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Thermal Comfort Assessment

Great Hall, Pensions Rooms, & Chapel, Gray's Inn, London

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1. Executive Summary

The following report details the findings of a thermal comfort and overheating assessment undertaken for the existing historic buildings at Gray's Inn, London. The plan below shows the extent of the areas included, which comprise of:

- Great Hall
- Small Pensions Room
- Large Pensions Room
- Benchers' Library
- Chapel
- North Library

The study assesses the overheating risk in the occupied rooms of the building and the effectiveness of passive measures in controlling overheating in the building.

The assessment uses CIBSE TM52 as the overheating criteria with which to define compliance and follows the procedures and guidance referred to as the 'cooling hierarchy' as defined in Camden Planning Guidance documents.

The building is modelled using computational thermal modelling software and compliance with the guidance is checked after each measure is introduced.

The study has identified that opportunities for introducing passive measures to the existing building is limited due to the historic nature of the buildings and that passive measures have limited impact on controlling overheating. Some occupied rooms in the building require active cooling to adequately control overheating in summer and maintain comfortable conditions for occupants.

2. Introduction

Oscar MEP Ltd have been appointed by The Honourable Society of Gray's Inn to undertake a thermal comfort study of the rooms and spaces as defined in section 1 of the report in support of a planning application for new associated plant space. The report has been undertaken to demonstrate that the 'cooling hierarchy' detailed in Camden's Planning Guidance has been followed and to identify the need for active cooling within the building.

The assessment is based on guidance from the Chartered Institute of Building Services Engineers (CIBSE) and assesses the overheating risk and thermal comfort of occupied rooms in the existing building. The assessment has been undertaken by a Chartered Engineer and member of CIBSE.

The following overheating assessment includes the principle occupied rooms of the Great Hall, Chapel, Small Pensions Room, Large Pensions Room, Benchers' Library, and North Library.

3. Policy Guidance

The London borough of Camden Planning Policy requires that a 'cooling hierarchy' is followed when assessing the need for cooling. The Requirements are set out in the Camden Local Plan Policy CC2 and can be found within the Camden Planning Guidance Energy Efficiency and Adaptation document, section 10, 'sustainable design and construction measures'.

With changing climate and warmer summers, the planning guidance recognises the increasing risk of overheating in occupied buildings. The cooling hierarchy contained in the planning guidance sets out to reduce the need for active cooling by prioritising passive measures first as a way to mitigate overheating risks.

The Cooling hierarchy comprises the following:

1. Minimise internal heat generation through energy efficient design.
2. Reduce the amount of heat entering a building in summer.
3. Manage the heat within the building through exposed internal thermal mass and high ceilings.
4. Passive Ventilation
5. Mechanical Ventilation
6. Active Cooling.

As can be seen above, active cooling should be the last measure to control overheating. This assessment and report explores the opportunities to reduce overheating risk in the building, following the priorities of the cooling hierarchy.

4. Assessment Criteria (Defining 'overheating')

CIBSE TM52 The Limits of Thermal Comfort: Avoiding Overheating in European Buildings is the basis of the overheating criteria to which the following assessment is undertaken. This technical memorandum document was released in 2013, replacing the previous CIBSE Guide A overheating criteria, which failed to account for adaptive comfort.

The following three criteria taken together are used to assess the risk of overheating of buildings in the UK and Europe. A room or building that fails any two of the three criteria is classed as overheating.

1. The first criterion sets a limit for the number of hours that the operative temperature can exceed the threshold comfort temperature (upper limit of the range of comfort temperature) by 1°C or more during the occupied hours of a typical non-heating season (1st May to 30th September). The criterion is set such that the operative temperature shall not exceed the maximum temperature by more than 1°C for more than 3% of the occupied hours.

2. The second criterion deals with the severity of overheating within any one day. This can be as important as its frequency, and the level of which is a function of both temperature rise and its duration. The daily weighted exceedance (hours x ΔT) shall be less than or equal to 6 in any one day.

3. The third criterion sets an absolute maximum daily temperature for a room. The operative indoor temperature shall not exceed the maximum value by 4°C.

5. Cooling Hierarchy

5.1. Minimise internal heat generation through energy efficient design.

The first point on the hierarchy is to minimise the heat that is generated. The less heat produced, the less risk of overheating and less need for cooling. The following are guidance notes and examples contained within Camden's planning guidance:

- Layout and uses: locate any spaces that need to be kept cool or that generate heat on cooler sides of developments.
- Reducing heat gains e.g. including low energy lighting.
- Seal/ insulate heat generating processes.
- Reduce the distance heat needs to travel and insulate pipework.
- Design layouts to promote natural ventilation e.g. shallow floor plans and high floor to ceiling heights.
- Consider evaporation cooling which cools air through the evaporation of water.
- Consider 'free cooling' or 'night cooling', which uses the cooling capacity of ambient air to directly cool the space.

