systems design. The roof plant is easily accessible through the stairwells in each core, and the fan coil units are each installed in the suspended ceiling within the office spaces and can be accessed through full size access tiles.

XI. Critique of System

The existing mechanical systems in the Palestra Building were well-designed and efficient, with the emphasis maintained on the ability of the system to be flexible, catering to its tenants (current and future), as well as creating a high level of reliability and redundancy.

The centralized boiler and chiller plant will be very useful in the coming years as more efficient technologies come along. Having all of the heating/cooling systems in one location will make it easier to replace them at once rather than disrupting locations throughout the building as is common with localized systems.

Accessibility to the main plant rooms was also well-designed with thought put into how future replacements for all of the equipment will be moved in and out. The fan coil units throughout the design are located in the suspended ceiling and can be accessed by removing the acoustic ceiling tiles.

In order to maximize the versatility and flexibility of the rentable office space the design team created open floor office plans with fan coil units placed on a grid system. This allows the space to function well with minimal walls and obstructions. If the tenants desire a cellular office layout, or would like to provide their employees with more personalized control over their environment, more fan coil units may be added to this grid. All additional capacity will be installed on AHU-3 and AHU-4.

The design team made a smart choice in selecting the 4 pipe fan coil system, and providing gas heating versus a 2 pipe unit using electric heating. Not only does Gas provide a much lower life cycle cost, but it is releases fewer emissions into the environment thus earning more ‘Green’ points which was a prime objective with the Palestra Building.

With all the benefits of the system and the forward thinking of the design team, there is no set means to control the humidity levels in the building. It is noted that London, England is a very moderate climate with minimal humidity issues through the spring, summer and fall seasons. However, there is a tendency for the humidity level to drop below 35% during the winter months. Accommodations have been made to allow for future installment of humidifiers in the Air Handing system as needed. Investigation into the feasibility of a dedicated outdoor air system could be a possible response to the humidity control issues. A closer look at what efficiency was compromised in order to maximize the flexibility would also be valuable, and how much efficiency the Building Management System can compensate for.

