QMUL

Francis Bancroft Building

Engineering Review

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Ove Arup & Partners Ltd
13 Fitzroy Street
London
W1T 4BQ
United Kingdom
www.arup.com

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		Name	Barry Austin	Mike Summers	Barry Austin
		Signature			
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		Name	Barry Austin/ Martin Shouler/Mike Summers	Mike Summers	Barry Austin
		Signature	[redacted]	[redacted]	[redacted]
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Executive Summary

As part of QMUL Legacy Project programme to restore existing buildings in their estate to a fully functional condition to meet the teaching and research demands now and into the future, Arup were commissioned in March 2017 to carry out an engineering review of the Francis Bancroft Building (FBB).

The FBB has history of poor performance with occupants regularly complaining of ill health and poor thermal comfort conditions that they believed to be caused by the building and its internal environment.

Our approach was to first establish a full appreciation of these complaints to define the nature of the problems and their prevalence in the building. This was followed by testing for air and water borne contaminants to identify what may be triggering the symptoms – carried out by RSK, an accredited testing laboratory. With the results of the RSK survey in hand, the engineering review could then focus on how the possible transmission paths that may be communicating the contaminants to the occupants and so, in turn, be mitigated.

The Original Building Design

The building was originally designed as a medical school with the majority of the space arranged in larger teaching and research laboratories. The building is now used by a wide mix of departments ranging from the School of Business and Management (SBM) to the Geography Laboratories whilst retaining the Medical and Dental Schools.

These changes have been accompanied by a greater occupancy density imposing additional stresses on the building. For example, the SBM staff numbers have increased from 36 in 2011 to 85 in 2017 whilst student numbers have increased from 850 in 2013 to 1800 in 2017.

The original heating ventilating and air conditioning (HVAC) system was designed as warm air mechanical ventilation system for winter operation with mechanical cooling only installed in specialised spaces. The critical factor in understanding how this building performs is the fact that large proportions operate without mechanical cooling. Thus the summertime temperature will swing in-line with outside air being mitigated only by the use of natural ventilation with openable windows.

Occupant Satisfaction

An occupant survey was carried out amongst the full time staff who use the building employing the internationally recognised BUS Methodology. The methodology allows a quantitative analysis of occupants’ subjective response on matters such as health, well-being and comfort. It also allows these responses to

be benchmarked against a national database of results to gauge how good or poorly the building is performing against statistical benchmarks drawn from 850 previously surveyed buildings. The approach also solicits an individual's comments which is also a rich source of information of how the building users see the building.
The building scored poorly across the 49 key variables placing it in the bottom 3 percent of buildings in the national database. The main problems cited by the occupants were:

- greater occurrences of colds, flu and respiratory problems
- allergic reactions
- headaches triggered by working in the building
- poor thermal comfort: too hot in summer, too cold in winter
- poor aural comfort: areas of the building where noise generated by air movement
- poor air quality and odours
- systems impacts on teaching activities
- frequent blockage and flooding of toilets on many floors
- poor cleanliness of the building
- over-crowding

The complaints were mapped out and whilst it was clear that there was a general malaise that affected the entire building there were particular areas where complaints were concentrated such as 1st floor north offices, 2nd floor north offices and 4th floor Business School.

In addition to the occupant survey interviews were held with department heads to understand better how the various parts of the building are used and how they will be used in the future.

Contaminant Testing

Testing for air and water borne contaminants was carried out by RSK to find if there was a clear link with physical symptoms being experienced by the occupants. An exercise of detailed monitoring was carried out between May and June 2017 to establish the presence of and concentration of:

- gaseous pollutants
- dusts deposited in occupied spaces and in air distribution systems
- micro-biological contamination
- allergens
- water quality

There were traces of gaseous pollutants such as formaldehyde, benzene, and ammonia found but at low concentrations significantly below the HSE workplace exposure limits (WELs). Similarly there were levels of mouse and dust mite allergens detected but again below the level at which sensitisation of an individual is expected to occur. The air distribution systems were tested and found in some instances to have an accumulation of dirt that supported micro-biological populations of Aspergillus and Pencillium which are capable of producing allergic reactions in sensitive individuals.

The results showed that although there were traces of substances that would be controlled under the COSHH regulations the concentrations were an order below the exposure limits that are deemed to constitute a risk to health.

Engineering Review

The engineering review was carried out on air and water distribution systems to establish:

- the adequacy of the capacity of heating, cooling and ventilation systems
- the condition of plant and equipment and its remaining serviceable life;
- the adequacy of the BMS and control of systems;
- the adequacy of the drainage and waste systems;
- the existence of transmission paths for contaminants to enter the occupied space.

Summarising our findings:

Main Air Handling Plant

- System cleanliness was poor with dirt build up in air intakes, and fouled heating coils;
- Air filtration frames by-passing or filters poorly installed rendering filters ineffective;
- Corroded casings principally on the supply air AHU sections
- Major fans isolated because of component failure or because of noise problems in teaching spaces, resulting in poor ventilation effectiveness;
- Poorly adjusted fan belts slack, slipping and fragmenting reducing ventilation air flow
- Air volumes measured were generally lower than the design requirements;
- Failure to regularly change filters reducing ventilation flow rate and disturbing pressure regimes in the building (e.g. extract filter blockage on AHU13 results in the space becoming positively pressurised and heightens the risk of odours migrating to the 4th floor)
- AHU13 & 14 exhaust air discharges in close proximity to fresh air intakes which under prevailing wind conditions will permit

short circuiting of exhaust air from 5th floor back into the fresh air supply of AHU02 and 03;

- Fume handling systems have positively pressurised discharge ducts downstream of the fan but still within the roof plantroom risking of leakage into the plant space.

BMS and Control Systems

- BMS system obsolete no longer supported by its manufacturer making spares difficult to source
- Control system poorly calibrated impacting on the systems' ability to deliver stable comfort conditions

Space Heating System

- The central boiler plant is in reasonable condition following refurbishment in 2008 together with the replacement primary and secondary pumps at the same time the plant should have at least another 10 years serviceable life;

- Room heating is carried by perimeter sill-line finned tube coils with no local control; flow temperature is modulated against outside air temperature - this is not ideal for cellular space with variable internal loads.

- DX cooling systems have been installed in spaces with high equipment loads such as language laboratories but operate independently of the space heating system controls leading to energy waste as one system fights another.

Waste Water Systems

- Under the new occupancy loads imposed upon this building there is an under provision of toilets in the building leading to greater maintenance demands and greater risk of blockage and flooding;
- Soil and combined waste vent pipes terminating in the vicinity of openable windows leading to ingress of foul air and odours. (the vent pipes adjacent to 4.23 and 4.24 have been extended up above the roof line and have shown improved conditions in the rooms where there were complaints of foul odours.

Critical Factors

From our investigation of FBB there were four critical factors affecting the way in which the building performed:

1. **Ageing and obsolete plant and equipment** - The majority of the central plant, distribution systems and controls are almost 30 years old and so have reached the end of their serviceable life and under any circumstances would require some measure of replacement, refurbishment or upgrade.

2. **Ineffective planned maintenance** – maintenance has been poor which has led to a deterioration in the physical condition of the plant and equipment and has subsequently impacted upon the building's performance

3. **Increased occupancy density** – in some departments such as the School of Business and Management the academic staff and student numbers have doubled in the last 7 years.

4. **Cellularisation of space** – spatial layout changes of larger open plan spaces have been changed to smaller cellular offices and seminar rooms without accommodating these changes in the heating, ventilating and cooling. The space changes in the past have been carried out in an ad-hoc way without reference to the wider impact on heating, ventilation

Action Plan

The action plan to rectify the defects found in this investigation will depend upon the strategic direction QMUL wish to pursue with the building particular in light of other developments on the site (e.g. possible move of the SBM to a new building in 2021).

The decision will therefore be to:

1. Rectify the problems in the existing systems – to make what is installed operate as originally intended with repair, refurbishment and upgrade. – this could be carried out keeping the building operational

2. A radical change to the systems to match the demands of the various academic departments now using the building using under significantly increased occupancy – vacant possession of some areas of the building will be necessary.

Option 1 - If the existing systems are to be brought up to a fully operational state then the following measures would be proposed.

HVAC Systems

- Refurbishment of AHUs including end of life replacement
- Decentralised HVAC for cellular space plan – e.g. local control of perimeter heating
- Intrusive inspections of the condition of the heating pipework
- Blanking of fresh air inlet adjacent to AHU13/14 discharge or otherwise limiting recirculation
- Duct cleaning
- Re-balance against a recalculation of design air loads.
- Air containment between 5th and 4th floor – remedial works to minimise air migration from 5th to 4th floor
- Fume cupboard sealing of positive pressures
- BMS upgrade to a Trend IQ4 generation of controllers to be consistent with policy across the QMUL Estate
- Night purge when the ambient temperature allows to freshen-up the spaces before occupancy late spring, summer and early autumn.
- Inter-locking of heating and mechanical cooling in those spaces where DX cooling has been fitted to avoid heating and cooling operating simultaneously.
- Addition of sub metering of principal loads to allow better energy management of the FBB.

Waste Water Systems

- Extension of soil and combined waste vent pipes above roof lines on south façade as carried out on north
- Review of toilet provision for current occupancy and how the building will be used into the near future;
- Inspect and repair toilet waste water systems where there has been history of blockage and flooding. e.g. clearing of uric crystal build-up
- Verify that water traps on waste pipes are effective and not dried out.

Electrical Systems

- Consideration of improving the electrical resilience of the building including installing a bus-section switch and reviewing those parts of the system that need support from the essential supplies (e.g. diesel generator)

1 Introduction

Queen Mary University of London (QMUL) appointed Ove Arup & Partners to carry out an engineering review of the systems in the Francis Bancroft Building (FBB). This review was one of several that QMUL have commissioned to address operational problems in their principal buildings. The investigation also addressed a number of complaints from building users of ill health and discomfort experienced in the building.

The work was carried out between March and September 2017 with the aim of identifying what were the main causes of the poor internal environmental conditions and, importantly identify what remedial work is necessary to bring the building back into a fully operational condition.

The building has had a history of poor performance with anecdotal evidence of occupants experiencing colds, flu, allergic reactions which they attributed to the building and poor thermal comfort.

Health and Safety, Estates and Facilities and Occupational Health teams were aware of staff concerns about the Frances Bancroft Building and wanted to conduct a full and detailed analysis the engineering systems to establish the nature of the health impacts and prevalence in the building.

This report should be read in conjunction with the associated document bundle which contains the full text and data from the BUS Occupant Satisfaction Survey and the RSK Gaseous and Particulate Contaminant testing.

1.1 Building Analysis: Method Statement

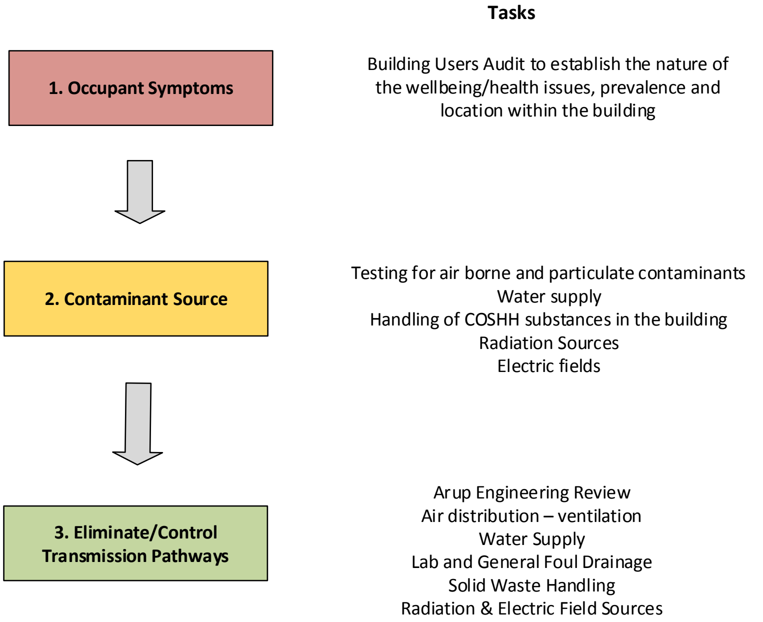
In order to identify any cause of health problems in FBB three elements in the chain must be understood and then dealt with. These steps are as indicated in Figure 1.1 - identify occupant symptoms, the contaminant source and then deal with transmission path to mitigate the situation. In this instance, any contaminant sources and any impact on building users health (receptors) would be established first to inform the site investigation of any potential transmission paths.

Once this process chain is identified, measures to eliminate or control any contaminants can be implemented. Elimination of any transmission paths is the main focus of the Arup engineering review. Elements 1 & 2 needed to be identified before site investigation could commence.

1.1.1 BUS Methodology – Occupant Survey

An occupant satisfaction survey was carried out using the Building Use Studies methodology (BUS) to identify the nature of the complaints of ill health and discomfort and where it was occurring. The data would establish if there was indeed any link between the health complaints and building or were they the same as one would find in the general population at large.

Figure 1.1 Sequence of investigations at FBB



1.1.2 Contaminant Testing

RSK are a UKAS certified test laboratory who were appointed by QMUL to carry-out survey and testing for air borne pollutants, allergens, micro-biological contaminants in the occupied spaces and in the water and air distribution systems. The results from this exercise informed where the engineering review should be focussed.

1.1.3 Engineering Review

The engineering review examined the following aspects of the building services to explain how the identified contaminants are getting from source to the occupants. Table 1.1 summarises the transmission paths the site investigation focussed on:

- Air Supply
- Water Supply
- Waste Water
- Solid Waste
- Toilets

The site investigation worked through the list of transmission paths in a systematic way eliminating those which were found to be 'clean' and identifying those which pose a risk so that action can be taken.

Table 1.1 FBB Investigation of Possible Transmission Paths

Potential Source of Contaminant	Areas of investigation
Air	• Fume handling containment • Short circuiting of discharges to AHU fresh air intakes or opening windows • Ductwork leakage • Ductwork cleanliness • Air transmission between spaces • Contaminated dusts in the space
Water Supply	• Backflow contamination • Water chemistry and micro-biology • Creation of contaminated aerosols
Waste Water	• Effectiveness of backflow protection on foul and lab drainage • Blood wastes • Effectiveness of dilution pots • Stack vents and cross contamination paths
Solid Waste	• Clinical waste handling • Biological waste handling
Toilets	• Hygiene Factors

2 Description of the Building and Systems

The FBB was completed in 1990 and is used by a mix of University teaching and research departments. It has a concrete frame with brick infill with 40% double ‘ribbon’ glazing which is openable for natural ventilation, see Figure 2.1. It is arranged over 6 storeys – ground to 5th floors with a roof top plantroom running the building length.

