

Power Hall & Decarbonisation Project

Package 3b - M&E strategy report

Power Hall and Site Decarbonisation Works

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ISSUE HISTORY

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1.0 INTRODUCTION

This report has been prepared by Max Fordham LLP on behalf of and in collaboration with the Science and Industry Museum and the rest of the Design team.

1.1 Overview

The Museum is looking to develop a site wide sustainability strategy with the aim to meet the carbon emission targets set by the Manchester City Council by 2030.

The Museum, as a public body and relevant Institution promoting scientific progress, aims to provide a tangible contribution to a more sustainable future and contribute to improve awareness on the Climate Change issue.

As part of this vision, technical investigations have been carried out to explore how innovative solutions as part of the building refurbishment works can contribute to reducing the operational carbon footprint of Site, with reference to the heating, cooling and lighting energy demand.

1.2 Objectives

The purpose of this report is:

- To illustrate the overall upgrading of the M&E systems across the Science and Industry Museum Power Hall building
- To describe the proposal for the new roof package, rooflights, windows and doors will improve the energy and comfort performance of the building
- To present the analysis taken for refurbishing the rainwater system, with particular reference to the roof gutters.
- To describe the new general lighting system, to be installed at high level contextually with the roof renovation
- To present the new M&E systems to be installed at high level, as part of the wider Power Hall system refurbishment
- To illustrate the interfaces of the new systems with listed building requirements.

2.0 THE PROJECT

2.1 Power Hall & Decarbonisation

The Power Hall and Decarbonisation project is to be delivered as one project. However, the required Planning and Listed Building Consent applications must be split into several separate applications due to the different Listings of the buildings and the deadlines for the Government’s Public Sector Decarbonisation Scheme which needs to be completed this year. Splitting the consent packages will also allow construction works to start on site earlier and ensure the Government deadlines will be met.

Below is the timeline table for the applications. This report will focus on work packages 3b

Power Hall & Decarbonisation - Work packages

WORK PACKAGES	PACKAGE DESCRIPTION	PLANNING AND LISTED BUILDING CONSENT APPLICATIONS	SUBMISSION DATE
1A	Water Source Heat Pump Network (External)	Application for Listed Building Consent for alterations to the Grade II Listed Power Hall for the creation of openings and the installation of plant plus the introduction of a services trench within its curtilage.	Determined 02.07.21 130170/LO/2021
	Water Source Heat Pump and other associated plant in the Power Hall	Application for Listed Building Consent for installation of a services trench within the curtilage of the Grade II Listed New Warehouse.	130173/LO/2021
1B	Boiler House External Modifications (to facilitate installation of a new sub-station)	Application for Planning Permission for external works to the Boiler Room including removal of an external staircase and making good in addition to the installation of a new balustrade and new doors.	130171/FO/2021
	Pipework in the 1830 Warehouse (to facilitate installation of a new water source heat pump)	Application for Listed Building Consent for alterations to the Grade I Listed 1830 Warehouse for the creation of openings and the installation of pipework plus the introduction of a services trench and borehole cover within its curtilage.	130172/LO/2021
2	Power Hall Roof Removal	Application for Planning Permission for removal of the Power Hall roof during refurbishment and repair works.	Determined 29.07.21 130614/FO/2021
		Application for Listed Building Consent for the removal of the Power Hall roof during refurbishment and repair works	130615/LO/2021
3a	Power Hall Timber Repairs	Application for Listed Building Consent for Timber Repairs in relation to the Power Hall roof.	Submitted 06.08.21 131290/LO/2021
3b	Power Hall New Roof, Windows & Doors, 1980s Platform Removal and Fabric Repairs	Application for Planning Permission & Listed Building Consent	Submitted 20.08.21
4	Power Hall Gallery Refurbishment, Internal Services and Rail Doors	Application for Planning Permission & Listed Building Consent	Autumn 2021

3.0 THE BUILDING

The Science and Industry Museum is located on the west of Manchester city centre, between Castlefield, to the south, and St John's Quarter, to the north. It is within the Castlefield Conservation Area and it represents a significant heritage of the Industrial history of the City.

This report will focus on the building fabric refurbishment of the Power Hall, a Grade II listed building, which is currently closed to the Public at the time this report is written.