The buildings considered in this assessment are existing historic buildings with solid masonry walls and existing single glazed sash windows and stained glass windows throughout. The layout and orientation of the building cannot be influenced or altered as it is existing. Similarly, the floor plans are inflexible due to existing load bearing walls and the historic nature of the building.

The opportunity for 'night cooling' is limited due to the location of the building preventing windows being left open overnight when the building is not occupied, as this would introduce a security risk.

In any refit of the spaces which includes replacement lighting, it would be proposed to install LED lighting, which is high efficiency and low energy, reducing the waste heat created.

<u>ACTION : For this assessment it is assumed that all lighting will be LED throughout.</u>

5.2. Reduce the amount of heat entering a building in summer.

The following are guidance notes and examples contained within Camden's planning guidance on ways to reduce the heat entering the building from external sources:

- Consider the angle of the sun and optimum daylight and solar gain balance.
- Orientate and recess windows and openings to avoid excessive solar gain.
- Consider low g-values and the proportion, size and location of windows.
- Make use of shadowing from other buildings.
- Include adequate insulation.
- Design in shading: e.g. include internal courtyards, large shade-providing trees and vegetation, balconies, louvers, internal or external blinds, and shutters.

As noted within the first point on the cooling hierarchy, the building is existing, with existing windows of fixed size and position. Due to the historic nature and appearance of the building and its location, external shading devices (e.g. brise soleil) would be impractical to install.

The existing building has a mixture of clear glazing and stained glass windows. There are companies that provide solar control films that can be retrofitted to existing windows to reduce the 'g-value' of the glass. This film blocks some of the suns heat (solar transmittance) and prevents it from entering the building, thereby reducing the overall heat entering the building. This would obviously not be a practical solution to the stained glass windows, which are of historic significance and should not be altered.

ACTION: This assessment will investigate the impact of lowering the g-value of the existing clear glazing (excluding Great Hall and Chapel) to 0.5 to simulate the application of solar film being installed ("Scenario 2", refer to Section 6 of the report).

5.3. Manage the heat within the building through exposed internal thermal mass and high ceilings.

Again, given that the building is existing, the opportunity for adding thermal mass or increasing ceiling height is not feasible. However, the building is constructed from solid masonry walls with some areas benefiting from high exposed thermal mass and very high ceilings, which will contribute to the benefits of thermal mass in the building.

It is worth noting that the benefits of thermal mass are greatest when night cooling can be implemented to purge the building of excess heat overnight. Unfortunately, as described previously, the opportunity for night cooling is limited as windows cannot be left open overnight.

5.4. Passive ventilation

Passive ventilation comprises ventilating a building using natural driving forces for air movement, such as exploiting the change in buoyancy of air with temperature change (the 'stack effect') and capturing the difference in air pressures due to wind movement.

The position of the building means that it is relatively sheltered from main roads and therefore it would be feasible to open windows for ventilation and purging heat. However, the majority of windows are historic features, some with stained glass, and as such it would not be feasible to introduce additional opening windows over and above what is already installed.

That said, the thermal model will look at maximising passive ventilation by modelling all available opening windows as being open in warm weather.

Windows to the large pensions room that face onto Gray's Inn Road are assumed to remain closed due to the close proximity of the road and consequent noise pollution.

ACTION: the assessment will investigate the benefits of using all available existing opening windows throughout the building ("Scenario 3", refer to section 6 of the report).

5.5. Mechanical ventilation

The following are guidance notes and examples contained within Camden's planning guidance on implementing Mechanical Ventilation as a way to control overheating and reduce cooling requirements:

- Ensure the most efficient system possible.
- Consider mechanical ventilation with heat recovery.

The historic nature of the buildings means that a mechanical ventilation system would be impractical to implement, without significant adverse effects on the heritage of the buildings. As such, mechanical ventilation is not considered as a feasible option for these spaces.