Figure 2.1 Francis Bancroft Building South Façade

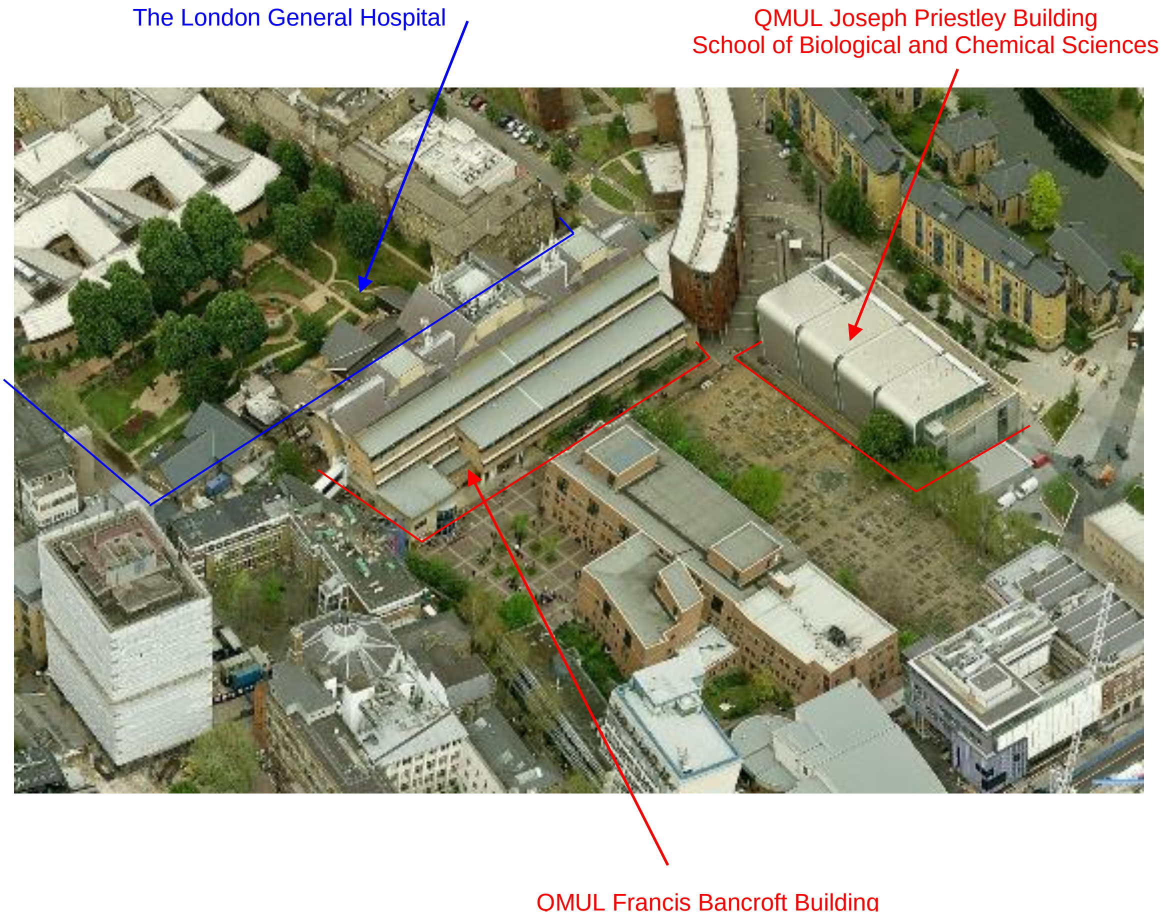
Occupied spaces are arranged either side of a central spinal corridor, see Figure 2.2 which shows as an example the 4th floor plan and Appendix A for all floors

Figure 2.2 Typical Floor Plan (4th Floor)

It can be seen from this typical floor plan that a lot of the spaces are arranged as small cellular spaces which have been converted from the original larger lab spaces to meet a changing demand of the building users. The conversion to small cellular space has highlighted some of the limitations of the existing heating and ventilation systems to control individual space conditions.

The adjacent buildings are shown in Figure 2.3 where the London Hospital is on the north boundary and the School of Biological and Chemical Sciences in the Joseph Priestly Building (JPB) to the east. The two central fume handling system discharges in the JPB are located on the north-west elevation adjacent to the FBB

Figure 2.3 FBB Environs



2.1 Building Use

The building started life as the Medical Building but now accommodates the following departments as detailed in Table 2.1. The activities and operational history for each of these departments are discussed more fully in section 3.0.

Table 2.1 FBB University Departments

Floor	Department	Activity	Area m²
Ground	Turnbull Centre (Medical School) NanoVision Microscopy	- Dissection Suite, - Mortuary - X-Ray Laboratories - AV Suite - Electron Microscopy Rooms - Teaching Rooms - Meeting Rooms - Offices	2570
First	General Teaching	- Teaching Rooms - Language Laboratories - Lecture Theatre - Offices	2910
Second	Dental Physics Department Geography Department	- Chemistry Laboratories - Geography Lab - Dental Laboratories - Offices - Teaching Rooms	2170
Third	Business School General Teaching	- Disability Teaching Space - Meeting Rooms - Teaching Rooms - Offices	1545
Fourth	Business School	Teaching Rooms - Lecture Theatre - Offices	1465
Fifth	SMD	- Research Laboratories - Offices	1112
Total			11,772
Roof	Plantroom	- Main AHUs - Boiler Plant - Tank Rooms - Lift Motor Rooms - Chillers - Fume Handling Fans	1112

3 Operational History

The operational history of the various departments that occupy the FBB are discussed below. This evidence has been gathered from interviews with department managers and comments made in the occupant satisfaction survey completed by permanent staff who have worked in the building for several years

3.1 Turnbull Centre (Medical School)

The Medical School is accommodated on the ground floor in the Turnbull Centre (TC) where the Dissection suite, Anatomy and Mortuary are located. There are no fume cupboards but the spaces have mechanical extraction systems ducted into dedicated ventilation systems. Substances used in the Department include:

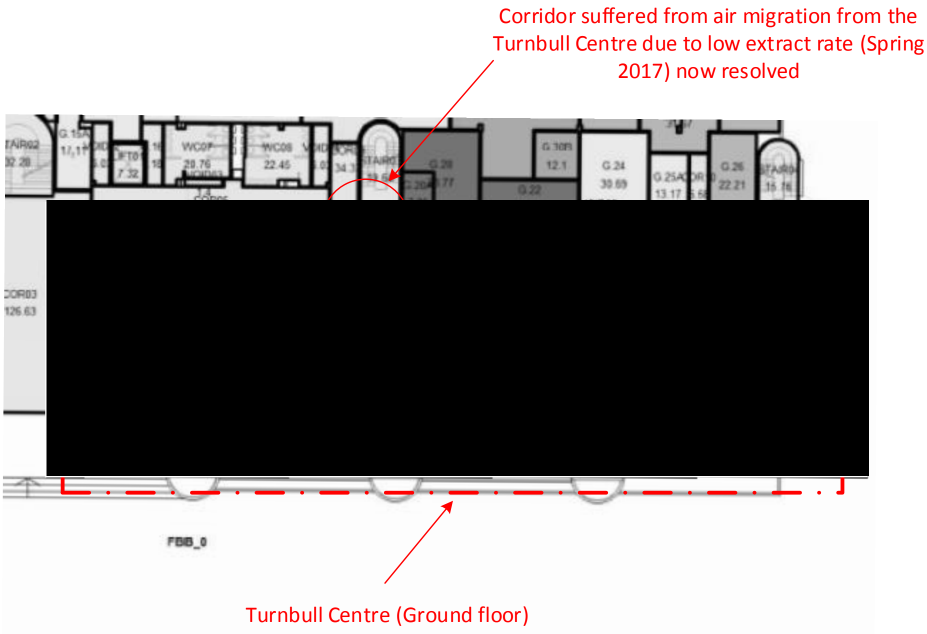
- Methanol
- Formaldehyde based embalming fluid.

A Phenol-chloroform mixture was used until 3-4 years ago, but has been disposed of via external haz-chemical / solvent waste contractor off site.

The Dissection and Embalming Suites (Mortuary) where cadavers are stored and used in the Anatomy and Clinical for both teaching and research purposes. A dedicated full fresh air handling unit , AHU 11, serves these spaces, see Figure 6.4.

The general arrangement of spaces in the Turnbull Centre is shown in Figure 3.1. The Anatomy section deals with dissected body parts and are kept below general internal occupied space temperatures as indicated.

Figure 3.1 Turnbull Centre Layout

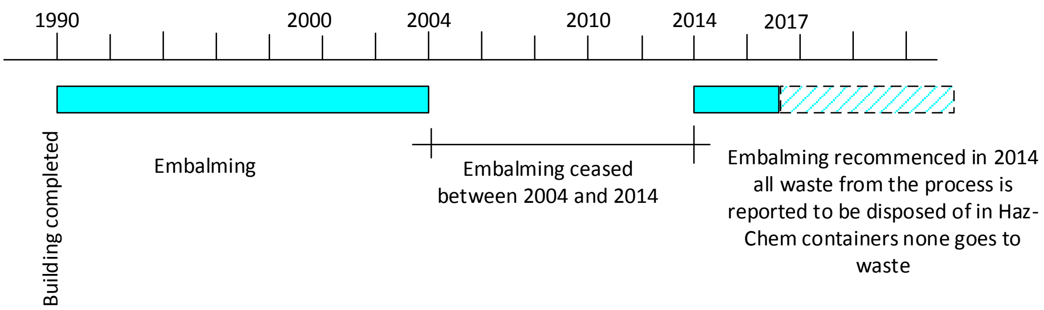


There were problems with the pressure regimes identified between the TC and the adjacent corridor where there was migration of odours. The cause of this was a partially closed damper on the exhaust air which the FM team have now rectified restoring a negative pressure in the TC in relation to the adjacent spaces. The complaints of odour migration have now ceased.

There were reports that there was some occasions of temperature instability hot in summer and cold in winter but it was not a chronic problem.

It was reported by the Department Manager that embalming activities ceased during the period 2004-2014 and recommenced in 2014, see Figure 3.2. The quantities of formaldehyde that are used in these activities are small - typical concentrations in TC were recorded at 0.4 to 0.5 ppm compared a WEL standard of 2ppm.

Figure 3.2 Embalming Activities in the Turnbull Centre



The FM team noted that there are occasional call-outs to unblock a fouled floor gulley in the Embalming suite.

3.2 NanoVision

The NanoVision department is located on the ground floor [redacted] The department essentially consists of instrument rooms which accommodate high resolution electron microscopes, see Figure 3.3.

Figure 3.3 NanoVision General Arrangement.

[redacted]

The Department is served off the general ventilation system delivered by AHU04 which is a mechanically ventilated warm air supply plant with no mechanical cooling. This is supplemented by local DX split air cooling systems in high heat gain spaces.

The Department has a low occupancy – 2 permanent staff but there are a lot of 'transient' occupants who utilise the instrumentation in the evening and weekends. The department contains two fume cupboards that deal with small quantities of organic solvents, acids and heavy metal salts.

The principal problems were reported by the Department Manager as being temperature stability in laboratory G.26 and the lack of a potable water supply. Interestingly, there were no complaints of odour migration from the Turnbull Centre that is located opposite that were noted by other building users.

3.3 First Floor – General & Language Teaching Spaces

The first floor accommodates lecture theatres and general teaching spaces as well as language Laboratories. There were general complaints relating to poor thermal comfort in these spaces throughout the year from occupants who experience extremes in internal temperatures.

There were a number of general health complaints raised on this floor – headaches and sickness. Poor control of air temperature too cold in winter; too hot in summer, and poor ventilation The cleanliness of the toilets was raised as an issue as was the frequent flooding from the toilets, see Appendix B.

3.4 2nd Floor General Teaching Spaces

The 2nd floor accommodates the Dental Physics Research and the Geography Teaching Laboratories. Both facilities use various chemicals and solvents in the course of teaching and research activities. QMUL working practices dictate that hazardous chemical stock solutions are not disposed of down drains.

There were general complaints of lack of thermal control and poor ventilation on the 2nd floor which was linked by occupants to impacts on health – viral infections and headaches. The frequent flooding of toilets was also raised as an issue.

3.5 Geography Department

The Geography Department is located adjacent to Dental Physics on the 2nd Floor, see Figure 3.4. The department is made up of general teaching spaces, laboratories and offices for academic staff. There are 35 permanent staff in the Department.

Figure 3.4 Geography Department General Arrangement

The Geography Department is served by the two general ventilation systems from AHU03 and AHU04, see Figure 6.4. Both of these systems are full fresh air, no recirculation with heating but no mechanical cooling. Part of the General Teaching space is served from AHU02 with a duct that runs in from the Dental Physics Department and feeds two VAV boxes. These boxes have been both been blanked off due to the 'dirty' air supply introducing dust into the space.

DX split cooling systems are fitted in some of the Laboratories but there are still complaints of poor thermal comfort throughout the year.

The Laboratories contain 8 fume cupboards – substances are typically used in small volumes and amounts of a few ml or mg to grammes quantity solutions during experiments. No industrial or 'scale-up' volumes are handled. A variety of laboratory salts, biochemical substances may also be used as required in a fume cupboard. Typically, this would include:

- Corrosive acids – nitric acid, hydrofluoric acid, sulphuric acid, phosphoric acid
- Corrosive alkalis – sodium hydroxide
- Flammables / solvents: acetone, acetonitrile, methanol, ethanol, hexane, petroleum spirit, tert-butyl alcohol, toluene
- Formaldehyde, phenol, hydrogen peroxide
- Uranyl acetate (radioactive)
- Lead and Lead Nitrate solutions
- Aluminium oxide and copper turnings

Room 2.22 accommodates two Induction Coupled Plasma (ICPs) incinerators that are both connected to a local extract system that does not have sufficient capacity to operate both at the same time.

3.6 Dental Physics Department

The Dental Physics Department is located on 2nd floor, see Figure 3.5 and is served by the supply and extract air delivered by General AHU02. This is a mechanically ventilated, warm air system with no mechanical cooling. Some of the Department is supplemented with DX Cooling systems to maintain a required condition between 20°C to 24°C.

The Department is active throughout the year and the period between April and August is often the busiest period with research activities carried out by PhD and Masters students.

The department Manager reported occasional heating problems and drain blockages in Lab1 principally caused by glass material going down the sink. Glass powders are generated following furnace treatment of specimens.

One major requirement was to have better separation between the academic offices and the Laboratories.

Figure 3.5 Dental Physics Department

The Laboratories use fume cupboards but substances typically are used in small quantities, as noted for the Geography Laboratories. Substances that are handled in the Laboratories include:

- Flammables / solvents:2-methyl-3 butyn 2-ol, Acetone, Acetonitrile , Alcohol, Butanone, Chloroform, Choramine T, Cyclohexane, Ethanediol, Ethanol, Ethyl-alcohol, Ethylene Glycol, Industrial methylated spirit, Petrol, Propan-2-ol, Tetrahydrofurfuryl, Toluene, Trichloroethylene

- Formaldehyde, Glutaraldehyde, Glutardialdehyde

- Corrosives: Ammonium hydroxide solutions, Ammonia solution, Sodium azide (NaN3)

- Inorganic acids
    - Sulfuric acid (H2So4)
    - Hydrochloric acid
    - Nitric acid
    - Orthophosphoric acid
    - Perchloric acid (HClO4)
    - Phosphorous pentoxide

- Organic acids
    - 5-Lodosalicylic Acid
    - Acetic acid
    - Acrylic acid
    - Amyl acetate
    - Citric acid
    - Ethyl acetate
    - Maleic acid
    - Methyl-salicylate
    - Para-toluenesulfonicacid-monohydrate
    - Ronacare-Olaflur
    - Trifluoroacetic acid
    - Vinyl acetate

In addition, there are sealed radioactive sources for X ray equipment.

3.7 Third Floor (SBM)

The third floor consists of general teaching spaces and offices for academic staff which are largely used by the School of Business and Management (SBM). The activities of SBM are dealt with in section 2.2.6 that deals with the 4th floor and the SBM in its entirety.

General complaints on the third floor cite the poor temperature control and inadequate ventilation in teaching spaces and offices.

3.8 4th Floor School of Business and Management

The 4th floor accommodates the main teaching spaces and offices for the School of Business and Management (SBM). The 4th floor was the seat of a large proportion of health complaints. The policy of the SBM for research staff is cellular offices rather than open plan which has led to the installation of increasing amounts of partitioning without necessarily modifying heating and ventilation systems to match.