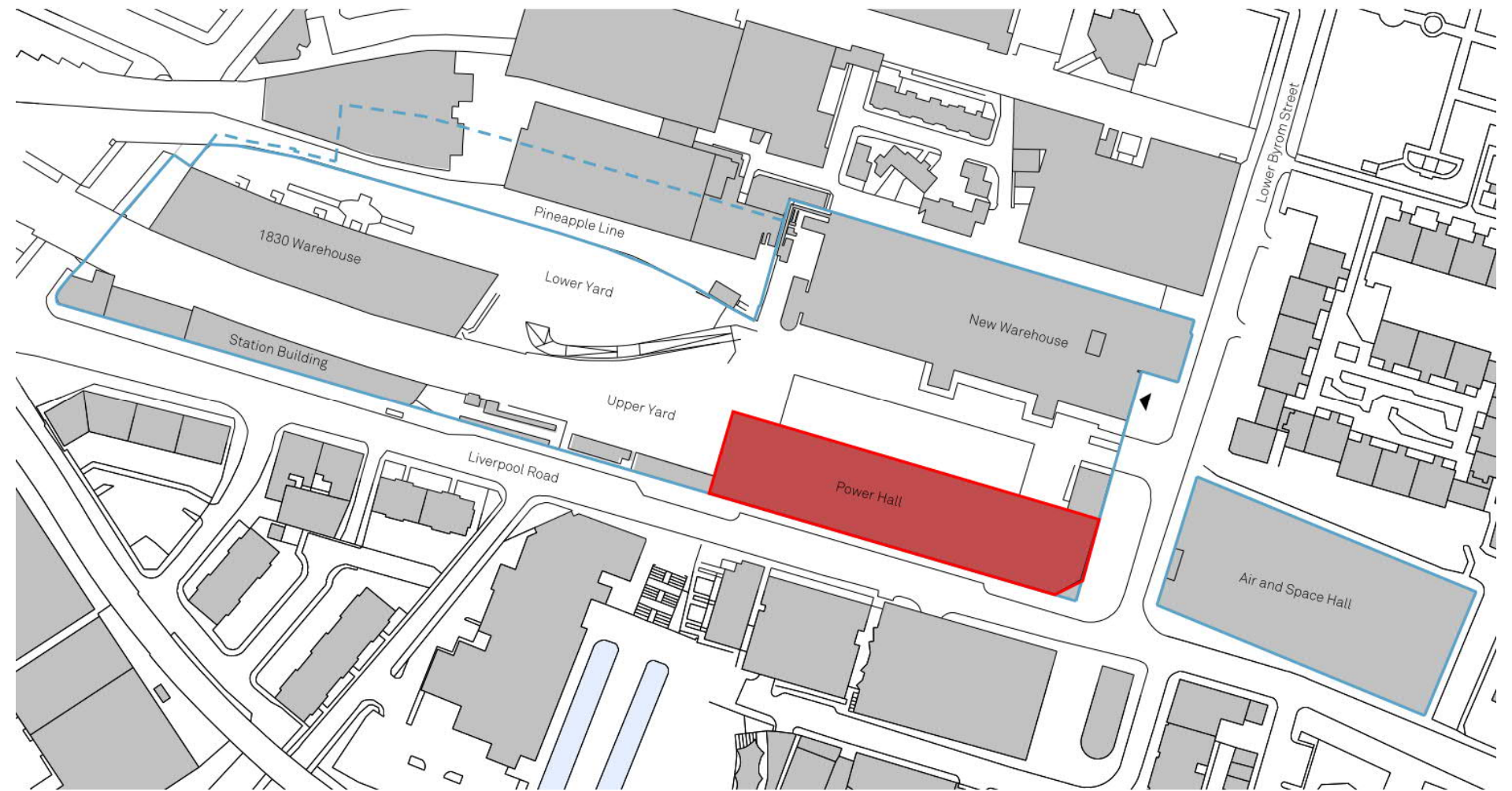


Figure 3-1 - Science Industry Museum key plan - Power Hall building

3.1 The roof

The existing double-pitched roof of the Power Hall consists of a timber structure.

There are multiple areas of water ingress which will threaten the integrity of the timber structure if left: it is in poor condition and has visible signs of damp and timber decay. The lead-lined gutters have suffered ponding and silt build-up and display several felt-patch repairs generally.

The existing rooflights consist of Georgian Wired panels, several of which display fractures and are also displaced generally. There are rooflights on all four sides of the double-pitched roof structure.

The rooflights are problematic and have resulted in leaks within the Power Hall in recent years. Their location next to the valley gutter is not ideal since the valley gutter is not deep enough to enable rain water run-off. Furthermore, the Power Hall was previously prone to overheating. Reducing the number of rooflights will help to limit potential overheating as well as any risk of future water ingress.

It is worth noting that the external roof elements have been consented to be removed already, as part of the Work Package 2 Planning & Listed Building Consent applications



Figure 3-2 - Existing rooflight detail



Figure 3-3 - Roof structure detail

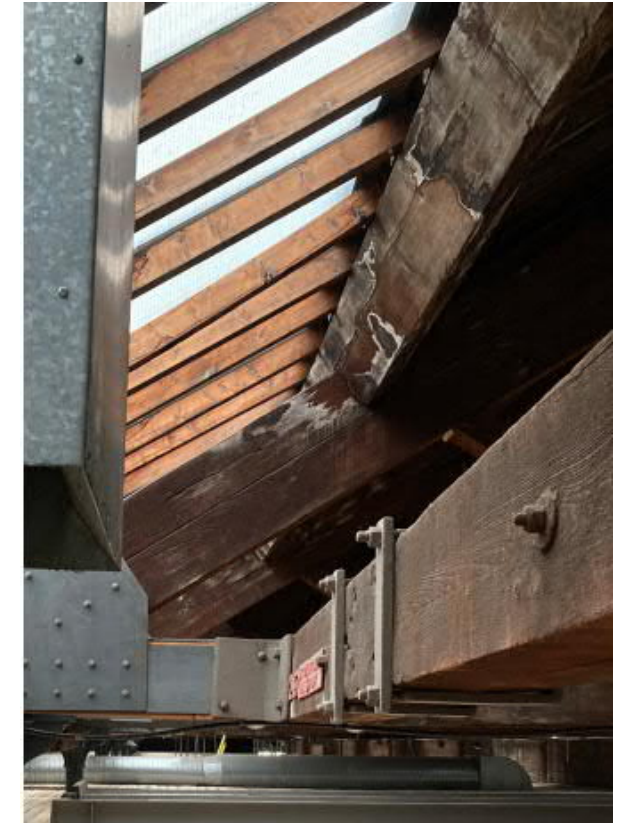


Figure 3-4 - Roof structure detail

3.2 The doors and windows

The Power Hall has large glazed apertures across the façade, which offers good daylight opportunity. However, the specification of these fabric elements is outdated and thermally inefficient.

There are six large windows with integral doors on the north façade and three large glazed doors on the south façade (including the entrance). The large glazed doors (Figure 3-6 Figure 3-5) are single glazed with some louvred elements manually operated for natural ventilation.

There are two uninsulated steel concertina doors on the west façade (Figure 3-7). It is proposed that these are replaced with insulated doors of the same area as part of the Package 4

The poor performance of these fabric elements contributes to different issues on the energy behaviour of the building:

- Contribution of the overheating – the poor solar control does not provide a sensible barrier to the solar heat gains during the hot season.
- Poor thermal insulation
- Poor acoustic insulation
- Air infiltration



Figure 3-7 - Existing concertina door detail



Figure 3-6 - Existing Window with integral door detail 1



Figure 3-5 - Existing window with integral door detail 2

3.3 The gutters

The existing rainwater system consists in linear gutters along the perimeter and to the valley of the pitched roof. The gutters discharge via exposed cast iron rainwater pipes on the perimetral walls, while alternate columns are hollow to enable rain water run-off from the valley gutter.