XII. References

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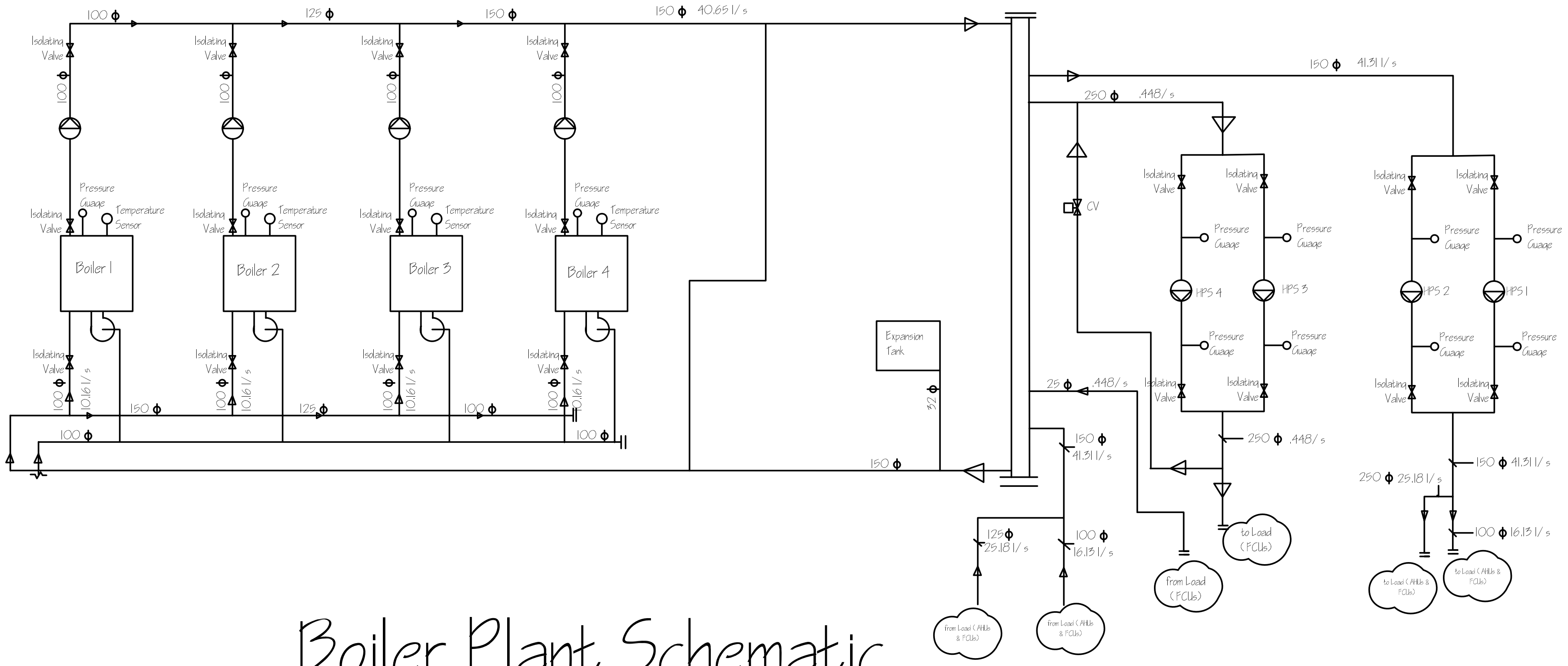
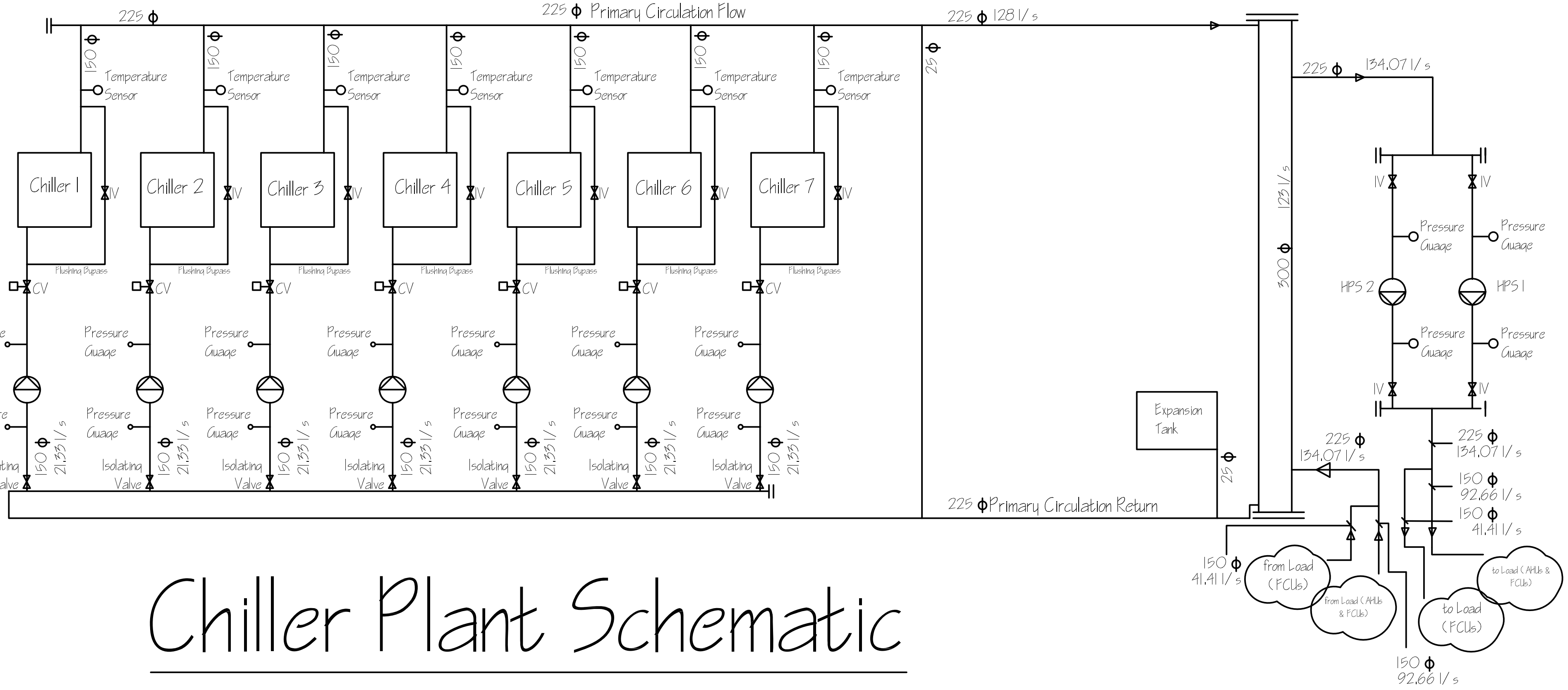
APPENDIX A