The SBM has highlighted a significant factor which ‘stresses’ the use of the building spaces and the systems that serve them and that is the growth in both staff and student numbers. Academic staff in 2011 numbered 36 this has now increased to 85. In parallel with that, the student body has increased significantly:

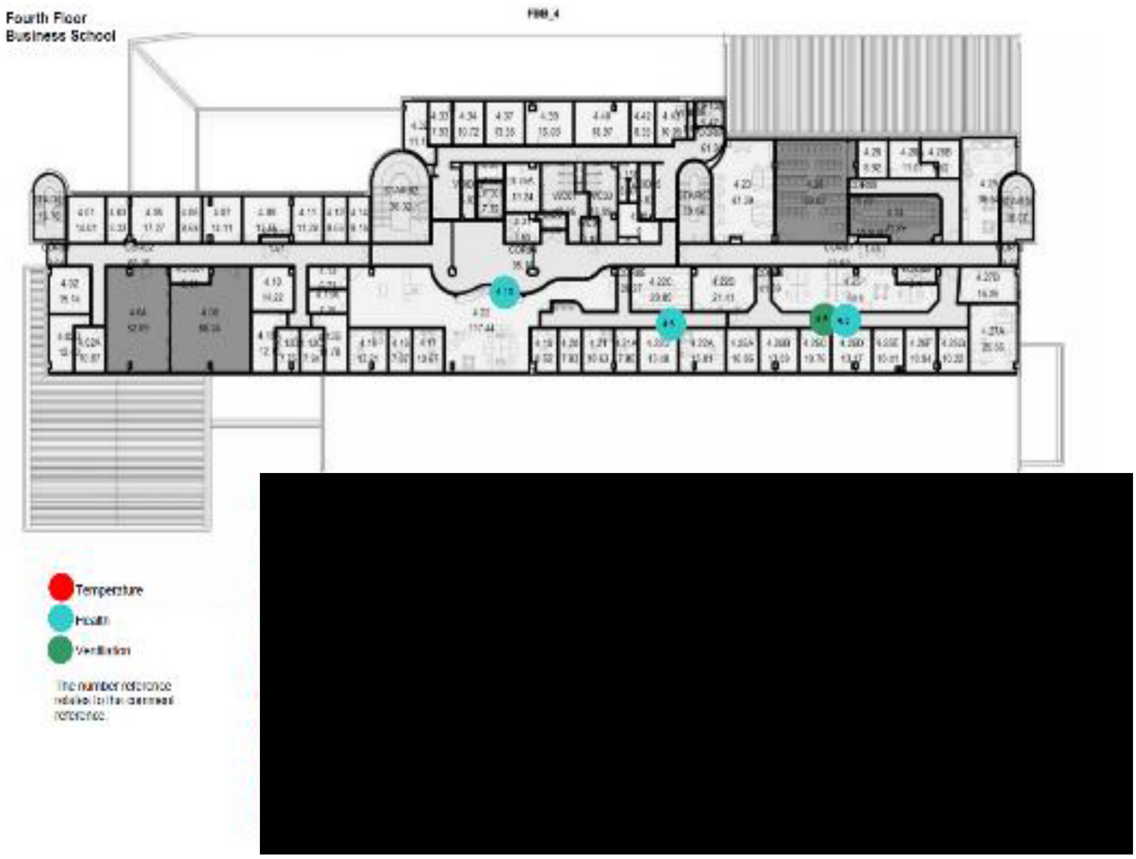
2013 - 600 undergraduates + 250 post graduates

2017 – 1100 undergraduates + 700 post graduates

This rapid growth of SBM student numbers has led to more space being sought on the 3rd floor and with a plan to move eventually into a new building proposed for where the Temporary Teaching Building is currently located in 2021.

The general malaise of poor thermal comfort and poor ventilation is evident but there was also a greater concentration of complaints of poor health too - complaints of headaches and respiratory problems are commonplace, see Figure 3.6.

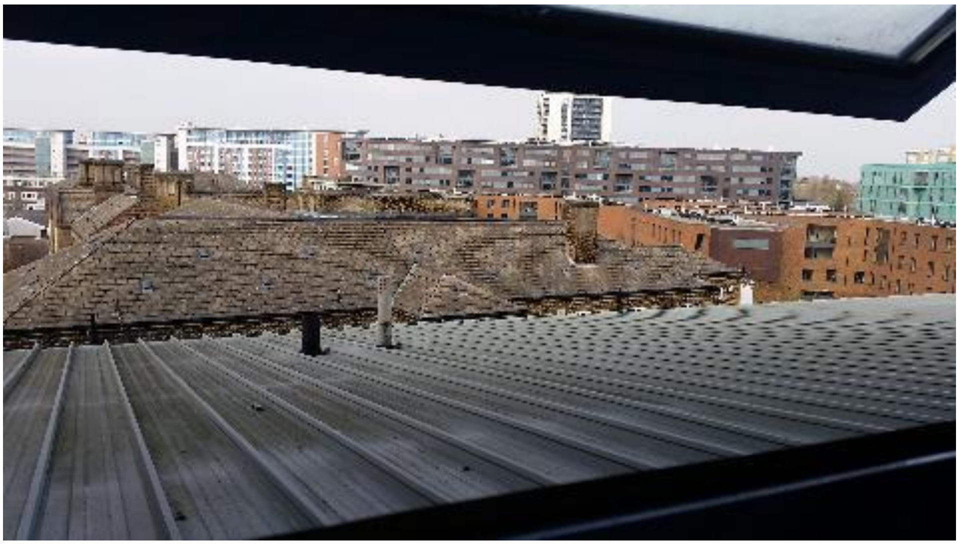
Figure 3.6 4th Floor School of Business and Management – Complaints Map



[redacted]

An open letter from FBB building users highlighted the problems in room 4.23[1] where reports of ill health have been reported for several years. They reported “a strong smell formaldehyde or ammonia and manure”. This room was vacated earlier in 2017 whilst works were carried out on the soil vent pipes immediately outside the openable windows, see Figure 3.7.

Figure 3.7 Soil Vent Pipes Adjacent to Room 4.23 Openable Windows (pre modification)



These soil vent pipes have now been extended above the roof-line and the room now has been re-occupied with reported improved air quality, see Figure 3.8.

Figure 3.8 Soil Vent pipes Extended above roof line (Spring2017)

The testing of air borne contaminants by RSK (see section 5.0) in Rooms 4.23 and 4.24 show residual concentrations of pollutants such as formaldehyde and ammonia but considerably below the HSE Workplace Exposure Limits (WEL) ,

[1] Open Letter from FBB Academic Staff 27/07/2017

see Table 3.1. This testing conducted in late spring of 2017 when there was dissection activities taking place in the Turnbull Centre to ensure data was collected under normal use of the building. The SBM has also suffered from insect infestation particularly in 4.22A on the south façade.

The SBM on both the 3rd and 4th floors is served by the 4 main general ventilation delivered by AHUs 01, 02, 03, and 04 as the Department occupies the whole floor footprint. All of which provide warm full fresh air with no mechanical cooling. The spaces in the SBM attract the same criticism of poor temperature control and poor ventilation throughout the year particular the in-board spaces such as 4.25 (The Glasshouse)

Table 3.1 Test Results for Contaminants in Rooms 4.23 and 4.24

Exposure Limits	**Formaldehyde** µg/m³ WEL 2500 µg/m³ WHO 100 µg/m³	**Ammonia** µg/m³ WEL 18000 µg/m³	**Benzene** µg/m³ WEL 3250 µg/m³	**Pest Allergens** ng/g of dust Heightened risk of sensitisation 2000 ng/g	**Dust Mites Allergens** ng/g of dust Heightened risk of sensitisation 2000 ng/g
Room 4.23	5.62 µg/m³	22.66 µg/m³	5.3 µg/m³	35 ng/g	74 ng/g
Room 4.24	6.67 µg/m³	11.83 µg/m³	<0.9 µg/m³	1089 ng/g	55 ng/g

3.8.1 5th floor

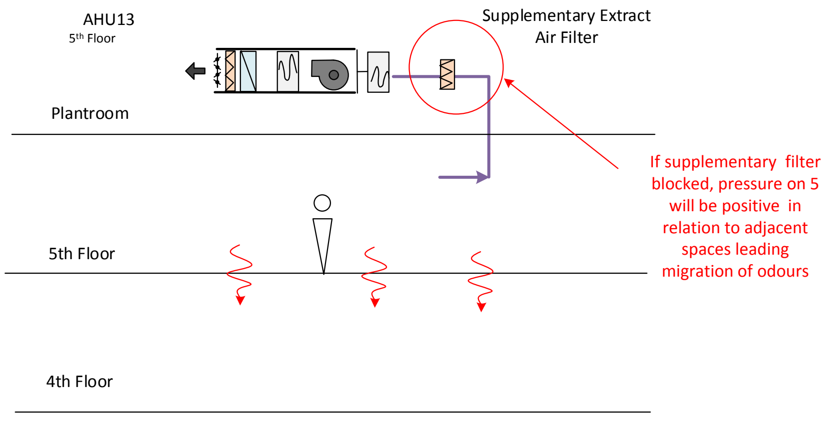
The 5th Floor spaces are served by the close control AHUs 12, 13 &14 that provide not only heating, but mechanical cooling and humidification too.

Figure 3.8 5th Floor

The branch ducts have reheat batteries fitted to give ‘trimming’ temperature control of individual spaces. It was reported by the department Manager that these reheat batteries are inoperative resulting in poor temperature control particularly in summer.

The supply air produces dust staining at the supply outlets suggesting that the central filters are clogged or by-passing. The extract from the 5th floor has an inline supplementary filter in the roof top plantroom that when left in a ‘dirty’ condition results in a significant reduction in air flow and a disruption to the pressure regimes leading to migration of smells into other parts of the building, see Figure

Figure 3.9 Possible Route of Air Migration from 5th to 4th Floor



It was also reported that when the cage wash dumps water at the end of a cleaning cycle this has led to flooding of the drainage system further down the building. This has been subsequently remedied by reducing the maximum flow rate from the cage wash-down and aquarium discharge.

Ducting / drains from autoclave cage washer room can contain residues of corrosive disinfectant other chlorine based disinfectants have been used in the past. Fish tank rooms can contain residues of Virkon (disinfectant) in floor drains. In the ducted microbiological safety cabinet (5.07) – no hazardous chemicals used.

4 Occupant Satisfaction Survey

In order to establish the nature of the complaints and the prevalence in the building a systematic survey was carried out using the internationally recognised Building Use Studies (BUS) Methodology, see ref[2]. This approach allows the subjective responses of occupants to health, wellbeing and comfort to be benchmarked against the national database (2014 UK non-domestic benchmark set).

The occupant satisfaction survey was conducted over the period 27/03 to 7/04/17. There were 77 full time staff responses to the questionnaire that was administered both in paper version and web–based:

- Paper questionnaires – 36 responses,
- Web based questionnaires - 41 responses

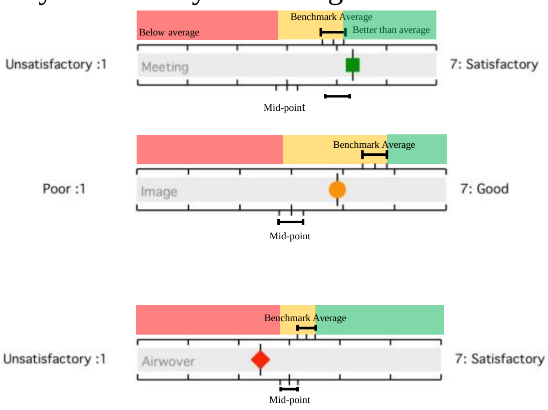
The results confirm the anecdotal evidence that this building was perceived as poor over most of the performance indicators of comfort health and wellbeing. It scored consistently in the bottom 5% of buildings when considering the 49 core performance variables in the national database.

On the specific question of whether occupants had sought medical help for health issues triggered by their work environment 26% of the sample said that they had. The type of health effects cited ranged from allergies, headaches, greater occurrence of colds and flu to isolated cases of urinary tract infection (UTI) and irritable bowel syndrome (IBS). In addition the poor standard of cleanliness in the building was another recurrent complaint.

4.1 Summary of Survey responses

The full results are in Ref1 in the accompanying document bundle to this report. A summary of the building scores are shown in Figure 4.1- scoring lower than the national database benchmark on the majority of the summary indicators.

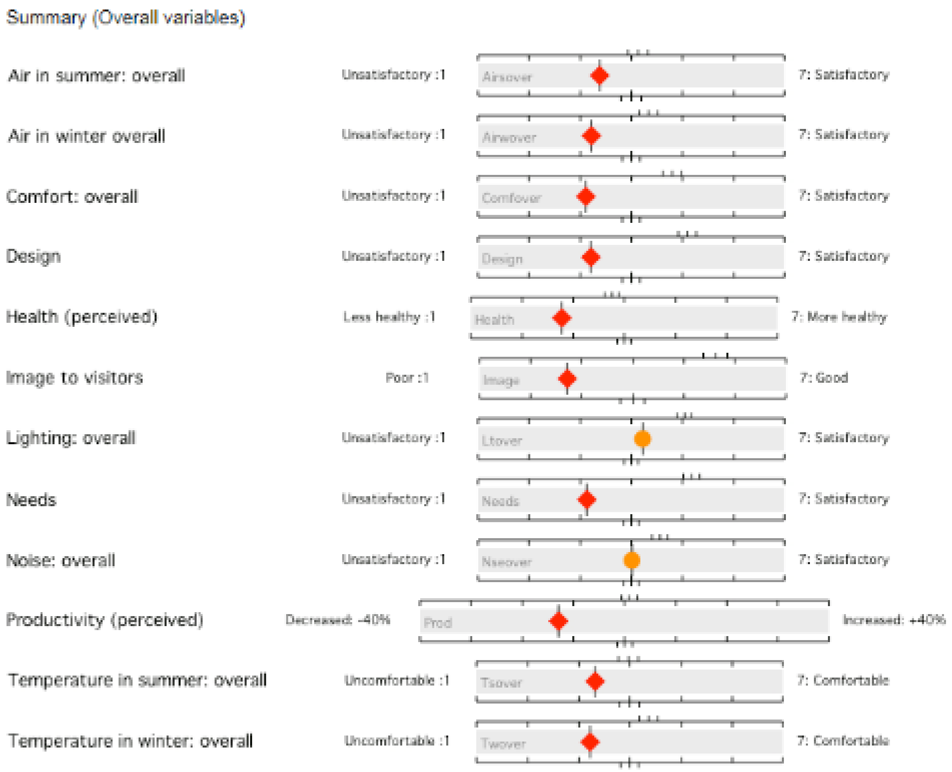
Key to summary slider diagram



- The ‘mid-point’ in these slider graphics represent a neutral response.
- The ‘benchmark average’ relates to the mean result of the benchmark set for this variable.
- A mean result for this building that is more satisfactory/good than the ‘benchmark average’ and the scale ‘midpoint’ is given a green indicator.
- A mean result for this building that is between the ‘benchmark average’ and scale ‘mid-point’ is given an amber indicator.
- A mean result for this building below the scale ‘mid-point’ and ‘benchmark average’ is given a red indicator.

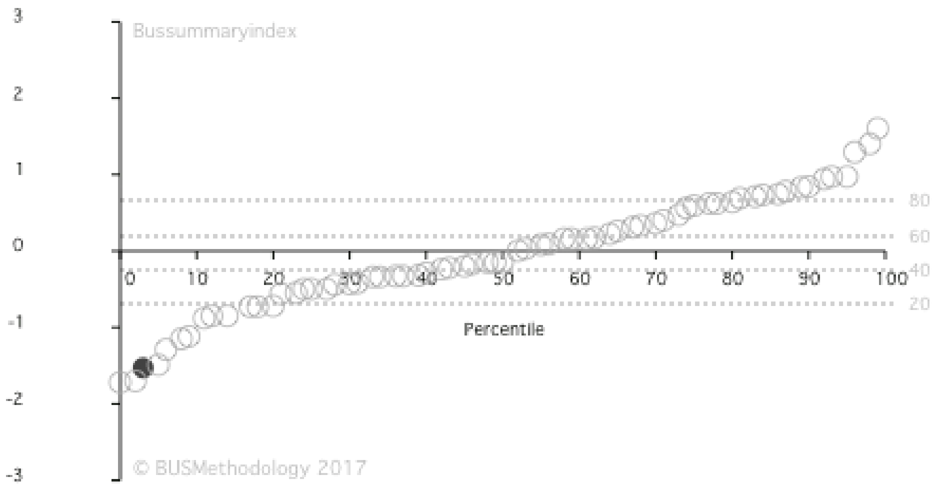
[2] BUS FBB Occupant Satisfaction Survey Report 24 April 2017

Figure 4.1 Summary Performance Indicators for FBB Occupant Survey



The Summary Index is a single overall percentile score, calculated from an average of responses to the 11 summary variables. FBB is at the 3rd percentile compared to the benchmark set of buildings.