Hollow column acting as rainwater pipe



Internal cast iron rainwater pipe

Figure 3-8 - Existing rainwater pipe details

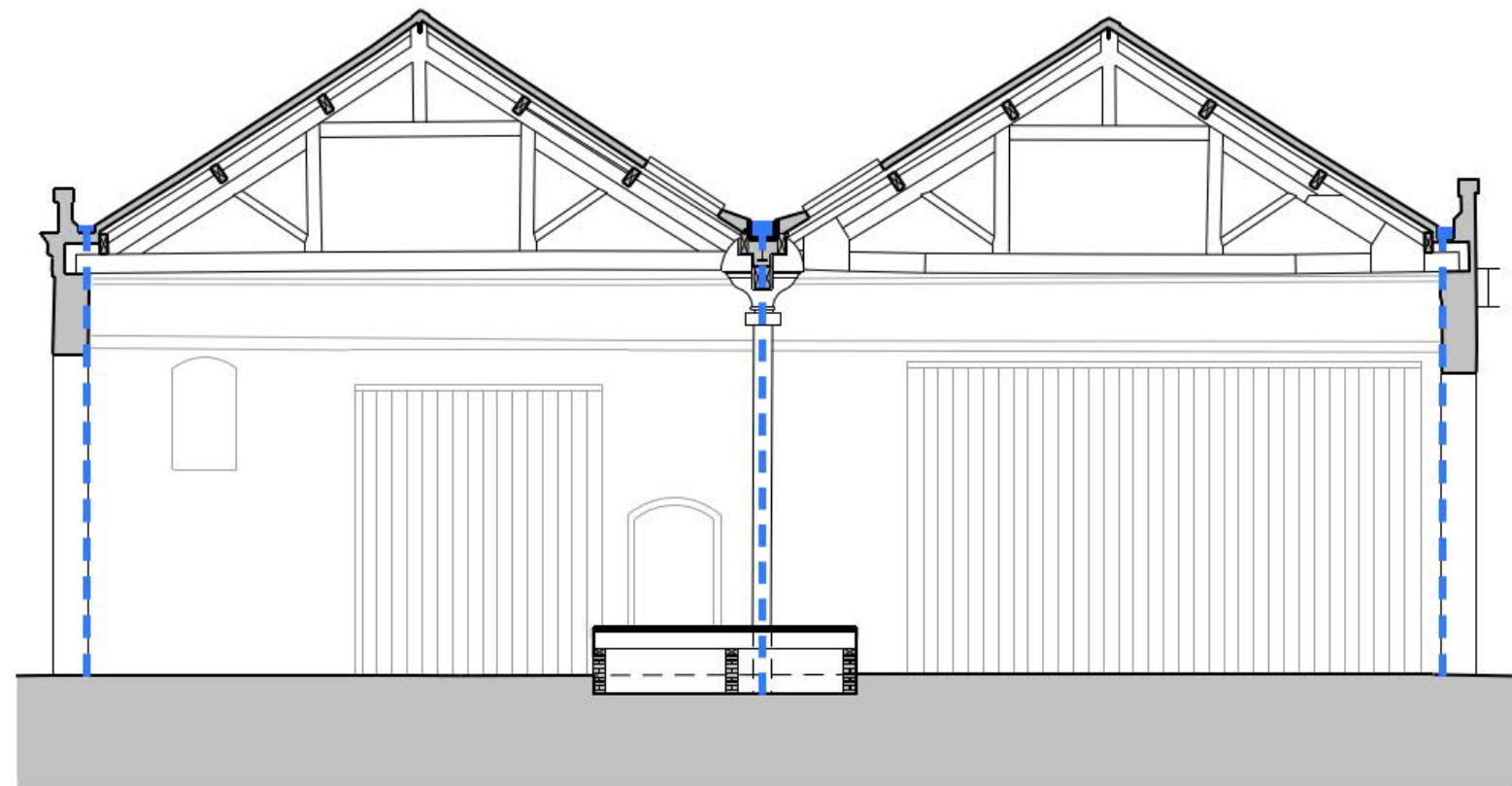


Figure 3-10 - Existing rainwater drainage strategy

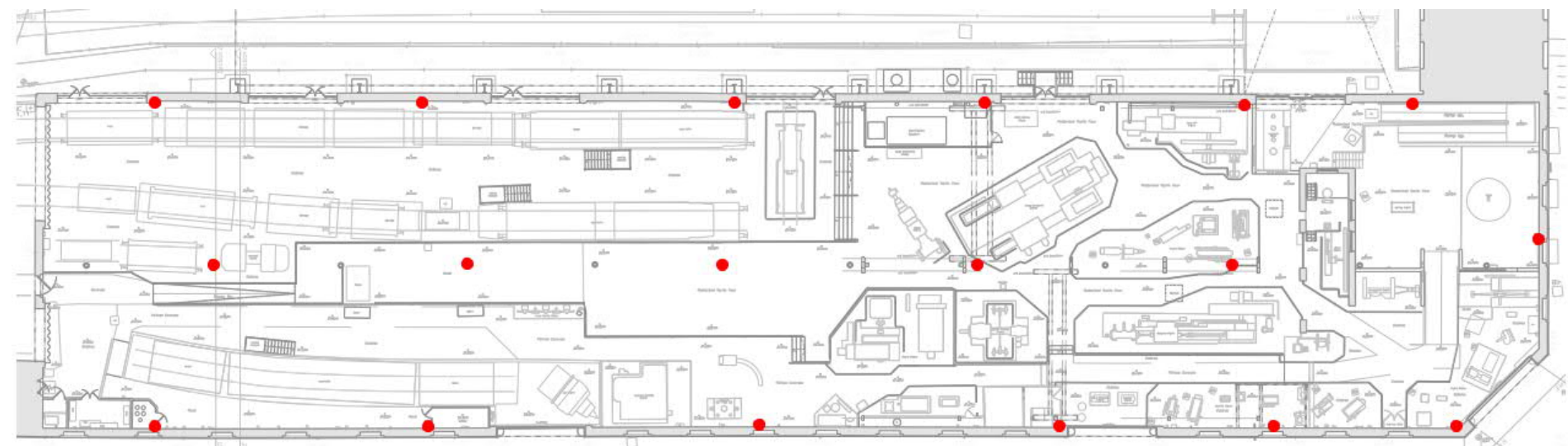


Figure 3-9 - Existing rainwater system - downpipe position

3.4 The existing lighting

The Power Hall lighting consists of several ceiling mounted high-bay fittings, as pictured in Figure 3-12.