5.6. Active cooling

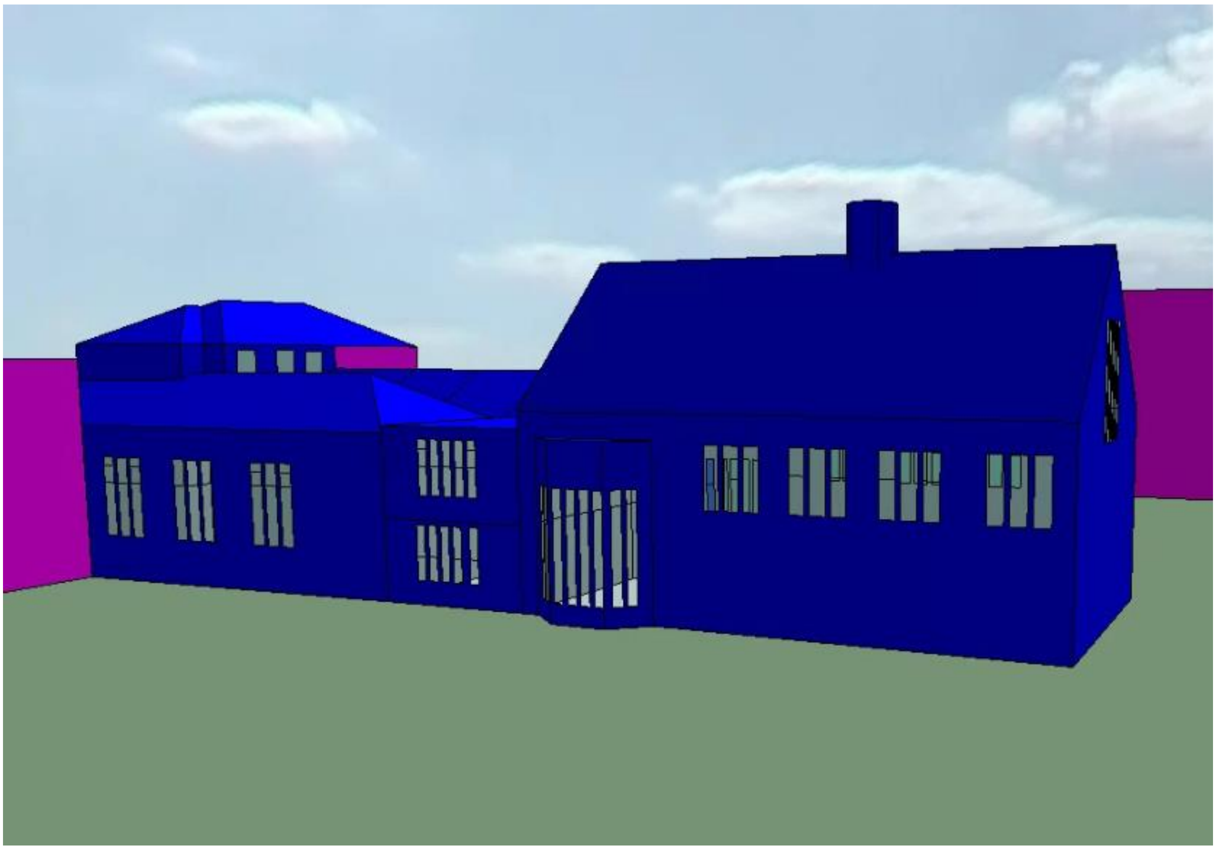
Following all of the above measures that have been identified as being practical within the constraints of the existing building, if any of the rooms still fail the TM52 overheating test, then active cooling will be modelled ("Scenario 4" refer to section 6 of the report).

6. Thermal Model

6.1. The model

In order to assess the risk of overheating and accurately model the building and compliance with CIBSE TM52 criteria, a dynamic thermal model was produced. The analysis was undertaken using IES Virtual Environment 2024 software, with the model being created in compliance with CIBSE AM11.

The thermal model includes details of the thermal fabric of the building, geometry, and internal heat gains in each room and space.



Images from thermal modelling software (purple blocks represent adjacent buildings)

6.1.1. Building Fabric

The thermal model includes details of the fabric of the building. Based on the age of the building and visual surveys, the following thermal performance was used to model the building:

Element	Thermal Performance (U-Value, W/m²K)
Walls	1.3
Windows	5.1 (g-value = 0.8)
Floors	3.0
Roof	2.0

6.1.2. Internal Heat Gains

Internal heat gains have been applied to the rooms and spaces in the building to represent real world heat generated within the building.

Internal Heat Source	Modelled heat gain
Lighting	10 W/m²
People	90W sensible heat gain
Occupied hours (during which internal heat gains are present)	8am to 6pm, Monday to Friday

Room	Peak Occupancy
Great Hall	180 people
Large Pension Room	110 people
Small Pension Room	30 people
Benchers' Library	30 people
Chapel	80 people
North Library	9 people

6.2. Climate

Within the modelling software (IES Virtual Environment) different weather files can be selected to simulate differing climates. In accordance with the planning guidance, CIBSE DSY (Design Summer Year) weather files have been used to simulate summer, based on the location of Central London and considering future proofing for future impacts of overheating from climate change.