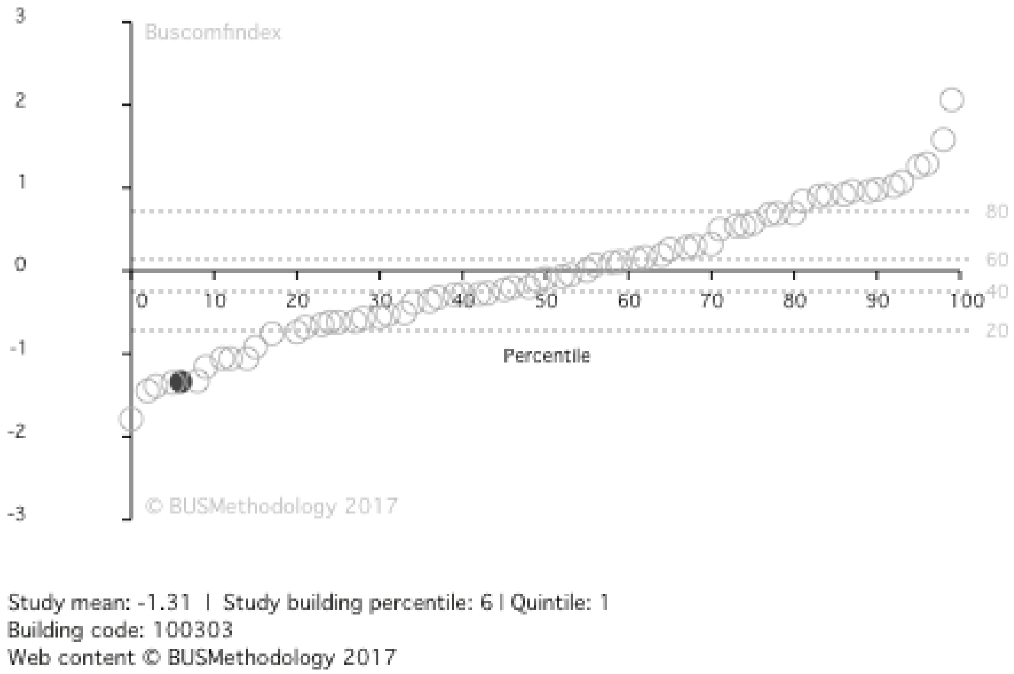
Figure 4.2 Summary Index for FBB



Study mean: -1.5 I Study building percentile: 3 I Quintile: 1
Building code: 100303
Web content © BUSMethodology 2017

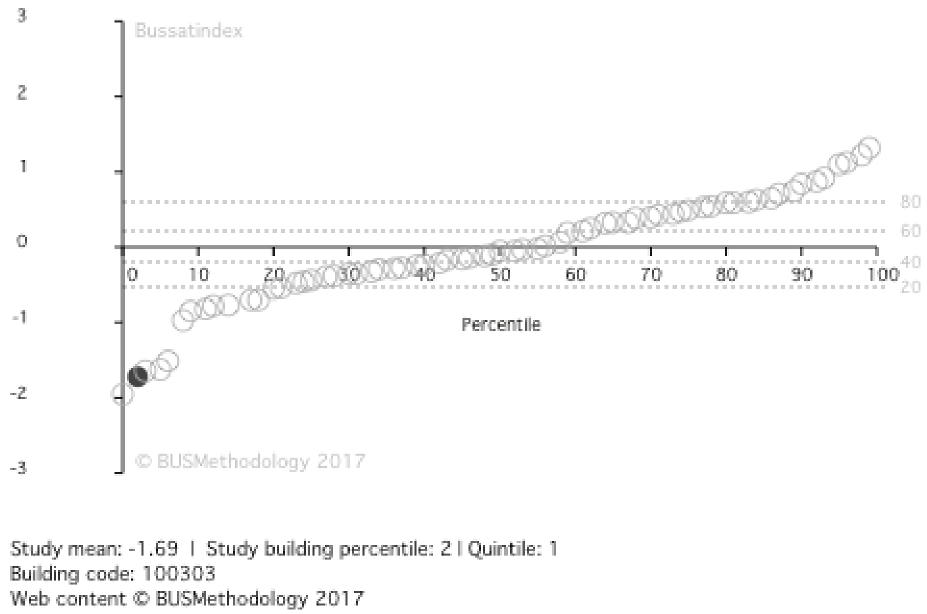
The Comfort Index is a single overall percentile score, calculated from an average of responses thermal, visual and aural comfort variables. FBB is at the 6th percentile compared to the benchmark set of buildings.

Figure 4.3 Comfort Index for FBB



Satisfaction Index is a single overall percentile score, calculated from an average of responses occupant satisfaction. FBB is at the 2nd percentile compared to the benchmark set of buildings.

Figure 4.4 Satisfaction Index for FBB



4.2 Occupant Comments

The staff responding to the questionnaire were also asked “ Have you experienced any health issues that you believe are / were attributed to your work environment? Their responses are listed below:

- Allergies, headaches.
- Apart from cold due to the poor temperature / ventilation control, no.
- As reported by [name removed] to [name removed]; kidney infection, UTI infection, high contagion rate of flu/cold, tonsillitis, allergies
- Asthma may be increased slightly by stuffiness at times
- Constant viral infections, headaches, neck and back pain and frequent coughing
- Dust inhalation and mild headaches from the lights
- FB is so FULL of staff and students that I really do NOT feel safe on the stairs, especially on the full hour when everybody moves around. I am really worried about an emergency, I believe that people will get trampled to death. I am convinced that something must be done about this. I can't believe it's OK as it is. I have uttered this often in conversations with colleagues, and never has anybody disagreed.
- Headaches from hot, dry air
- I have been sick often this year, which is not normal for me. It seems viruses circulate in the room as most of my colleagues were down with the same symptoms
- I suffer from severe IBS symptoms, at various times of the year and I am of the firm opinion that my work environment has contributed to this condition that I suffer from. It concerns me that we do not know what is carried out in all the rooms where as I feel that we should be informed at all times.
- In 2011 I had a constant cough while at work. I have changed desk and this problem has not recurred.
- In the last few winters the lack of heating in my office contributed significantly to colds in the winter. Also, the lack of ventilation and the dry air from the heater could be at times difficult to bear.
- Migraine, stomach problems
- Migraines
- Nothing I've attributed to me work environment
- Stress/back pain. I have already seen occupational health and it has been resolved.
- The windows are filthy and as far as I can see have never been cleaned.
- Whether my current illness is due to too much work and a lot of stress and lack of sleep, or to something in the Bancroft building where I’ve spend a lot of time lately is up for debate, but I've been unable to shake a cough and respiratory issues for almost two months now.
- Yes, coming into work with a slight sniffle; leaving with a full on cold, headaches when heating is too high, general need for fresh air.
- Yes, I get headaches in the building. This is due to noise levels, poor air quality and poor lighting.

- Yes, I think I am catching a cold more often due to ventilation problems I reported about this to my line managers. I have complaints about the same issue from other people in the lab.

4.3 Complaint Mapping

The questionnaire responses have been plotted on floor plans to indicate how the complaints cluster and where the contaminant testing should be focused. These are shown in Appendix B of this report cross reference to spreadsheet *21-04-2017 JBB Occ Comments.xlsx* in the Document Bundle. Whilst there are complaints of poor conditions throughout the building there are 3 distinct clusters of complaints of poor indoor air quality, thermal comfort, and health, these are in areas:

- 1st floor Language Centre North zone offices
- 2nd floor North zone cellular offices
- 4th floor Business School

The 4th floor performs particularly badly with complaints of allergic reactions, headaches, drowsiness being reported. These 3 zones should be the core of the detailed monitoring of dusts and airborne pollutants to be carried out by RSK.

5 Building Contaminant Testing

Detailed testing for gaseous and particulate contaminants was next undertaken with the appointment of RSK to carry-out the following scope of work:

The agreed scope of the assessment was as follows:

- A 'high level' desktop review of likely ambient air quality at the site, and potential nearby sources of air pollution;
- Review of Legionellosis risk assessment and water temperature and
- microbiological testing records;
- Sampling of domestic water services for selected chemical and microbiological analyses;
- Desktop review of plans of HVAC intakes & discharge locations and system schematics, where available;
- Air supply ductwork inspection and sampling for dust and microorganisms;
- A review of basic air quality sampling carried out by the client; and
- Indoor air quality monitoring.

Reference should be made to their report "Investigation of Indoor Air Quality & Environmental Conditions at the Francis Bancroft Building[3] recording test results over the period May – June 2017.

5.1 Report Conclusions

The conclusions from RSK report were:

"RSK Environment Ltd (RSK) has conducted document review, initial inspection and sampling of selected building services, water and indoor air quality in the Francis Bancroft Building, at Queen Mary University of London.

The site would approximate to urban background conditions, and ambient air quality is likely to be similar to that experienced at the nearby monitoring locations.

Domestic the water services in the building appear satisfactory, though some comments and recommendations are made. It is understood that an overall building services review is planned in the near future and a review of water hygiene and Legionellosis control will be included in this process.

Supply AHU had dust loadings which indicated that cleaning would be recommended, and some locations showed evidence of corrosion. The majority of microbiological populations in ducts were low or medium, though some 'high' bacterial results were obtained, and small populations of Aspergillus and Penicillium were present in some samples. These organisms are common and not unusual in ductwork samples, however these organisms may cause allergic responses in sensitive individuals. Single elevated results should not necessarily

[3] RSK Investigation of Indoor Air Quality & Environmental Conditions at the Francis Bancroft Building Report No 442591-01 July 2017

be considered cause for concern, however a more thorough inspection or survey of the air handling systems is recommended.

On the basis of a Building Use Survey carried out by others, and consultations regarding chemicals used in the Francis Bancroft Building, indoor air quality sampling for a range of parameters was carried out.

Concentrations were generally within the normal range and do not exceed relevant Workplace Exposure Limits (WEL) or other guidelines for indoor or ambient air quality. One elevated but sub-WEL concentration of cyclohexadecane was obtained in room 4.23.

The reason for this is not clear and re-sampling is recommended.

Some slightly elevated (but well below the WEL) concentrations of ammonia were measured. The results should be interpreted with care due to the short sampling period, but further sampling is recommended.

On the basis of these results, there is no evidence that air quality in the Francis Bancroft building is unsatisfactory, or that contamination of non-laboratory areas with air from laboratory areas occurred"

5.2 Formaldehyde

Formaldehyde is used in the Mortuary and Dissection suites as embalming fluid for cadavers used in the Dissection Suite and so was of particular interest in these tests. The results showed that:

"Formaldehyde concentrations measured were orders of magnitude below the WEL of 2500 µg/m3 (2ppm) and also below the WHO guideline for indoor air of 100**µ**g/m^3"

The results for various locations around FBB are shown in Table 5.1.

Table 5.1 Summarises the Formaldehyde test results in various locations in FBB

Room	Formaldehyde (µg/m^3)
2.07	20.65
2.08	12.37
1.02.6A	16.56
3.18	3.99
3.20	7.87
3.26	17.85
1.01	4.16
1.22	1.92

Room	Formaldehyde (µg/m^3)
4.24	5.62
4.23	6.67
Plantroom	1.77
1.20	1.85
Outside	2.17

6 Mechanical Systems Site Investigations

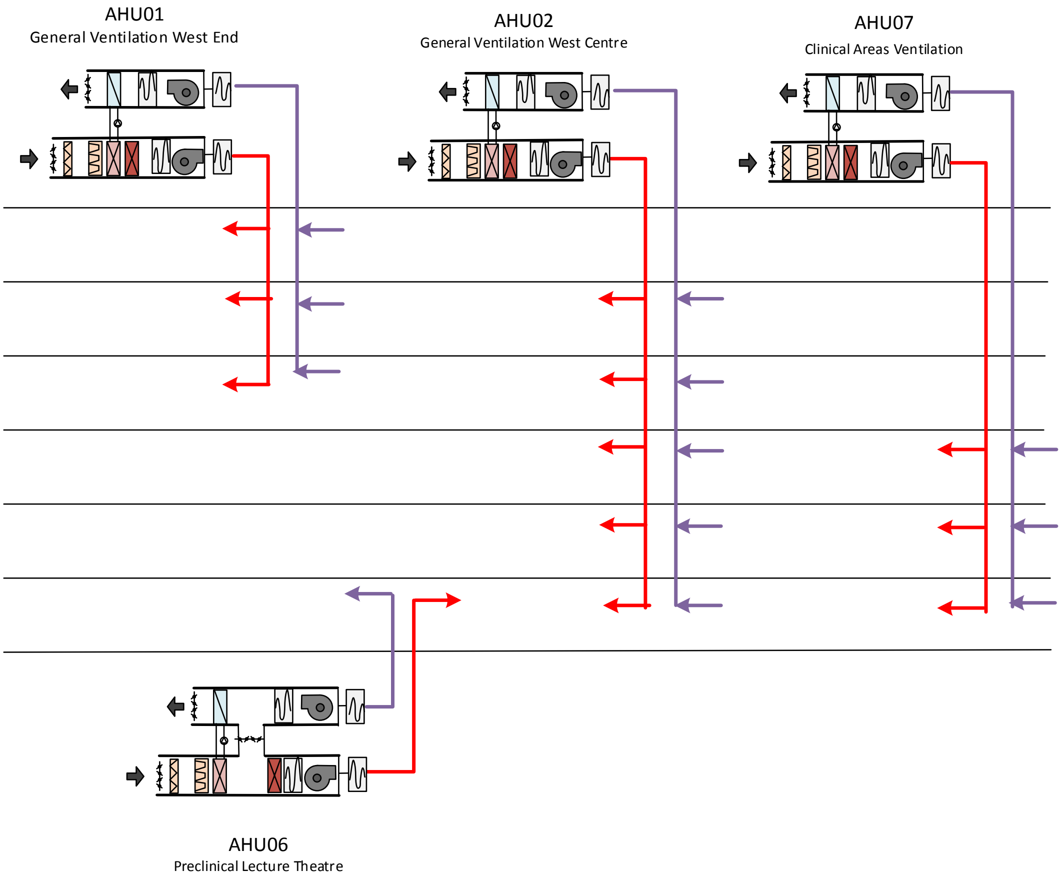
6.1 Air Handling Systems

The principal AHUs are generally full fresh air systems providing warm air supply to the occupied spaces. A limited number have mechanical cooling specified and these tend to be those serving close controlled environments such as 5th floor. All the AHUs were originally manufactured by Flakt who had a good reputation for quality products.

The AHUs serving the West End of the building are shown in Figure 6.1 the original plant labels have been used. AHU01, 02 and 07 provide general ventilation to the spaces and warm air heating. Heat is controlled by modulation of the 3 way valves – first stage the heat reclaim coil (Run-around Coil), second stage the 3way valve on the LTHW coil is modulated to maintain the supply air temperature at the set point – these settings are given in Table 2.2.

The areas served by each AHU by floor are given in Figure 6.4.

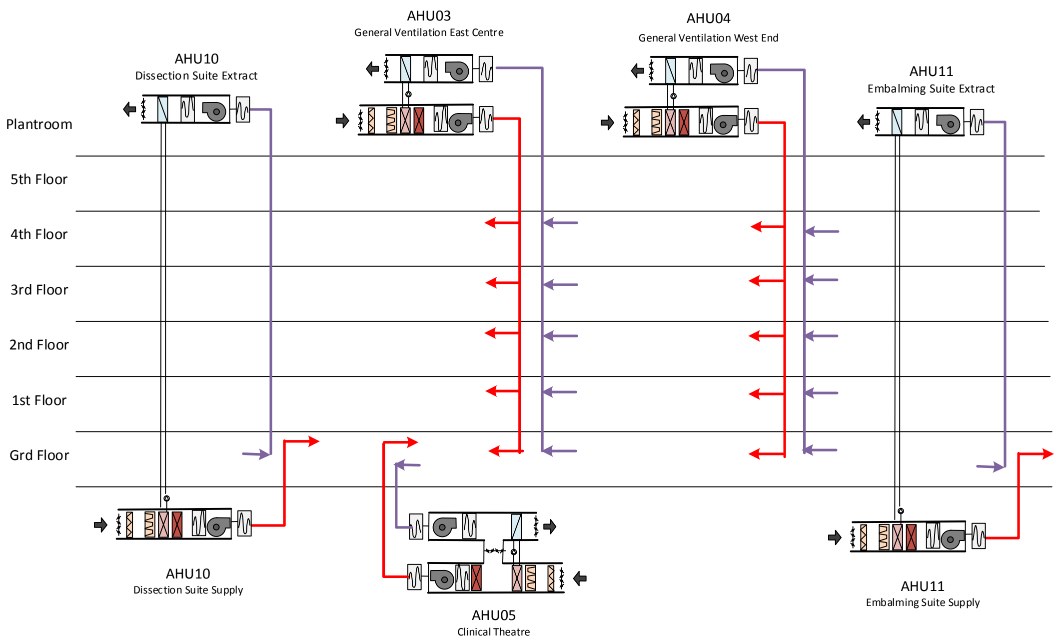
Figure 6.1 Principal AHUs – West End of Building



AHU06 is located in the ground floor plantroom behind the main reception and serves the large lecture theatre and has the facility to recirculate the air. This is operated only when the lecture theatre is occupied.