The general house lighting is covered by the high-bay fittings and the other pendant lights pictured are only used as additional feature lighting.

The high-bay fittings are fixed at the apex of each roof-pitch and mounted at the height of the lowest truss. There is a fitting mounted at every other bay of trusses. Based on this visual assessment, it is assumed that there are 24no. high-bay fittings installed in the Power Hall.

The high-bay fittings, as pictured in Figure 3-11, are high-pressure mercury-vapour high-intensity discharge lamps, now obsolete from an efficiency point of view.

Lighting fixture efficiency is generally measured in lumen/circuit Watt (lm/cW), that indicates how much lighting effect is given for every watt of energy used. For these existing lamps the luminaires efficiency is in region of 50 lm/cW. Making them a very inefficient choice when compared to a modern LED luminaire whose efficiency levels are around three times better than the Halide fitting.



Figure 3-12 - existing lighting fixture detail



Figure 3-11 - existing lighting details

4.0 BUILDING ENERGY ANALYSIS

4.1 The existing building

The refurbishment works for the roof and the glazed elements sit on a wider picture of Decarbonisation of the site, where the renovation of elements of a listed building can be a good chance to reduce the carbon footprint of the energy used by the building.

A dynamic thermal model of the existing building has been produced, for having a realistic meter of comparison to quantify the benefit in terms of energy saving and sustainability.

4.2 Thermal modelling main assumptions

4.2.1 Existing fabric

The existing fabric elements provide poor performance in terms of energy saving and occupant comfort.

- The walls are solid brick, around 400mm thick, with no insulation, and they represent the most historic part of the building, together with some floor sections, that still retain the original construction. Despite not being insulated, the existing walls provide an excellent thermal mass that helps to attenuate the hot and cold peaks during the seasons.
- Glazed elements consist mainly in aluminium framed single glass, without element of solar gain controls. Except the entrances and escape doors, windows are not openable and ventilation is achieved via manual glazed louvres. The energy performance of these elements is poor, with limited U values, limited thermal inertia and poor control over air infiltration in winter and natural ventilation in summer
- The existing floor consists in part of original cobbles and in part of recently modern concrete slab, probably realised during the refurbishment works of the '80s.

Based on information gathered from site surveys and client feedback, the following building fabric U-values and construction build-ups have been assumed in the model in order to simulate the existing fabric performance.

Table 1 Assumed U-values of existing fabric

Element	U-Value, W/m ² K
External Wall	1.55
Ground Floor	2.62
Roof	2.44
Door	5.85
Glazing	5.56
Rooflight	5.80 ¹

¹ Figure based on available literature for 6mm clear wired glass. Refer to <https://www.metroglass.co.nz/catalogue/023.aspx>

All existing glazed elements were modelled using the following properties;

- Light transmittance: 0.71
- G-value: 0.6
- Frame factor: 5%
- Frame material: metal

The fabric is assumed to have an air infiltration rate of 0.6ACH.

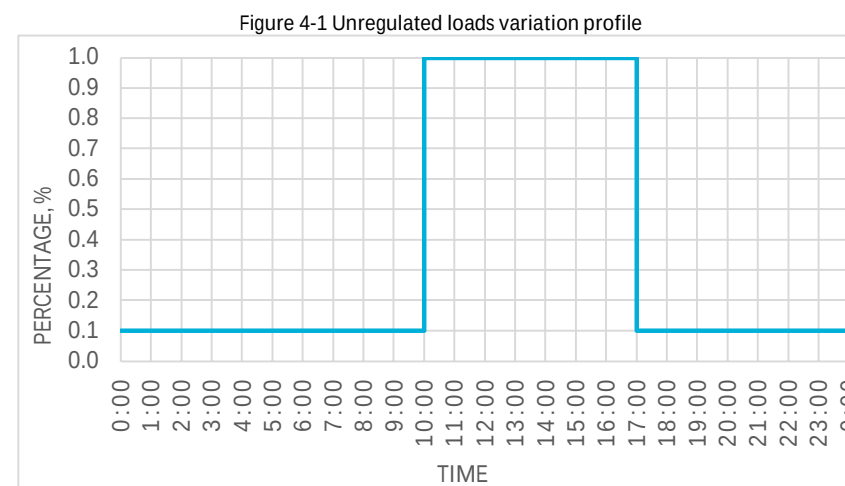
This figure has been extrapolated from data in CIBSE Guide A Table 4.20, which tabulates empirical values for air infiltration rate of rooms in warehouses on normally exposed sites in winter. The figure selected was based on a leaky building (air permeability of 20m³/m²h @50Pa).

4.2.2 Occupancy

The site is assumed to be open between the hours of 10:00 and 17:00. Occupancy is transient and therefore internal heat gains by people have not been accounted for.

4.2.3 Unregulated loads

A peak load of 5W/m² was assumed to account for unregulated loads, such as small power. The load was modelled under a profile that assumed a peak load during occupied hours and background load of 10% during unoccupied hours.