The weather file used in this assessment is the London Weather Centre 'Design Summer Year' LWC_DSY 2, which is the most onerous of the three DSY weather files available and is representative of a property in the central London urban zone.

6.3. Scenario 1: The Existing building prior to implementing the cooling hierarchy.

The base case scenario assumes the building envelope and fabric is as existing, no active cooling is installed, and occupied spaces are provided with minimum fresh air requirements of outdoor air.

The following results demonstrate the performance of the building relative to the requirements of CIBSE TM52 overheating criteria:

Room	Occupied Summer Hours	Criterion 1: % Hours Exceeding Comfort Range	Criterion 2: Peak Daily Weighted Exceedance	Criterion 3: Hours Exceeding Absolute Limit	Pass / Fail
Great Hall	1000	4.7	43	7	Fail
Small Pension Room	1000	8.6	44	6	Fail
Benchers Library	1000	10.8	53	9	Fail
Large Pension Room	1000	41.7	78	10	Fail
North Library	1000	4	29	4	Fail
Chapel	1000	2.7	29	6	Fail

6.4. Scenario 2: The addition of solar film to existing windows.

The g-value of the existing windows was lowered to 0.5 to simulate the application of solar control film applied to glazing, and the overheating assessed again. The benefit of this was extremely limited due to large amounts of stained glass windows:

Room	Occupied Summer Hours	Criterion 1: % Hours Exceeding Comfort Range	Criterion 2: Peak Daily Weighted Exceedance	Criterion 3: Hours Exceeding Absolute Limit	Pass / Fail
Great Hall	1000	4.6	43	7	Fail
Small Pension Room	1000	7.5	43	6	Fail
Benchers Library	1000	10.1	53	9	Fail
Large Pension Room	1000	33.4	71	9	Fail
North Library	1000	2.7	29	6	Fail
Chapel	1000	2.7	29	6	Fail

6.5. Scenario 3: The addition of natural ventilation.

Following on from Scenario 2, rooms were modelled with opening windows during occupied hours in the day. The results are below:

Room	Occupied Summer Hours	Criterion 1: % Hours Exceeding Comfort Range	Criterion 2: Peak Daily Weighted Exceedance	Criterion 3: Hours Exceeding Absolute Limit	Pass / Fail
Great Hall	1000	2.6	33	6	Fail
Small Pension Room	1000	3.5	32	6	Fail
Benchers Library	1000	5.2	40	8	Fail
Large Pension Room	1000	16.4	59	8	Fail
North Library	1000	1.1	15	3	Pass
Chapel	1000	2.3	29	6	Fail

6.6. Scenario 4: Controlling overheating with active cooling.

The assessment in Scenario 3 demonstrates that with practical passive measures and enhanced ventilation provision, the overheating severity is reduced, but many rooms are still not compliant with TM52. Therefore, a final scenario has been undertaken with active cooling included within the thermal model. The results are shown below:

Room	Occupied Summer Hours	Criterion 1: % Hours Exceeding Comfort Range	Criterion 2: Peak Daily Weighted Exceedance	Criterion 3: Hours Exceeding Absolute Limit	Pass / Fail
Great Hall	1000	0	0	0	Pass
Small Pension Room	1000	0	0	0	Pass
Benchers Library	1000	0	0	0	Pass
Large Pension Room	1000	0	0	0	Pass
North Library	1000	0	0	0	Pass
Chapel	1000	0	0	0	Pass

7. CONCLUSIONS

7.1. The need for active cooling

The overheating assessment has determined that passive measures alone (following the cooling hierarchy) are not sufficient to ensure compliance with TM52 for overheating. This is largely due to the existing building constraints providing limited scope for passive measures, including, lack of cross flow ventilation, lack of opening windows, and the historic nature of the buildings preventing any more major interventions such as mechanical ventilation systems.

As existing spaces within the building are refurbished and updated, the development will look to implement passive measures where practical and feasible, including low energy LED lighting and exposed thermal mass to assist with controlling overheating.

The application of active cooling in the rooms within the building has provided a way to demonstrate compliance with CIBSE TM52 overheating criteria.

7.2. Optimising the active cooling design

It is intended that wherever possible, active cooling will be provided by the proposed central heat pump systems that will also be used to provide space heating. This type of simultaneous heating and cooling system is highly energy efficient, allowing heat to be recovered from one area of the building and put to use to heat other areas of the building, rather than simply wasting the heat energy by rejecting it to outside air. It will provide Gray's Inn with a holistic, energy efficient approach to heating and cooling, designed to future proof against anticipated climate change.