The AHUs which serve the West end of the building are shown in Figure 6.2 – general ventilation and warm air heating is provided by AHUs 03 & 04. The Dissection Suite in the Turnbull Centre is served by AHU10 with its extract unit located in the roof plantroom and its supply at ground floor. These are full fresh air systems with no recirculated air.

Figure 6.2 Principal AHUs – East End of Building



AHU05 which serves part of the Anatomy Section of the Turnbull Centre on the ground floor does have facility for recirculated air – this Section would be dealing with dissected material.

The rooms on the 5th floor are served by AHU 12 13 & 14 which provide closer environmental control with the addition of cooling and dehumidification, see Figure 2.5. The areas served by these units are indicated in Figure 6.3 – AHU 13 serves the majority of 5th floor whilst AHU12 the north east and AHU14 the north spaces. The west end of the 5th floor is served from general ventilation plant from AHU01 which is providing fresh air and warm air heating.

Figure 6.3 5th Floor AHUs

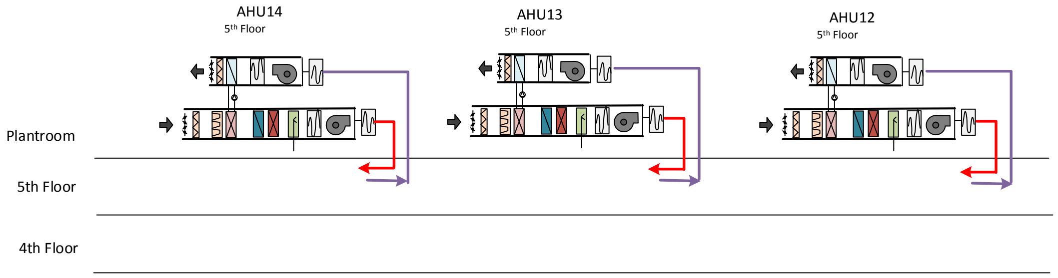


Figure 6.4 AHU Zonal Diagram

[redacted]

[redacted]

[redacted]

6.2 Performance of the Air Distribution Systems

The condition of each of the AHUs is detailed in Appendix C of this report which records the findings of site inspections carried out in September 2017. The AHUs are approaching 30 years old and naturally are showing evidence of wear and tear on components that have a statistical life expectancy of 20 years.

Our site inspections have focused on the causes of the complaints of poor internal environment and how the air distribution systems may have contributed:

- Poor control of thermal conditions
- Poor air quality and insufficient ventilation air
- Migration of odours/pollutants from 'dirty' spaces to adjacent clean spaces

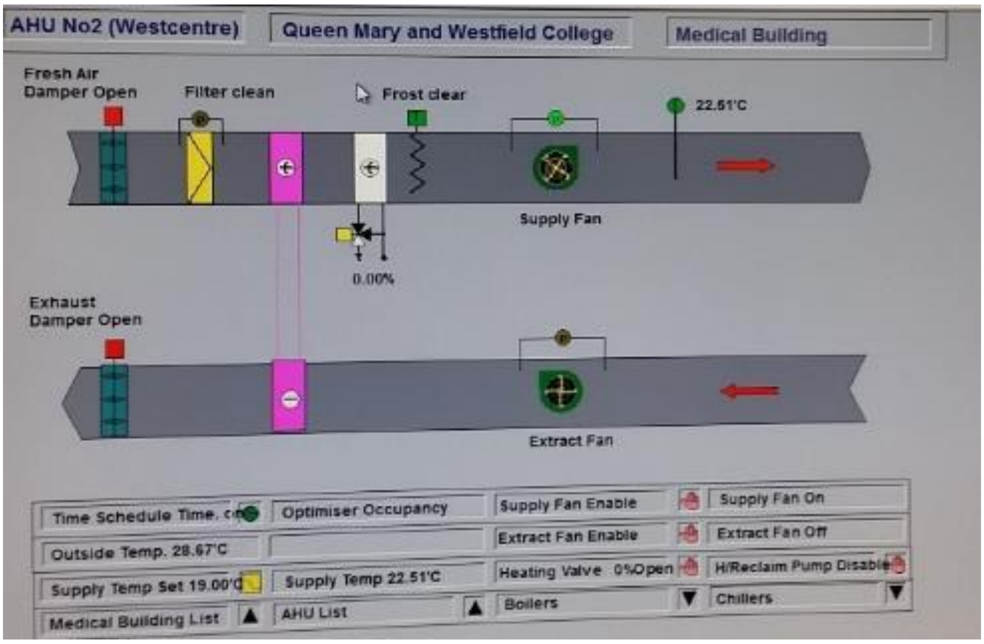
6.2.1 Poor Thermal Conditions

There were general complaints of poor thermal conditions throughout the building and throughout the year. In essence, the majority of the AHUs are delivering full fresh air and warm air heating to the occupied spaces. The principal AHUs providing general ventilation do not have mechanical cooling fitted – the typical arrangement is shown in Figure 6.5.

The AHU is controlled with two stages of heating to maintain a supply air temperature set point by initially starting the run-around coils pump to recover heat from the exhaust air then modulating the LTHW heating coil control valve if further heat is required. This is controlled by a P+I action to eliminate any offset in the controlled condition.

This arrangement means that there is no feedback from the occupied space and the system can only provide tempered air relying on the sill –line perimeter heating to carry-out the main modulation of heat in the room

Figure 6.5 Schematic of AHU02



The building design incorporats openable windows suggesting that mechanical ventilation would have operated in the winter and for summer operation would have been supplemented by natural ventilation. This means that for summer operation it was expected that the temperature would swing in line with external conditions.

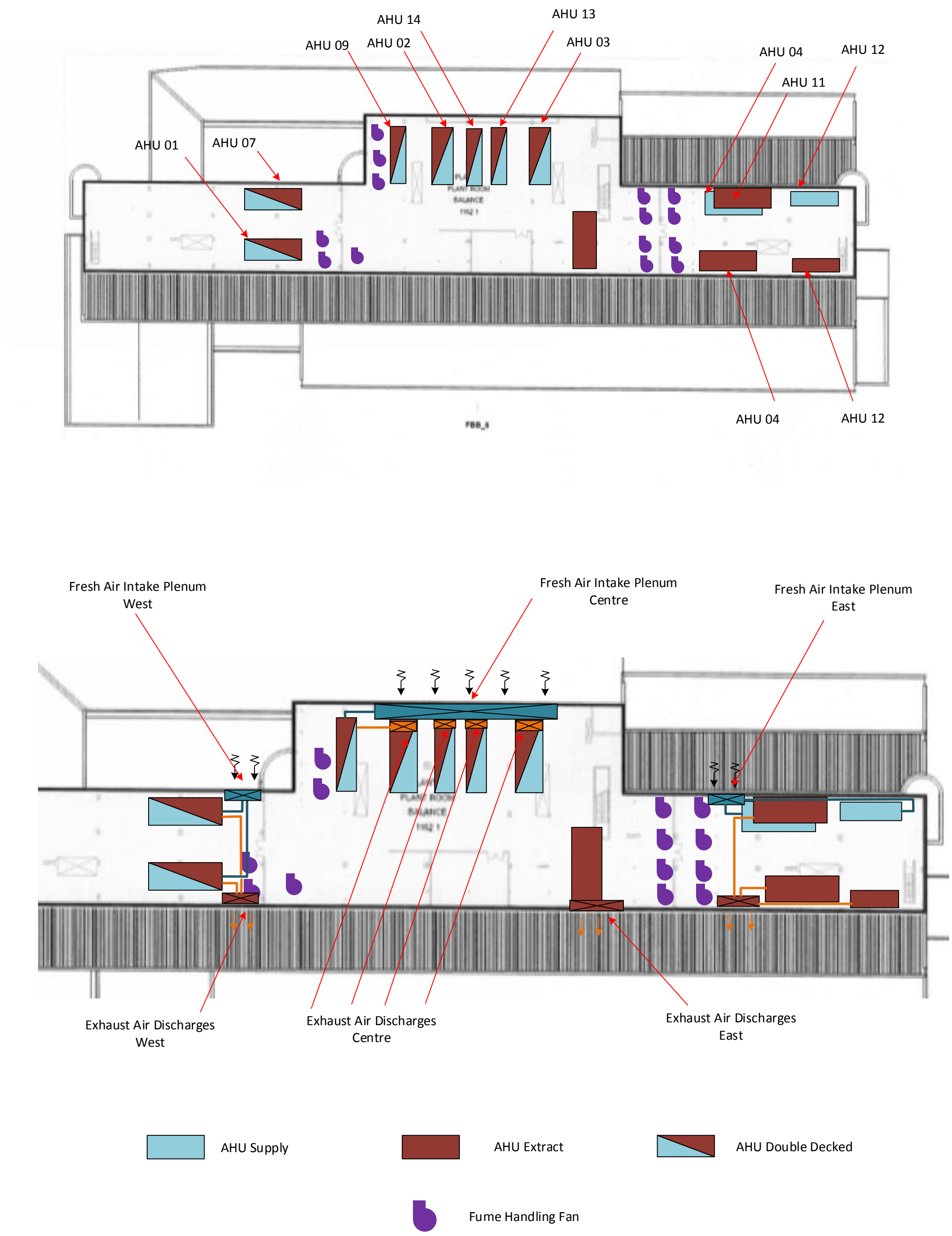
In naturally ventilated buildings, summertime temperatures can be mitigated by introducing high air movement. This is not the case with FBB as the centre pivot windows have opening restrictions to something like 150mm which limit the amount of air that can be introduced.

In those spaces in FBB with higher internal heat gain like laboratories supplementary cooling systems have been fitted in form of DX split cooling units. In those spaces without supplementary cooling the summertime temperatures will be at least on par with external conditions.

6.2.2 Air Quality

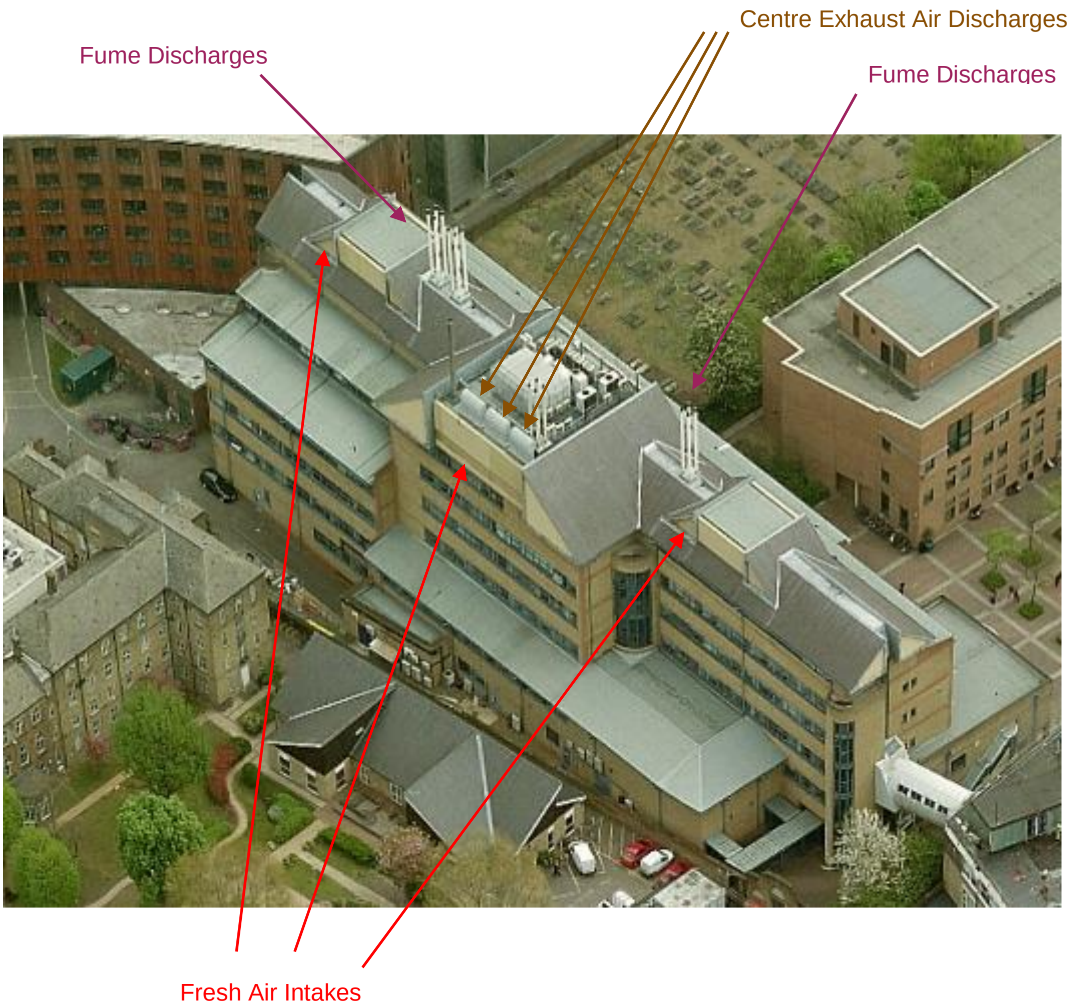
There are numerous complaints of poor air quality that affect the majority of the building. The arrangement of AHUs, fresh air intakes and exhaust discharges are shown in Figure 6.6.

Figure 6.6 Roof Plantroom General Arrangement



Generally, the fresh air intakes are arranged on the north façade of the building with the discharges on the south. The exception to this is the centre zone where the fresh air intake plenum is in close proximity to the discharges from the General Ventilation from AHU02 & 03 and AHU13 & 14 as well as that from the toilet extract discharge of AHU09 - these are shown in aerial views of the building in Figures 6.7 and 6.8

Figure 6.7 FBB North Façade – Air Intakes and Exhausts



The proximity of the centre exhaust discharges to the centre fresh air intake is a possible route for air to short-circuit back into fresh air supply of AHUs 02 & 03 which serve the general ventilation of a large proportion of the building.

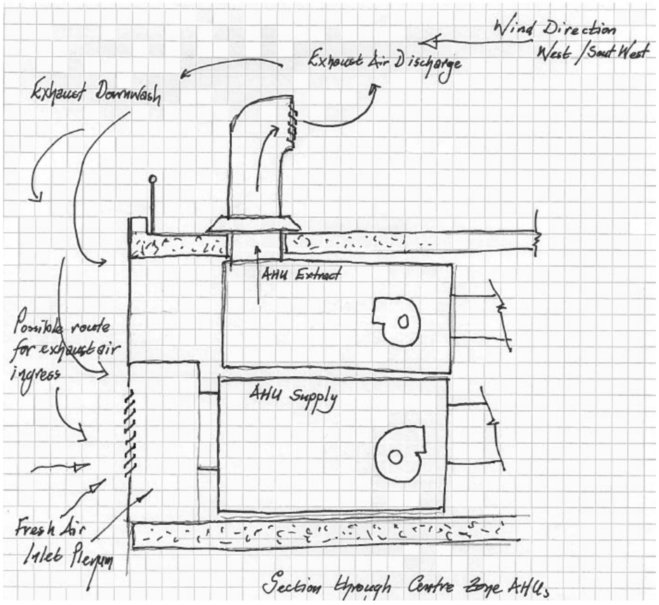
Figure 6.8 FBB South Façade – AHU Exhausts

The deatil of the central exhuast discharges are shown in Figure 6.9

Figure 6.9 Exhaust discharges from AHUs

Figure 6.10 is a section through the fresh air intake and exhaust air discharge and indicates how the discharge may possible short circuit into the fresh air inlet plenum. The discharges from AHU13 & 14, located in the centre of the bank of three will have exhaust air from the 5th floor.