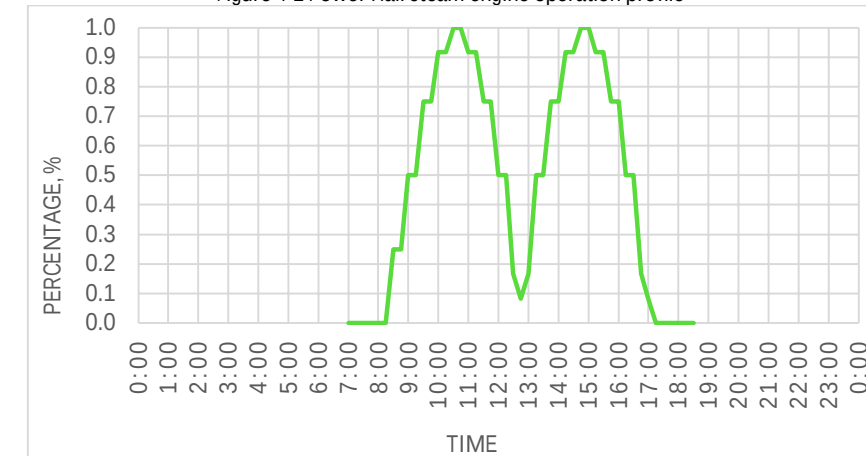
4.2.4 Equipment gains

Steam engines

The historic working machines represent a tangible contribution of the internal gains. These units are not properly insulated, working with live steam they produce a significant radiant effect to the surrounding ambient.

Estimating this heat gain contribution is empirical: as starting point it has been assumed that 10% of the assumed steam energy demand of the units was dissipated in heating on the ambient, during the display operations.

Figure 4-2 Power Hall steam engine operation profile



4.2.5 Lighting loads

The existing lighting is assumed to be operational during occupied hours and does not have any daylight dimming or presence control.

Lighting internal gain and electrical power consumption is dependent on the type and quantity of light fittings installed. The type of light fitting in each space is assumed based on survey information.

The power and luminous efficacy of each type of fitting is based on manufacturer's data for a light fitting of similar specification.

The radiant fraction is taken from standard figures recommended by the IES user guide.

Power Hall	
Fitting type	High-pressure Mercury
Total power of fitting, W	425
Luminous efficacy, lm/circ.W	49
No. of fittings	24
Power density, W/m ²	4.08
Radiant Fraction	0.62

4.2.6 Heating system

The baseline thermal model has been simulated to quantify the annual energy consumption of the existing building, assuming the fabric and operational factors set out in this section and the performance of the heat generation equipment currently installed.

The efficiency of the Power Hall heating plant is based on manufacturers' literature for plant of similar specification;

Location	Heating plant	Efficiency
Power Hall	Gas-fired steam boiler	0.94

4.2.7 Set-points and control

The assumed set-point temperature and hours of operation are outlined below;

Location	Set-point, °C	Hours of operation
Power Hall	18 day – 15 night	24hr per day

The baseline thermal model is assumed not to have any BMS installed.

4.3 Existing building – winter results

The Energy demand for heating throughout the year is 810 MWh with a max peak demand of 400kW (assuming an internal temperature of 18°C with set back at 15°C during night)