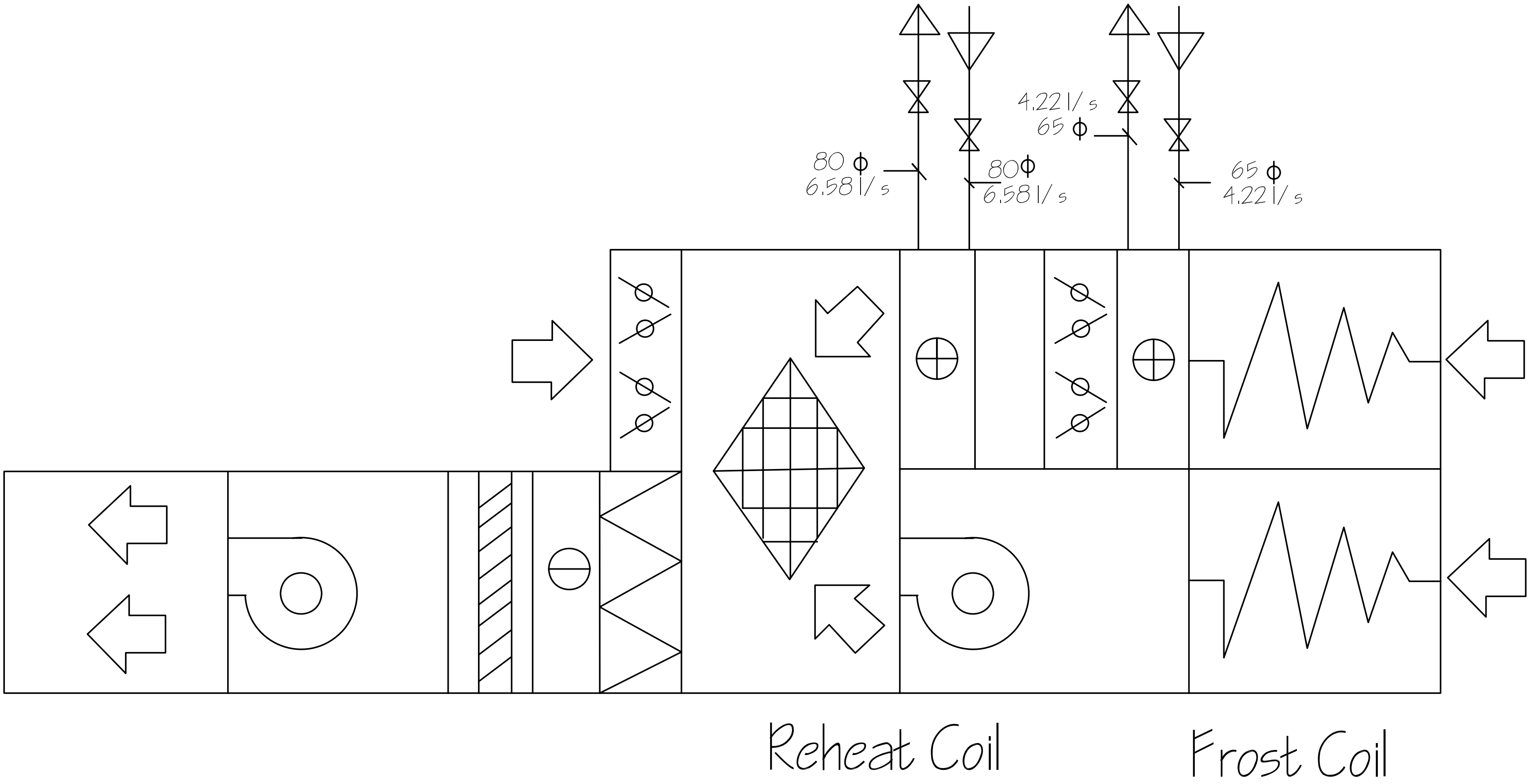
Mechanical Schematics



Boiler Plant Schematic



Chiller Plant Schematic



Typical Flow through AHU