Figure 6.10 Section through Centre Zone Exhaust Discharges and Fresh Air Intake



The fresh air plenum extends over the full width of the bank of 5 AHUs, see Figure 6.11. A measure to reduce the effect of short circuit would be to baffle the centre sections where discharge air from AHU13 & 14 may be at its most concentrated

Figure 6.11 View along the Centre Zone fresh air plenum

There is evidence of bird fouling at roof level that may also be finding its way into the air intakes, see Figure 6.12. The fresh air centre intake plenum, although dirty was free from this type of material, see Figure 6.11.

Figure 6.12 Evidence of bird fouling of the roof areas and roof mounted equipment

Figure 6.13 Bird fouling of roof Mounted Condensing Unit

6.2.3 Dirty Ventilation Air

In many of the areas in the building there is evidence of dirty supply air being delivered to the occupied areas, the results of this are clear in the occupied spaces, see Figure 6.14.

Figure 6.14 Fouled Supply Louvres in General Teaching spaces

The condition of the AHUs is detailed in Appendix C of this report. There is a general pattern of defects which impact on the cleanliness of the air distribution systems - these are summarised in Table 6.1 to 6.5.

The fresh air intakes were found to be in many instances dirty with corroded dampers. The upstream supply air sections had corroded pans with evidence that water had ponded at some time but were generally dry at the time of our inspection.

In a number of AHUs the filter banks were found to have by-pass air paths so that filter banks were rendered ineffective. Coupled with this the first coil to see the air flow was often badly fouled and corroded suggesting that the filters had been by-passing, collapsed or perhaps intentionally removed at some time.

The extract air paths tended to be in better condition than the supply.

Table 6.1 Dirty Air Intakes

The fresh air intakes and air dampers were found to be in a dirty condition. The build up of dirt to this level will support micro-biological growths with a risk of contaminating the air delivered to the building

 AHU04	 AHU14

Table 6.2 By- Passing of Filter Banks

There were several instances of air paths around the filter banks. The filter support frames have been tampered with as it is unlikely have been delivered in this condition form the Flakt. Dirty air by-passes the filter and then fouls the next coil downstream, in most instances this is the run-around coil. This example below was found on AHU12 which serves part of the 5th floor shows the staining of the clean side of the filter where dirty air has impinged on its flow past. This also the probable cause of the dust staining seen at the room diffusers

Table 6.3 Fouled AHU Coils

Several of the AHUs that had badly fouled and corroded coils, normally the run-around-coil that encounters the incoming air first. The amount of fouling suggests that the filters were being by-passed, collapsed or had been removed for prolonged periods. Fouling of coils will reduce air flow rate, increase fan energy use and accelerate deterioration of the coil.

 AHU09	 AHU12

Table 6.4 Corrosion of the Supply Air Sections

The upstream sections of the supply AHUs showed evidence of corrosion particularly on the pans where it appeared that at some time in the past the AHUs suffered from water ponding. The extract sections seem to be less affected

 AHU09	 AHU14

Table 6.5 Dirty and Poorly Fitted Filters

On several of the AHUs filters were found to be in a dirty condition and some poorly fitted/missing securing clips are allowing air to by-pass them contributing to dirty supply air.

 AHU03	 AHU13

6.2.4 Adequacy of the Ventilation Air

Table 6.6 gives the design flow rates taken from the original record schematics and equates those to approximate air change rates to the area they are serving.

The design flow rates for general ventilation AHUs 01, 02, 03 & 04 were to deliver 3 to 5.5 ac/h of ventilation air which would have been satisfactory for winter operation but would not have been adequate for summer without the provision of mechanical cooling. For this system to work with natural ventilation a good flow of air would be needed in summer of the order of 10-15ac/h to improve occupants' sensation of thermal comfort

At the time of site investigation 3 of the 4 general ventilation extract fans were not operating which would have impacted upon the effectiveness of the system.

The measured air flow rates tended to be significantly lower than the design figures. For example AHU02 was only delivering 40% of its required volume flow. The reasons for this are likely to lay in the defects already discussed - blocked filters, fouled coils, poorly adjusted fan belts, etc.

The toilet extract system (AHU09) was found to have its motor and belts rotating but the fan seized so effectively there was no toilet extract leading to migration of toilet odours to the rest of the building.

By the comparison the AHUs serving the floors and dissection suites had higher flow rates that were only showing marginal shortfalls against design.

6.2.5 Air Flow Balance

The air flow balance on the various air distribution systems needs to be reviewed as there are parts of the building that are experiencing high air flows and as a result air generated noise and other spaces where there is a deficit. One of the causes of the imbalance of the air supply systems are the numerous modifications where ducts have been cut in or blanked off over the years without reference to the overall balance of the system.

For example Room2.22 in the Geography Department general teaching spaces has its VAV boxes blanked off because of the 'supply of dirty air'. Room 1.20 was an example where air noise generated at the diffuser was impacting upon teaching activities, see Figure 6.16.

Figure 6.15 Room 2.22 VAV boxes blanked off

Figure 6.15 Room 1.20 Experiencing Air Generated Noise Problems.

Table 6.6 Summary of AHU Design Duties and Test Results

AHU Ref	Area Served	Design Supply	Design Extract	Floor Area served	Supply ac/h (approx	Test results			
		m3/s	m3/s	m2		Supply m3/s	Static press Pa	Extract m3/s	Static press Pa
1	General Vent West 3rd to 5th Floors	2.82	2.12	1274	2.95	2.2	287	0	0
2	General Vent West Central Grd to 4th Floors	6.52	6.32	3204.6	2.71	2.46	300	0	0
3	General Vent East Central Grd to 4th Floors	7.02	5.56	2490	3.76			0	0
4	General Vent East Central Grd to 4th Floors	8.54	5.97	2043	5.57	5.4	200	2.32	-286
5	Clinical Theatre	1.87	1.87	261	9.55			0	0
6	Pre-Clinical Theatre	3.29	3.28	374	9.05			0	0
7	Clinical Vent Ground to 2nd Floor Dining & Kitchen Supply	7.49	5.04	1614	4.77	4.72	330	3.15	-128
8	Kitchen Extract		2.11						
9	General Toilets Grd to 4th Floors	1.39	1.74	292	4.89			1.54	-382
10 ext	Dissecting Suite Extract		9.5					5.66	-200
10s upp	Dissecting Suite Supply	9.45		284	44.37				
11	Embalming Unit	2.44	2.11	455	7.15			0.7	-83
12	North Side Vent	1.23	1.23	186	8.82	0.83	103	1.017	-182
13	Biological Facility B South Side	3.36	3.46	530	8.45	3.05	176	3.85	-147
14	Biological Stores	1.39	1.23	232	7.99			0	0

The areas of the building with high levels of air distribution noise are shown in Figure 6.16. these are spaces where there is frequent complaints of high noise levels impacting on the use of the rooms particular teaching spaces where theremedy has been to isolate the AHU temporarily.

Figure 6.16 High Air Noise Areas

[redacted]

[redacted]

High Air Noise Spaces

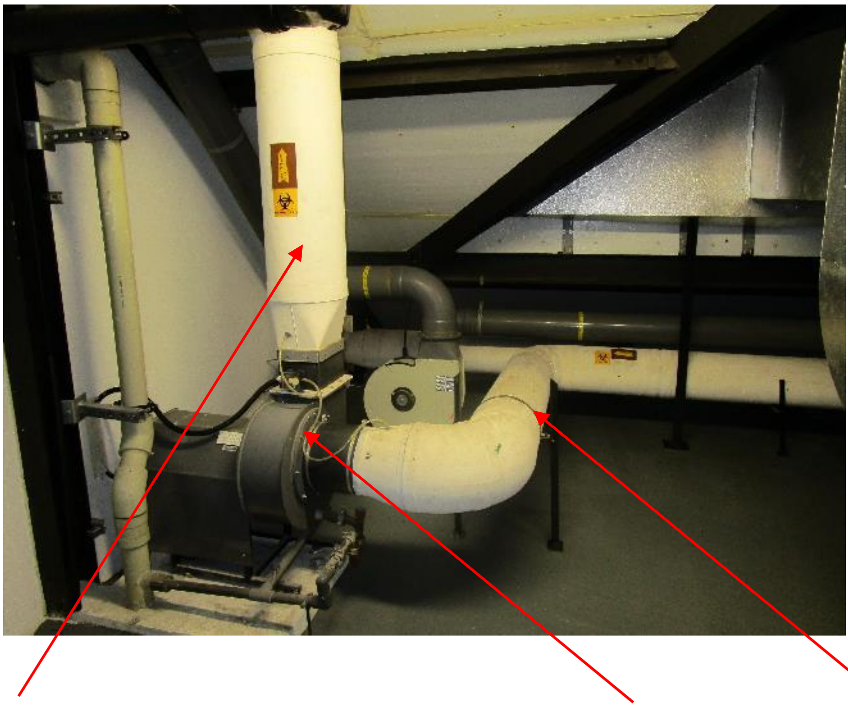
6.2.6 Fume Handling Systems

The building has several fume handling systems which tend to have a decentralised arrangement in that 1 fan serves 1 fume cupboard and flue discharges are taken up 6m above the roof line, see Figure 6.16.

An example of the fan arrangement is shown in Figure 6.17 which are all located in the roof plantroom space (6th floor), see plantroom layout in Figure 6.6.

Figure 6.16 Fume cupboard individual discharge flues (centre zone)

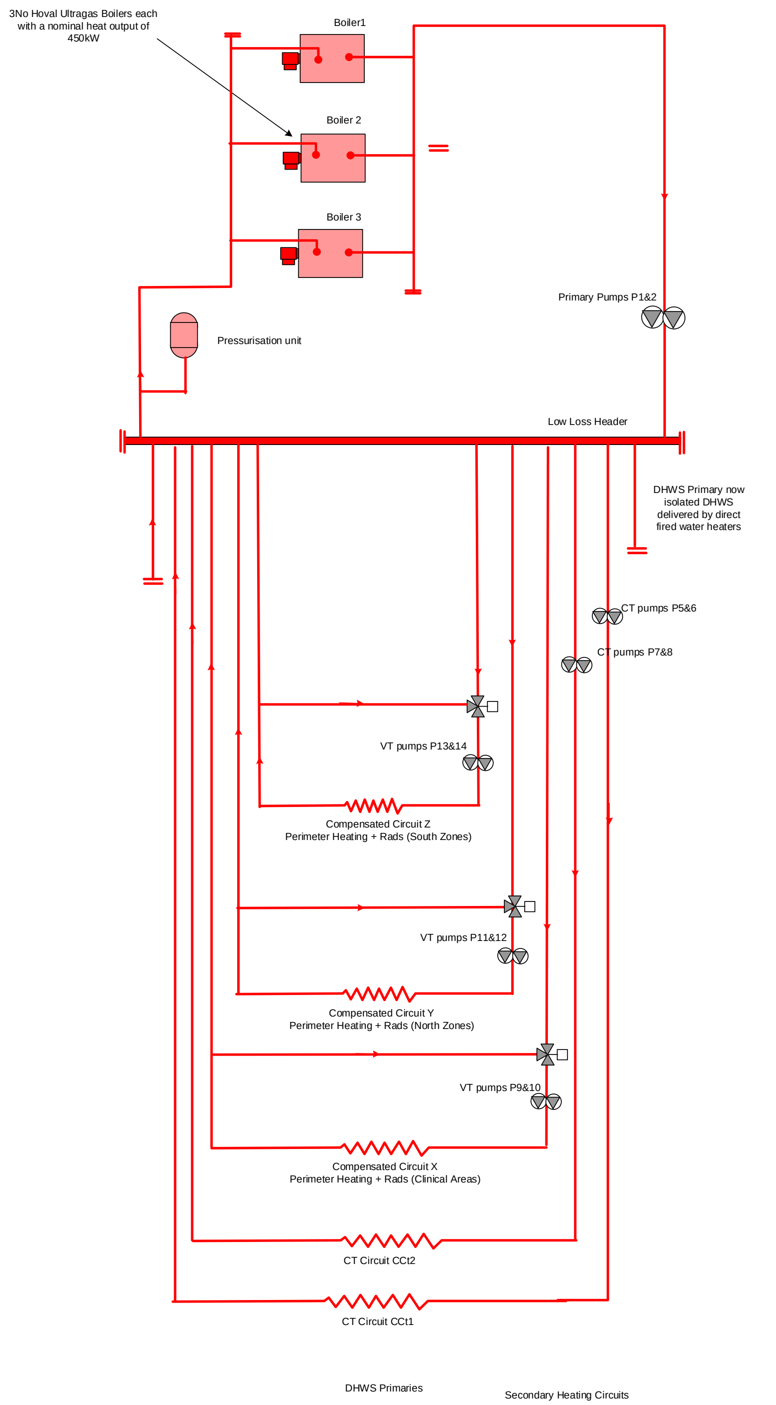
Figure 6.17 Typical fume cupboard arrangement



6.3 Heating Systems

The building is heated with an LTHW distribution system serving the heating coils in the AHUs and the perimeter finned tube sill line heaters. A simplified schematic is shown in Figure 6.18 showing the primary and secondary circuits

Figure 6.18 LTHW Boiler Simplified Schematic



The boiler plant was refurbished in 2008 with the installation of 3No Hoval Ultragas 450kW condensing boilers that each have a maximum nominal heat output of 450kW. These premix gas burners are capable of turning-down to 89kW.

The total installed load is therefore 1350kW which over a gross internal area of the FBB of 11,772m^2 yields a specific capacity of 114W/m^2. As the AHUs are generally full fresh air it is important that the heat reclaim systems are operational for the boiler plant to match the load.

The occupied spaces are heated by the LTHW compensated circuits with predominately sill line fin tube natural convectors, see Figure 6.17. A view from below shows that the coils are connected in series without any control valves, see Figure 6.18.

Figure 6.19 Sill Line heaters

Figure 6.20 Sill Line heaters fin tube coil (view from below)

The heating temperature of the LTHW circulating in the compensated circuit is set according to the outside weather - there is no feedback from the space. The only control that is provided is the air damper button for manual control of output. This would have been adequate for larger open plan spaces where occupancy is relatively uniform but is not ideal for cellular spaces where occupation and hence thermal loads can vary.

The building originally had larger laboratories in its first incarnation as a medical school but these have been altered over the years with successive spatial layout changes which have become more cellular in nature. The original lab spaces were larger and had more uniform loading which would make the compensated perimeter heating control more viable.

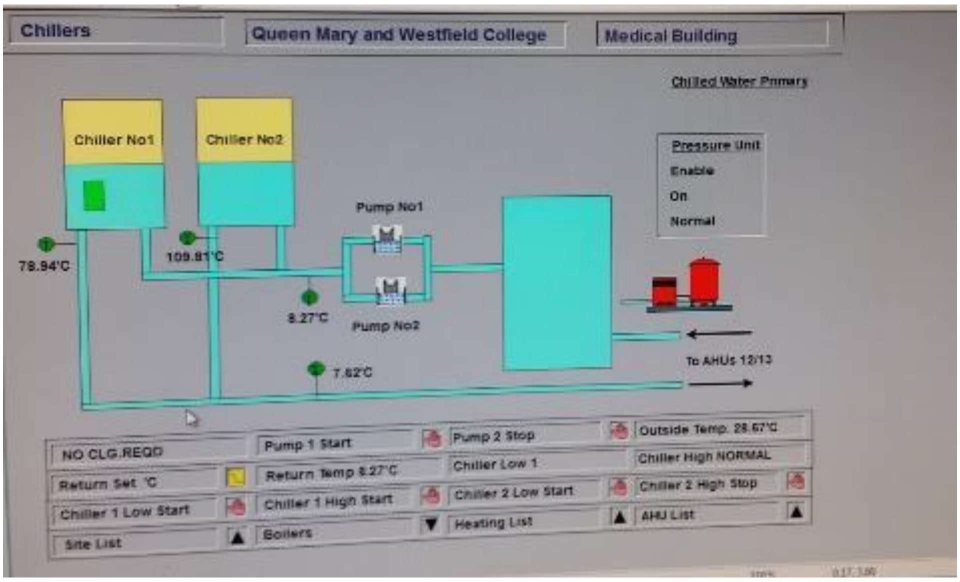
The DHWS was raised by the main LTHW primaries which have been subsequently isolated on the main plant. It is now delivered from two Lochinvar direct fired gas water heaters see Figure 6.21.