Figure 4-4 - Power Hall - existing rooflight detail

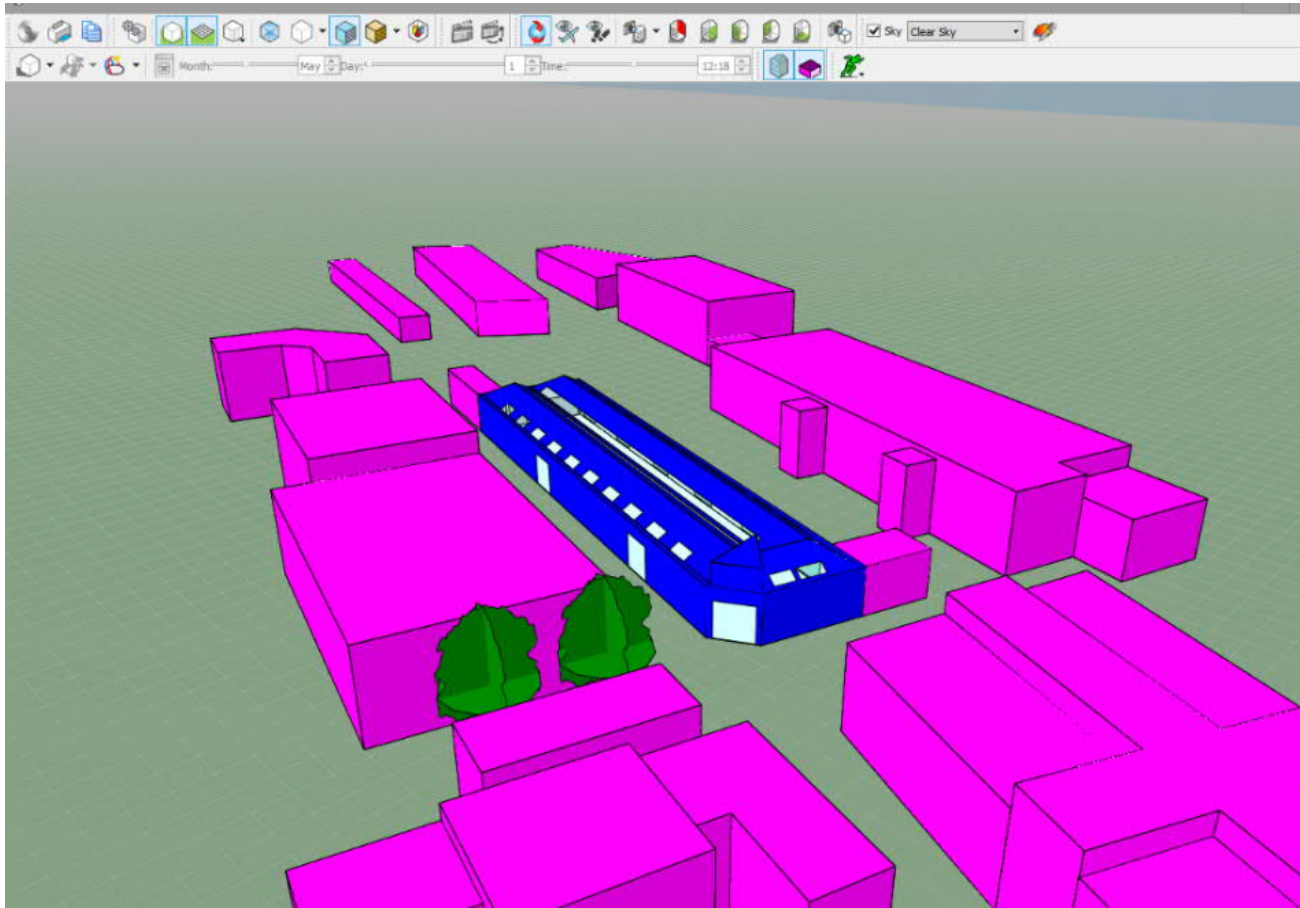


Figure 4-3 - Power Hall 3D thermal model detail

4.4 Existing building – summer results

Summer results have been assessed mainly for evaluating the risk of overheating. The Museum staff reported that during hot days, there is occupant discomfort in the Power Hall.

The modelling results for the existing building suggest that the space is warmer than outside throughout the summer and does become uncomfortable for occupants during periods of hot weather. This tallies with reports of the experience of the existing building reported by the museum.

The space would not pass the requirements of CIBSE TM52 and therefore does not meet the minimum recommended standard for a naturally ventilated space.

The overheating in the existing building is primarily driven by large amounts of solar gain through the rooflights and windows, with no ventilation (other than the entrance door) available to help purge the heat that builds up in the space.

Figure 4-5 shows that with the current assumptions there is an element of overheating in the existing building. The internal temperature will go above 26°C and above the outside air temperature during the hottest days.

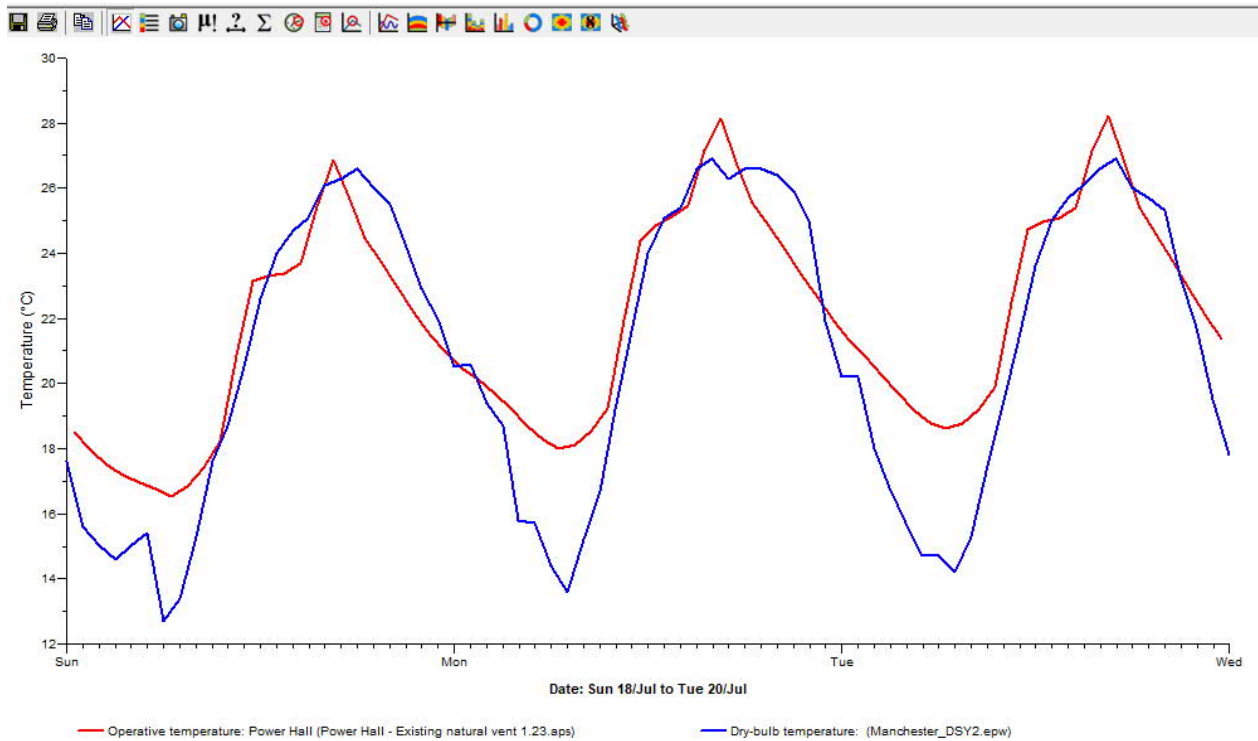
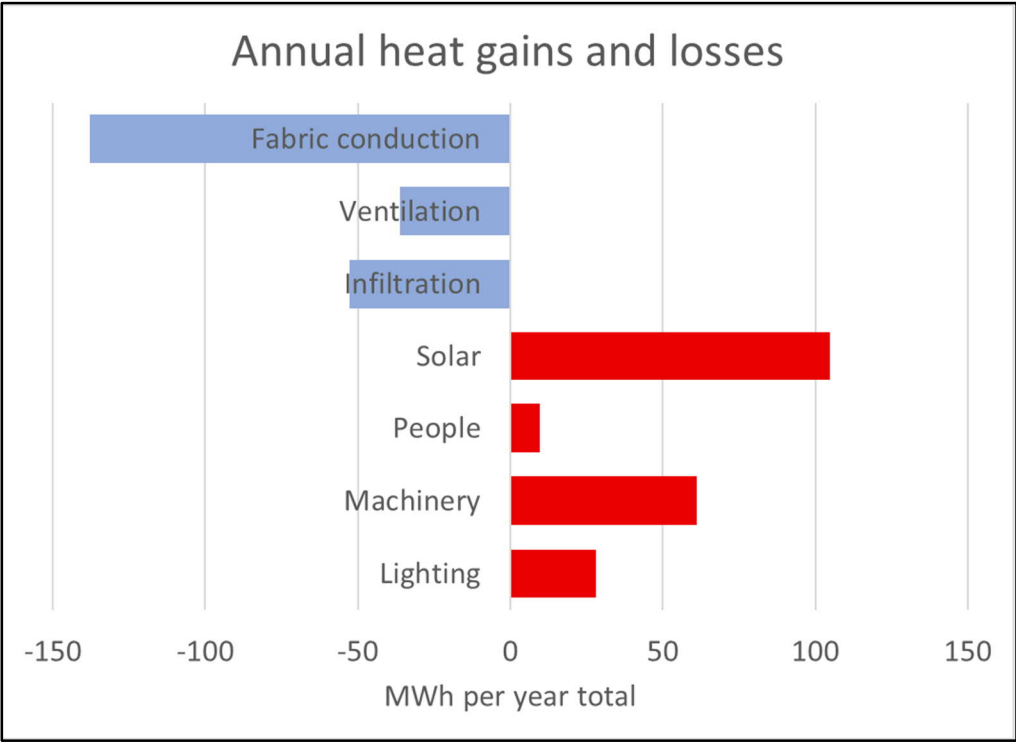
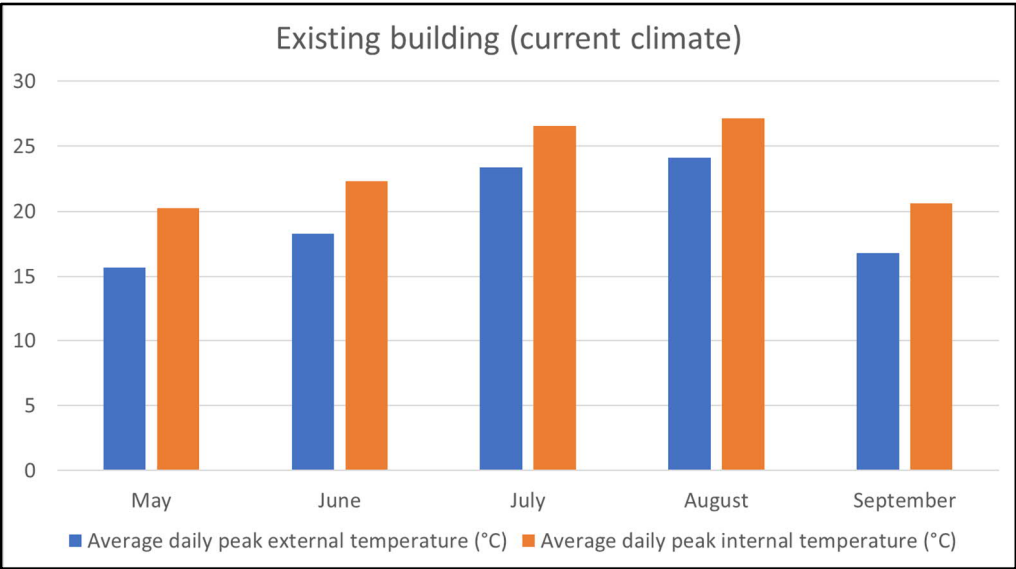


Figure 4-5 - Power Hall existing building - Outdoor temperature (blue) vs Internal temperature (red)



Overheating metric	Results
CIBSE TM52 compliance check	FAIL
Percentage of occupied hours where internal temperature > 25°C	20%
Percentage of occupants who would feel uncomfortably warm on the hottest day of the year	88%

5.0 BUILDING FABRIC REFURBISHMENT – DECARBONISATION BENEFITS

The building fabric repairments will sit within the wider decarbonisation strategy of the building. Despite refurbishment works on GRADE II listed buildings will not be subject to minimum statutory limits on energy efficiency (like Building Regs. part L requirements), it is the right chance to design the new element maximising the overall sustainability performances, whilst minimising the impact on the listed building heritage.

It is proposed then to include the following energy performance improvements together with the new building fabric elements:

- Enhancing the roof insulation to limit the winter heat losses, to improve air tightness and reduce the overheating in summer.
- Installing better performing glazed elements for thermal and solar characteristics, that can limit both the winter heat losses and the solar gains in summer. On this element is it worth noting that the existing glazed elements are a particular weak point of the current building energy behaviour, due to the poor glass characteristics.
- Providing dedicated openable sections on the new windows for natural ventilation purposes, to be used mainly for mitigating the overheating risk in hot season.
- Installing a new LED lighting system for reducing the energy consumption and internal heat gains in summer.
- Reducing the number of rooflights to limit the summer overheating issue of the building.

The following paragraphs will present the analysis and results for each proposed intervention.

5.1 Building fabric improvements

The thermal model was run across different building fabric configurations to better assess the benefit of each proposed change.

The analysis was carried out to investigate the optimum balance among energy benefits, costs, and listed building requirements.

The tables beside summarise the energy loads and condensation risk within the internal ambient for different configurations of roof U values, Windows U values and fabric infiltrations.

This matrix can help to identify what can be the optimum combination of different elements improvements while minimising the impact on the listed building requirements and cost implications.

The numbers show the internal temperature set point and the infiltration rates have the highest impact on addressing energy consumption and mitigating the risk of condensation.

Maintaining a constant internal temperature at 18°C will sensibly mitigate the condensation risk but it will also increase the energy consumption.

Improving the roof and glazing U values will help reduce the energy consumption and mitigate the surface condensation risk, however they should be considered holistically together with the other parameters.