Figure 6.21 DHWS Direct Fired Gas Water Heaters

6.4 Chilled Water System

The chilled water system essentially serves the cooling requirements of the 5th floor in AHUs 12 &13, the BMS graphic is shown in Figure 6.22. There are two water cooled water chillers located in the roof plantroom that operate to maintain a chilled water flow temperature of 6°C. A buffer vessel has been installed to the circuit to increase the water content of this small circuit to minimise cycling of the chiller compressors.

Figure 6.22 Chilled Water System Schematic (BMS Graphic)



6.5 Building Management System

The HVAC are controlled by a building management system that was originally a Satchwell BAS 2000 which were acquired latterly by TAC systems. An example of an existing MCCP and controls section is shown in Figures 6.23 and 6.24.

Figure 6.23 Existing MCC and Control Panel Sections

Figure 6.24 Controls Enclosure showing original Satchwell BAS 2000 badge

The existing BMS has a number of defects which impact upon the way in which the HVAC systems perform and in turn on the comfort and well-being of the occupant.

For example the external air temperature was indicating a temperature of 28.67°C when the actual temperature was 14°C, see the BMS graphic for AHU02 in Figure 6.5.. The poor calibration of this sensor results in the 3 heating weather compensated circuits operating at a considerably lower temperature than it should leading to underheating of the building.

The BMS uses TAC System Manager software release 4 (Build 3.42.43) 2006. This is old software using hardware that is no longer supported by the manufacturer and so is obsolete. The BMS and controls therefore need to be upgraded to the standard being used across the QMUL estate which is to use Trend controls.

6.6 Action Plan

6.7 Action Plan

The action plan to rectify the defects found in this investigation will depend upon the strategic direction QMUL wish to pursue with the building particular in light of other developments on the site (e.g. possible move of the SBM to a new building in 2021).

The decision will therefore be to:

1. Rectify the problems in the existing systems – to make what is installed operate as originally intended with repair, refurbishment and upgrade. – this could be carried out keeping the building operational
2. A radical change to the systems to match the demands of the various academic departments now using the building using under significantly increased occupancy – vacant possession of some areas of the building will be necessary.

With the probability of the SBM moving to a new building in 2021 the strategy may be to carry-out the priority measures on the existing systems to reach that point then carry-out more radical refurbishment when part of the building becomes vacant.

The high priority measures are discussed below

6.7.1 Air Handling Systems

The priority measures to return the existing air handling systems are to fully operational state would be as follows:

1. Recalculation of the design air volumes for the buildings spaces as they are currently used – in many instances, this will be different to those assumed in the original design 30 years ago.
2. Refurbish the existing AHUs
    - Clean fresh air intake of dirt and debris
    - Repair filter banks – sealing by-pass air paths, and failed support structures.
    - Clean AHU sections repairing or replacing corroded sections – mainly supply sections;
    - Clean motorised dampers, replace faulty actuators and linkage where necessary;
    - Replace inter-section seals where leaking (e.g AHU09 extract);

- Clean fouled coils and replace those coils badly corroded;
- Upgrade fans in accordance with the new design air volumes calculated in [1]
- Check calibration of sensors and replace failed components;
- Check run-around-coil pumps and their controls ,replace failed components

3. Clean distribution ductwork from AHUs through to room diffusers and grilles
4. Rebalance air supply systems in accordance with new design air flow volumes determined in [1].
5. Install baffle plates on the fresh air intake weather louvre on the plenum which serves AHU02 & 03 plus AHU13 & 14 to minimise short circuit from exhaust air from certain discharge louvres which are in close proximity.

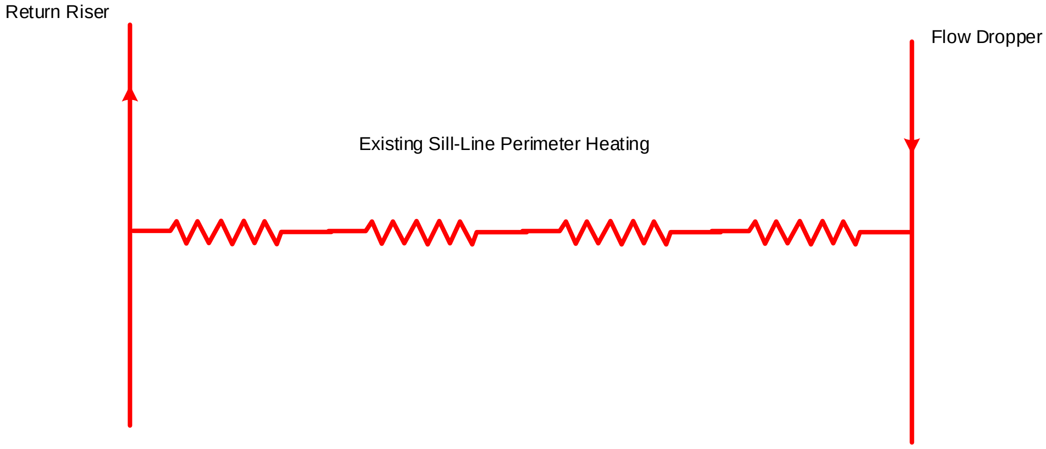
6.7.2 HVAC Improvements for Cellular Spaces

Over the buildings 30 years of operation, it has undergone spatial layout changes which have made it more cellular than the original design. This is certainly the case in the SBM where cellular offices are preferred to open plan.

It will be necessary modify the heating system so it is better equipped to match the local requirements of individual spaces. The existing sill line perimeter heating has no local control of heating water temperature this is achieved centrally through weather compensated control of 3 secondary circuits, see Figure 6.18. The colder the outside weather, the higher flow temperature set point.

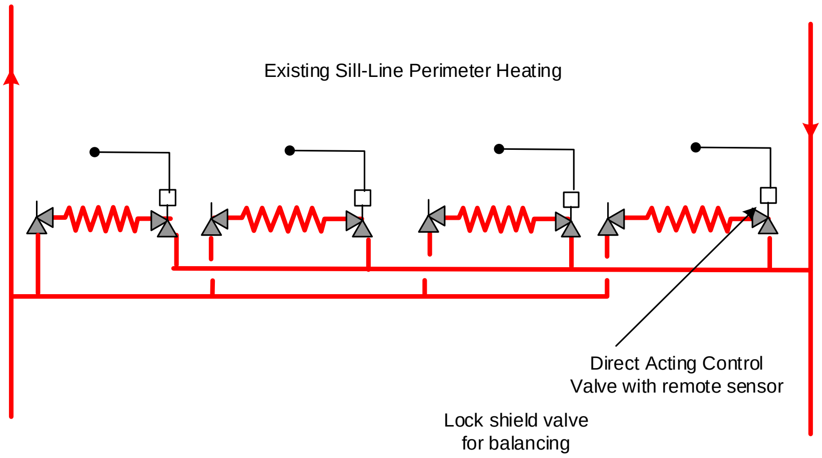
The existing perimeter heating finned tubes are served in a ladder pipework arrangement, see Figure 6.25. Local control could be introduced by converting the system into a two pipe arrangement with a local direct acting control valve for each space, Figure 6.26.

Figure 6.25 Perimeter Heating System – Existing Ladder Arrangement



A two pipe feed is proposed so that a local direct acting thermostatic valve can be introduced with a remote sensor located in the room air. A lock shield valve will be introduced for flow balancing.

Figure 6.26 Two Pipe Modification of the Ladder Heating System to introduce local control.



An alternative to pipework modifications will be to introduce a direct acting thermal actuator for the 'hit and miss' damper located on the front of the sill- line heater.

6.7.3 Air Containment between 5th floor & 4th floor

Feedback form the occupant satisfaction survey indicated there were occasions when there was migration of smells into the 4th floor SBM particularly when the pressure regimes on the 5th floor were disturbed. This was reported to occur when extract filters were not replaced on AHU13 for example leading to loss of suction pressure and loss of containment.

To minimise the risk of this disruption to the pressure regimes, not only must planned preventative maintenance be carried out rigorously but any substantive air leakage paths between the 4th and 5th floors must also be sealed.

A survey is needed of the false ceiling void on the 4th floor to identify gaps in the structure or breaches where there are service penetrations. These transmission paths then should be sealed and/or appropriately fire stopped.

6.7.4 Fume Cupboard Discharge Ductwork

The FBB has several laboratory areas that have fume cupboards and generally these are arranged with compact fume handling distribution systems with de-centralised fans handling one or two fume cupboards. These fans are located in the roof top plant space resulting in a limited amount of fume discharge ductwork inside the building which is under positive pressure.

We noted that on a number of these fume discharge ducts there were air leakage paths to the plantroom where, for example traverse point test plugs had been removed leading to a transmission path for contaminants into the plantroom areas.

The sections of ductwork under positive pressure need to be leak tested and any breaches appropriately sealed.

6.7.5 BMS Upgrade

The existing Satchwell/TAC BMS system is obsolete no longer supported by its manufacturer and therefore is in need of urgent upgrade. The preferred approach by QMUL Facilities Managment is to upgrade to a Trend IQ 4 system to provide consistency across the Estate.

The upgrade will need to be carefully planned if it is to be undertaken whilst the building is fully operational. The approach will be to install a parallel system in new control enclosure panels carrying out the changeover from the existing to the new system out-of- hours (weekend). The new panels will need to be tested and fully commissioned to return the systems to a fully operational state before the resumption of occupancy.

The control strategies will be revised to improve the control of thermal comfort and the systems energy efficiency this will include:

- Inter locking of heating and mechanical cooling in those spaces where DX cooling has been fitted. The BMS will release the D-X cooling system to operate when above set point to avoid heating and cooling operating simultaneously.
- Night purge when the ambient temperature allows to freshen the spaces up before occupancy late spring, summer and early autumn. This will involve running the AHUs overnight (on the off peak tariff) to improve air quality and provide a modicum of pre-cooling of the building in spaces with no mechanical cooling.
- Addition of sub metering of principal loads to allow better energy management of the FBB.

7 Electrical Systems Site Investigation

7.1 General arrangement

The Francis Bancroft Building is served from two separate UKPN Substations located at Ground level at the north eastern end of the building with the associated LV Switchgear directly above. The LV Schematics indicate that two UKPN services are connected (assumed to be one from each substation) each terminating on an 800A Moulded Case Circuit Breaker in the LV switchgear. It should not be inferred that the UKPN supplies are rated at 800A, see Figure 7.1.

Figure 7.1 UKPN Substations

A stand by diesel generator is housed in a plantroom immediately adjacent to the LV switchroom, connected through an auto-changeover contactor panel to the essential services busbar located in Riser 4. The generator does not appear to be connected to any other services in the LV switchroom, therefore it is assumed that all essential services are served from the essential services busbar in Riser 4.

Distribution Busbars and distribution boards are located in four vertical electrical and data services risers.

The plantroom on the 6th floor includes Motor Control Centres serving the mechanical plant.

7.2 LV Schematic

From detailed conversation with Estates Team engineers and examination of the switchgear, it is evident that the LV schematic on the wall of the LV Switchroom does not present an accurate reflection of the electrical network.

For example, the schematic shows a 55kVA generator and provision for connection of a mobile generator through a 400A 4 pole isolator however the small generator is not present and no facilities for the connection of a mobile generator were found. The 150kVA generator and changeover switchgear is not shown and the Essential Services rising busbar in Riser 4 is shown terminating on Level 2 but in fact it rises to level 5.

7.3 LV Switchgear

The LV switchgear was built by MEM Delta and is most likely contemporary with the building construction, therefore approximately 27 years old. It includes a mixture of switchfuses for outgoing circuits and Moulded Case Circuit Breakers used as bus section switches. Labelling of the switchfuses includes the original manufactures' designations, handwritten permanent marker and more recent engraved labels, see Figure 7.2.

In view of the known inaccuracy of the LV schematic on the wall of the switchroom, the indicated function of the various switchfuses must be treated with caution.

The schematic does not indicate a bus section switch between the two halves of the switchgear, each of which is separately supplied from one of the two UKPN substations. Examination of the switchgear confirms that there is no bus section switch present. It would be challenging to install a free-standing switch now, although not impossible.

A bus section switch allows one of two supplies to support the building, although some load-shedding would probably be necessary. It would provide a degree of flexibility of service in the event that one of the UKPN supplies were to one unavailable for any reason. As the building electrical services stand at present, were one of the UKPN substations to need maintenance or were a local equipment failure to occur, half of the building would lose power and not be able to be supported from the remaining substation.

Figure 7.2 LV Switchgear

The switchpanel was not opened however from an external inspection it appears to be in a reasonable condition for its age. A problem with all switchgear as it ages is the diminishing availability of spare parts and replacements should a failure occur. It is likely that direct replacement switchfuses and MCCBs are no longer available therefore a strategy for how to reinstate supplies in the event of a failure should be considered.

Several unlabelled cut ends of cables were noted in the LV switchroom with no indication of the services that have been removed. It is good practice to identify as dead and label redundant services and cables.

7.4 Generator

A 150kVA standby diesel generator is located in a space immediately adjacent to the LV switchroom. Cables for control and output are installed at high level to a Telemechanique changeover controlled by a Deep Sea Electronics panel at the far left hand end of the switchroom.

The generator was built in 2007 and appears to be well maintained and in good condition. The diesel fuel tank is integrated into the generator base. The engine exhaust from the generator discharges through a side-wall, and little if any attenuation appeared to be installed. The exhaust discharge externally is approximately 6 metres above ground level and is close to opening windows of student residences and overlooking a circulation area adjacent to a sitting-out area associated with the Curve Restaurant. It is likely that noise and pollutant nuisance is experienced when the set is running on test or during a mains failure.

7.5 Electrical Risers

The electrical risers are distributed though the building with three spaced out along the spine of the building and Riser 4 in a central position adjacent to the Goods Lift.

In each riser there are non-essential Busbars serving mostly local distribution boards (some are remote) which are equipped with meters, however it is understood that these are not monitored centrally. Data cables are routed through the electrical risers and at one location a rack of disused servers was found in the riser.

Riser 4 includes a non-essential riser and distribution boards and in addition the 250A Essential Rising busbar from the generator is located in this riser. Access was not possible to view the distribution boards and meters on levels 3 and 4 however observation of the meters elsewhere that could be viewed suggest that the busbar and hence the generator is only lightly loaded in use.
On level 5 the space appears to be supported from the generator however we were informed that the mechanical services controlling the environmental conditions (heating, cooling, ventilating) on the 5th are not supported.

The LV Schematic in the LV switchroom appears to show some alternate means of supplying the chillers and Motor Control Centres that are understood to serve the 5th floor, but as previously stated the schematic cannot be trusted and no mean of interlocking the alternative sources appear to be indicated.

7.6 Lighting

Lighting in the building reflects a number of replacement and development projects that have taken place over the years with linear and compact fluorescent sources, also LED luminaires noted in those spaces that could be visited. The luminaires range from surface to suspended up/down lighting luminaires, recessed, louvred and micro diffuser types.
The occupant satisfaction survey has made references to poor lighting although with no specific complaint ie too bright, too dim, excessive glare, no daylight. Lighting is often cited in buildings where occupants are generally unhappy however apart from extreme examples of poor lighting design or maintenance it is

the visual environment as a whole that causes complaint. High contrast ratio, poor control of daylight, no daylight, poor distribution of light (especially in relation to whiteboards and screens) colours and textures used in decorations can all cause discomfort.

A study of all of these factors (and more) is outside the scope of this Review. Should lighting continue to figure in user satisfaction surveys a more detailed study of the lighting environment is recommended.

8 Public Health Systems

The drainage system that serves the Francis Bancroft Building currently provides conveyance to the municipal sewer for

(i) ‘domestic’ foul and wastewater from toilet accommodation and kitchenettes, etc; and

(ii) wastewater from the 5th floor and the Medical Suite where dissection of cadavers are conducted. Waste fluid from dissection and embalming are reported not to go to drain but are contained and dealt with by disposal in bio-chemical waste containers,some of the wash down;

There are pathogens potentially present in all forms of wastewater.

8.1 Drainage system

The drainage system can play a part either directly, or indirectly, as a source or pathway for the release of contaminated air into habitable spaces.

(1) Directly – wastewater and foul water (containing pathogens hazardous to heath) are discharged into a gravity drainage system for onward conveyance to the sewer via the internal drainage system in a buildings.

(2) Indirectly – the drainage systems provides a possible pathway for airborne contaminates to be passed between compartments in a building as it connects various spaces with the buildings.

In above-ground drainage design, a seal is provided to prevent the release of foul or hazardous gases from the drainage system into a building. Within the building, a water trap is the typically seal used however other form of positive seal can be used. External to the building, drainage ventilating pipes should be positioned so as to not allow gases that are released in normal usage to enter the building.

8.2 Depletion of water traps

The loss of drainage water trap seals can provide a possible pathway for transfer of between air and contaminants between floors and habitable spaces. Pressure variations of water flows in drainage and other pressure gradients can lead to the release of gases from the drainage system into habitable spaces

There are various mechanisms for the depletion of water traps:

- Evaporation of trap
- Self-siphonage
- Induced siphonage
- Back pressure
- Surcharging of the underground drainage pipework

- Wind effects

The possibility of the occurring are minimised by good design and the proper operation and maintenance of the system.

8.3 Positioning of ventilating pipes

The Approved Document H – Drainage and Waste Disposal of the Building Regulations provides guidance on the positioning of ventilating pipes. AD H states:

> *'Ventilating pipes open to outside air should finish at least 900mm above any opening into the building with 3m and should be finished with a wired cage or other perforated cover, which does not restrict the flow of air'.*

Remedial work has already been undertaken on ventilating pipes on the south side of the buildings has already been undertaken to prevent the possibility of gases from the drainage system entering openable windows and air vents, see section 3.8.

8.4 Toilet accommodation provision and usage

The current occupancy of the Francis Bancroft Building is in excess of toilet provision (British Standard BS 6465 Part 1 Sanitary installations. Code of practice for the design of sanitary facilities and scales of provision of sanitary and associated appliances). The increased (congested) usage of sanitary appliances can increase the propensity of blockages and overflows.

Congested use can increase the risk of the depletion of water trap seals. There is evidence of a history of blockages of urinals and WC causing water damage to both toilet accommodation and adjacent spaces such as corridors.

8.5 Action Plan

The following recommendations will help minimise the risk that the drainage poses a direct or indirect health hazard to the occupants of the Francis Bancroft Building:

1. Complete remedial work on soil and combined waste vent pipes to extend above roof-line to prevent migration of foul/contaminated air back through openable windows.
2. Carry-out intrusive investigation inspection of waste and soil pipe drainage to clear uric crystal build-up and other blockages
3. Maintain proper maintenance of the drainage system;
4. Verify water traps are effective identifying and correcting those which;
5. Investigate waste-water discharge from the Medical Suite.

Appendix A Building Floor Plans

Figure A.1 Ground Floor Plan

Figure A.2 First Floor Plan

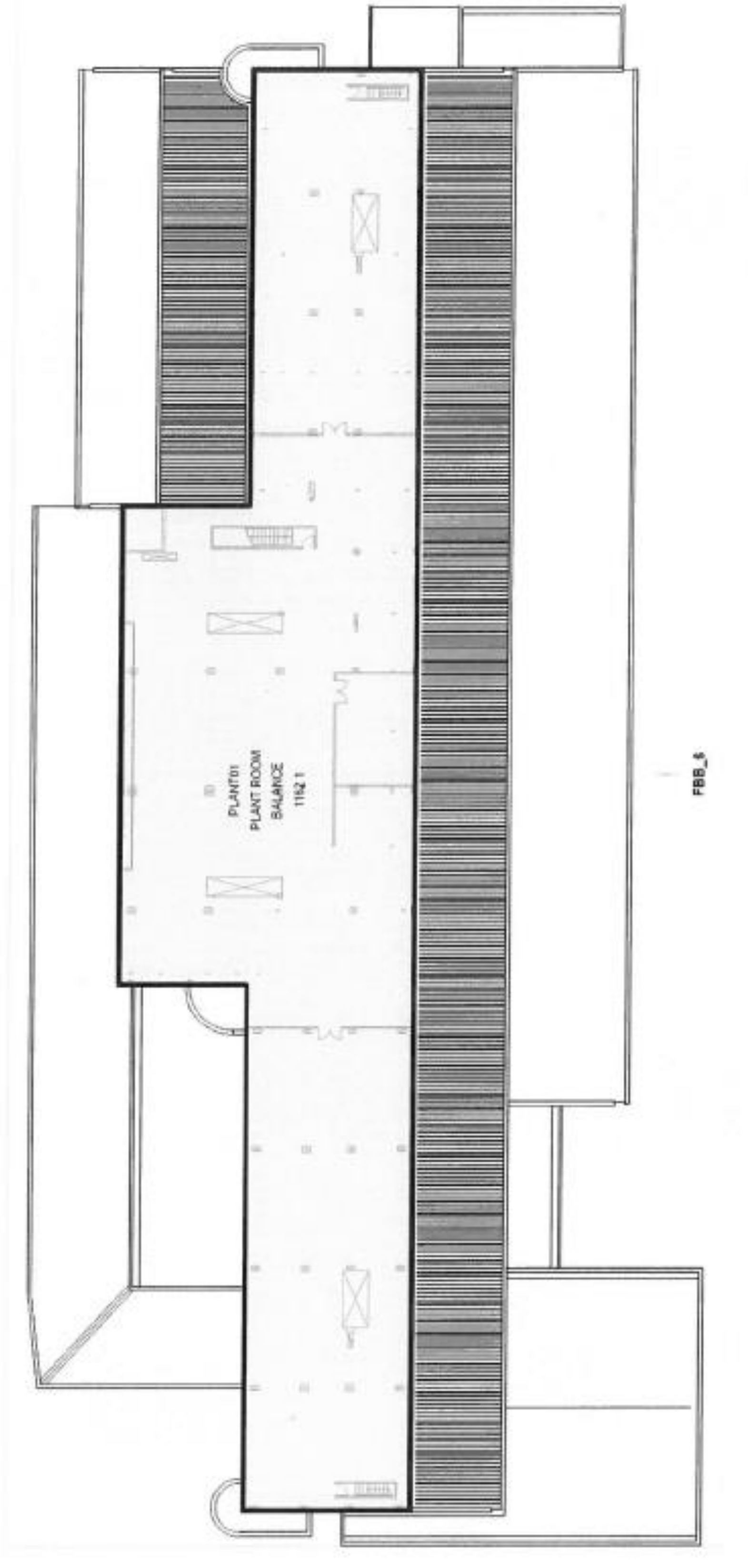
Figure A.3 Second Floor Plan

Figure A.4 Third Floor Plan

Figure A.5 Fourth Floor Plan

Figure A.6 Fifth Floor Plan

Figure A.7 Roof Plan



Appendix B Occupant Satisfaction Survey Data

The floor plans below have the occupant complaints mapped on them to identify whether there is a general problem in the building or whether it is restricted to specific areas.

Figure B.1 Ground Floor Complaints Map

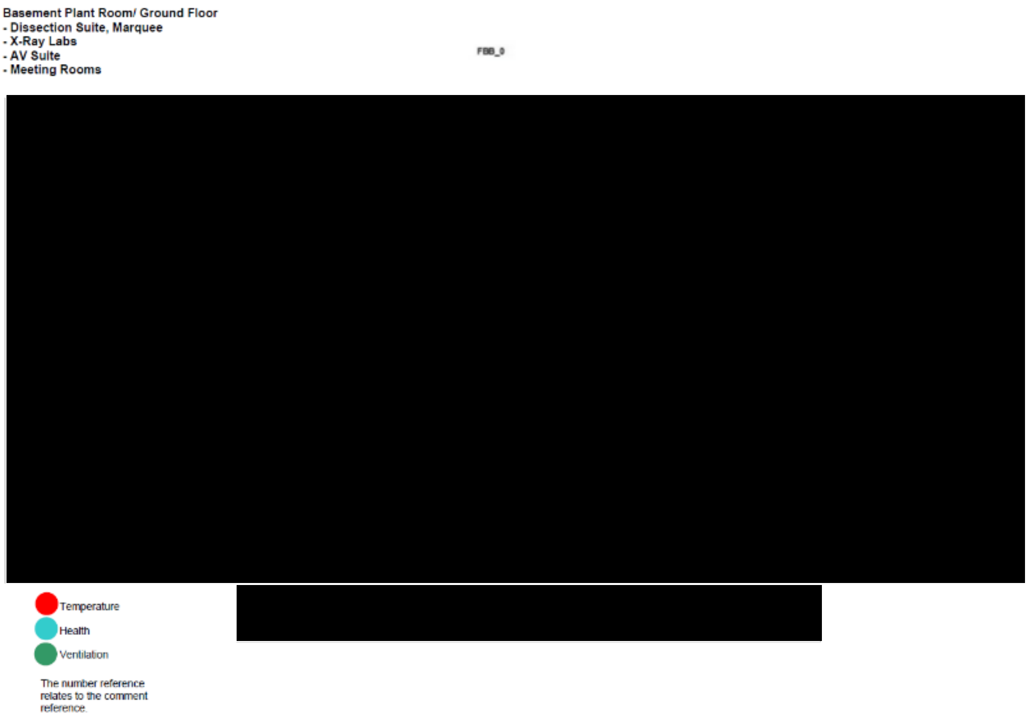


Figure B.2 First Floor Complaints Map

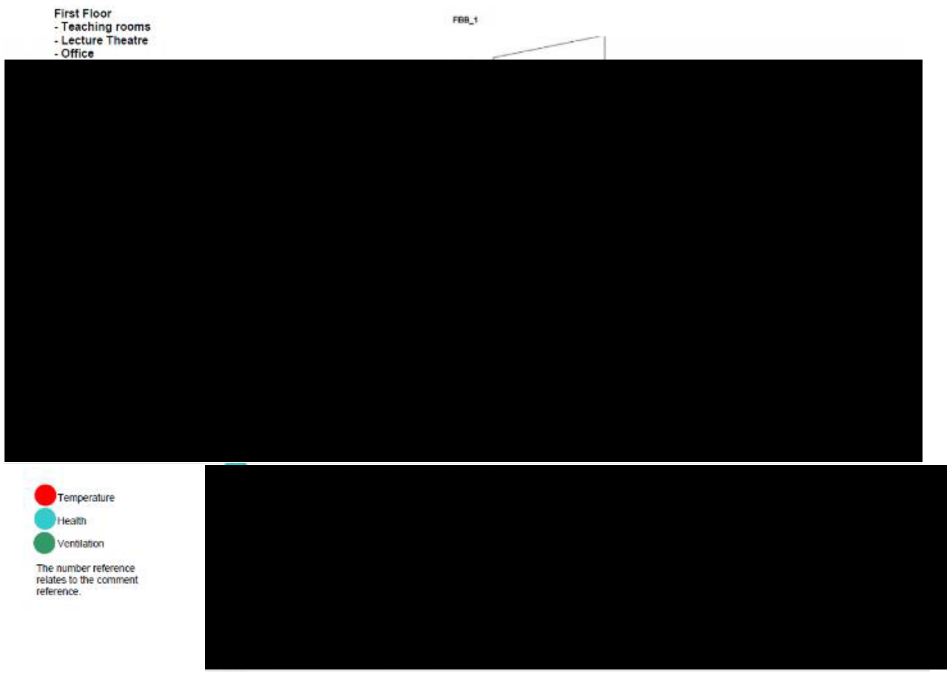


Figure B.3 Second Floor Complaints Map

Figure B.4 Third Floor Complaints Map

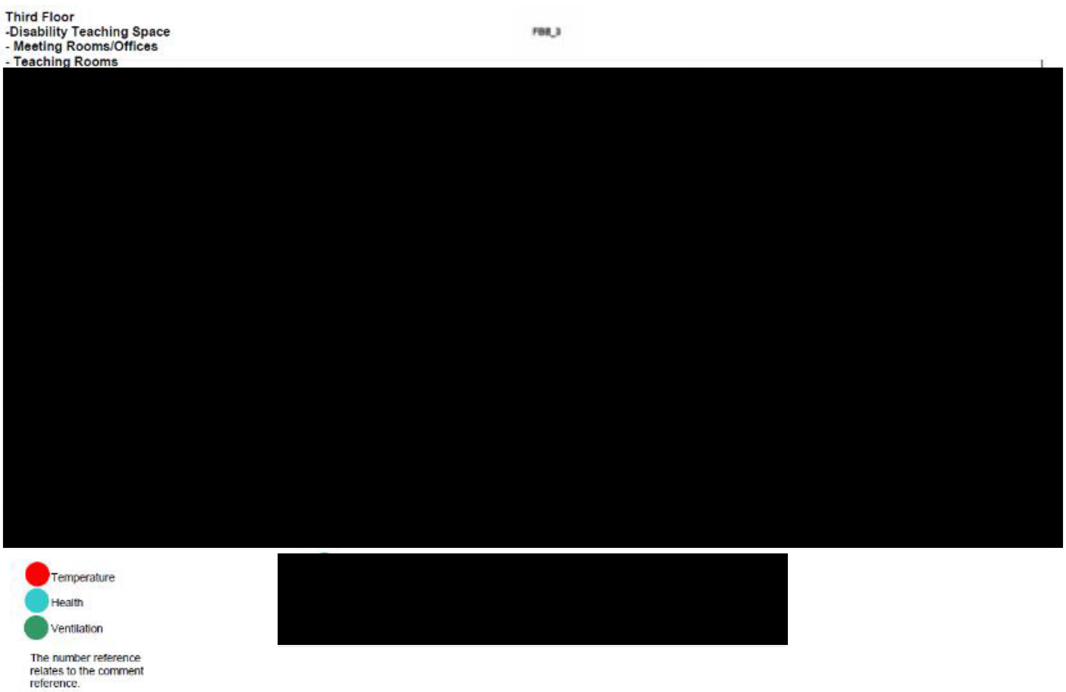
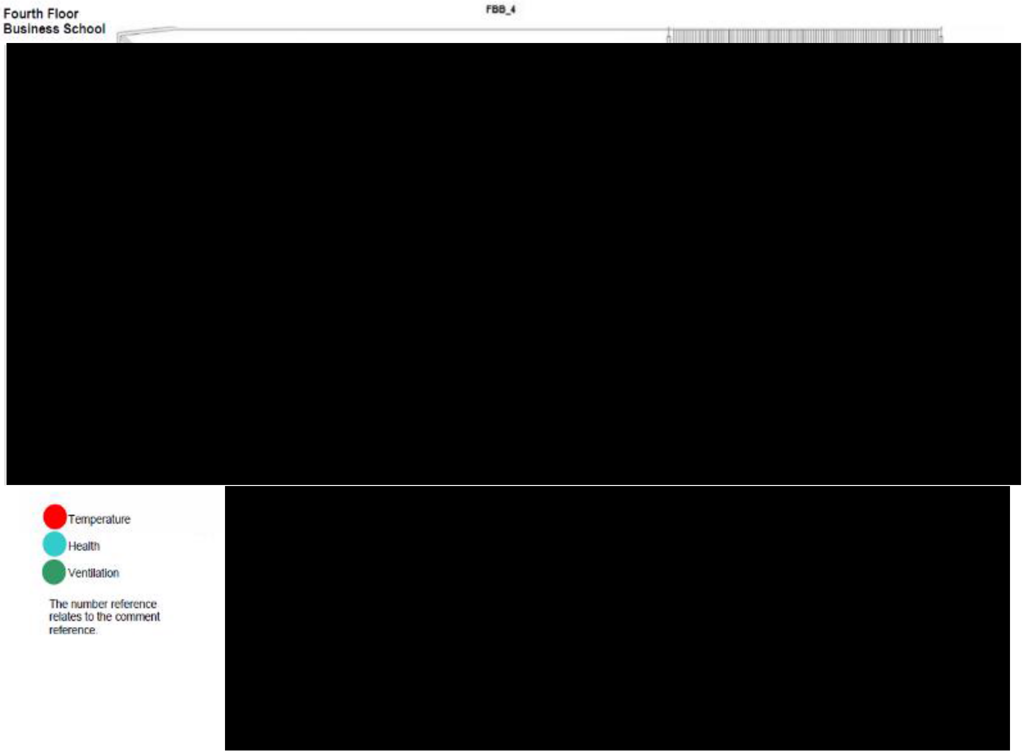


Figure B.4 Fourth Floor Complaints Map



Appendix C Air Handling Plant Surveys