For the building fabric refurbishment, it is then proposed:

- A new roof U value of 0.2 W/m2K
- A targeted infiltration rate of 0.2 ACH (comparable on having an average 6 mc/h/sqm with a 50 Pa of differential pressure), to be achieved with the new roof, windows and door installation
- A new window overall U value of 1.4 W/m2K
- An internal day temperature of 18°C with the night set point of 15°C

These proposed interventions will reduce the building CO2 emission by 30%

	Heating demand	CO2	CO2 Savings
	[kWh/year]	[kg/year]	[%]
Power Hall existing building envelope	829,898	200,152	
Power Hall - new roof and glazed elements	581,500	140,244	30%

Power Hall thermal analysis - building fabric improvement - summary table results							
Simulation	INPUT PARAMETERS			HEATING RESULTS		CONDENSATION RISK ASSESSMENT	
	Heating set-point	Roof U-value (W/m2K)	Infiltration (ach)	Annual heating demand (MWh)	Peak heating load (kW)	Condensation risk?	No. of hours/year surface temp < dew point
1.04	15°C constant	0.30	0.6	591.4	221.6	YES	60
1.05	15°C constant	0.30	0.2	411.9	140.2	YES	36
1.06	15°C constant	0.20	0.6	580.7	216.3	YES	61
1.07	15°C constant	0.20	0.2	401.5	135.5	YES	36
1.08	15°C constant	0.15	0.6	575.2	214.6	YES	62
1.09	15°C constant	0.15	0.2	396.2	133.2	YES	36
1.10	18°C with 15°C set back	0.30	0.6	819.4	359.7	YES	36
1.11	18°C with 15°C set back	0.30	0.2	593.2	270.7	YES	29
1.12	18°C with 15°C set back	0.20	0.6	807.2	354.9	YES	36
1.13	18°C with 15°C set back	0.20	0.2	581.5	264.9	YES	28
1.14	18°C with 15°C set back	0.15	0.6	801.1	352.4	YES	37
1.15	18°C with 15°C set back	0.15	0.2	575.6	262.4	YES	28
1.16	18°C constant	0.30	0.6	1001.3	270.2	YES	1
1.17	18°C constant	0.30	0.2	733.8	177.7	NO	0
1.18	18°C constant	0.20	0.6	986.6	264.3	YES	1
1.19	18°C constant	0.20	0.2	719.6	172.3	NO	0
1.20	18°C constant	0.15	0.6	979.2	261.3	YES	1
1.21	18°C constant	0.15	0.2	712.4	169.7	NO	0

Power Hall thermal analysis - building fabric improvement - summary table results - Glazing U value						
Simulation	INPUT PARAMETERS			HEATING RESULTS		
	Heating set-point	Roof U-value (W/m2K)	Infiltration (ach)	Glazing U-value (W/m2K)	Annual heating demand (MWh)	Peak heating load (kW)
1.07	15°C constant	0.20	0.2	1.40	401.5	135.5
1.25	15°C constant	0.20	0.2	1.60	406.9	137.5
1.24	15°C constant	0.20	0.2	1.80	412.1	139.5
1.13	18°C with 15°C set back	0.20	0.2	1.40	581.5	264.9
1.26	18°C with 15°C set back	0.20	0.2	1.60	587.9	267.2
1.27	18°C with 15°C set back	0.20	0.2	1.80	594.3	269.4
1.19	18°C constant	0.20	0.2	1.40	719.6	172.3
1.22	18°C constant	0.20	0.2	1.60	727.1	174.6
1.23	18°C constant	0.20	0.2	1.80	734.7	176.9

5.2 Summer analysis

The thermal analysis on the existing status reports the building suffers of overheating. The same discomfort was also confirmed by the Museum staff, confirming the modelling results coming from a desktop analysis.

The refurbishment works propose to minimise the thermal discomfort during the hottest days with passive strategies, that will take advantage of the significant thermal mass of the building and the generous volume of the ambient space

For assessing the risk of overheating, the following parameters have been considered:

- CIBSE TM52 compliance results. TM52 is a standard for assessing the risk of overheating in naturally ventilated buildings. Passing TM52 for a space should be considered the very minimum standard for a design to meet. For extra robustness, each option has been assessed against three standard “design summer year” (DSY) weather files, each of which represents a different type of warm summer.
- Percentage of occupied hours with internal temperature greater than 25°C. This is given as a percentage of the total number of hours between 10am and 5pm from May to September (when overheating risk is greatest). It is generally accepted that 25°C is the temperature at which some people would start to feel uncomfortable during summer. These results give an indication of how often this might occur over the entire summer for each option.
- Percentage of occupants who would feel uncomfortably warm on the hottest day of the year. This measure is of course a subjective one. However, the results are based upon scientific studies of people’s comfort at various conditions (including temperature, humidity, air speed, clothing level and activity level). These results give an indication of the extent of discomfort that museum visitors are likely to experience on the hottest day of the year for each option.
- Annual heat gains and losses graph. This gives an overview of the types of heat transfer that are behind the conditions in the space and the risk of overheating. Heat leaving the space is shown in blue, whilst heat entering the space is shown in red. The losses and gains are shown as total energy summed over an entire year.
- Average daily peak temperatures graph. This shows how the predicted internal temperature in the Power Hall compared against the external temperature. The peak internal and external temperatures for each day of the year have been averaged by month and graphed.

The thermal analysis on the existing model highlights that the major contribution to the summer overheating are the solar gains.

The strategies investigated to limit the overheating issue are:

- Reducing the number of roofglasses.
- Providing free cooling via natural ventilation
- Improving the solar performances of the glass

5.2.1 Reducing solar gain

Different options have been considered for reducing the solar gains whilst limiting the impact on the historic aspect of the building.

Introducing glasses with selective coating would help on cutting the amount of radiant energy entering within the building, however this option will affect the lighting colour within the ambient, interfering with the original object colour of the collection.

Using internal blinds has also been considered, however this option may present more disadvantages than advantages:

- Internal blinds will not stop the solar energy from entering into the building, they just reduce the thermal wave within the ambient.
- They present an objective impact of the visual appearance of the historic roof, significantly difficult to integrate within the listed building.
- Internal blinds will need to be motorised, as installed at high level on the rooflight, with additional impact on the visual aspect, installation and maintenance costs.

A reduction of the rooflights combined with a better solar performance of the glass (better G-value) will give a sensible reduction of the solar gains as well.

The thermal model analysis reports a 56% reduction on annual solar heat gains because of reducing the rooflight area, as explained on the Design and Access Statement.

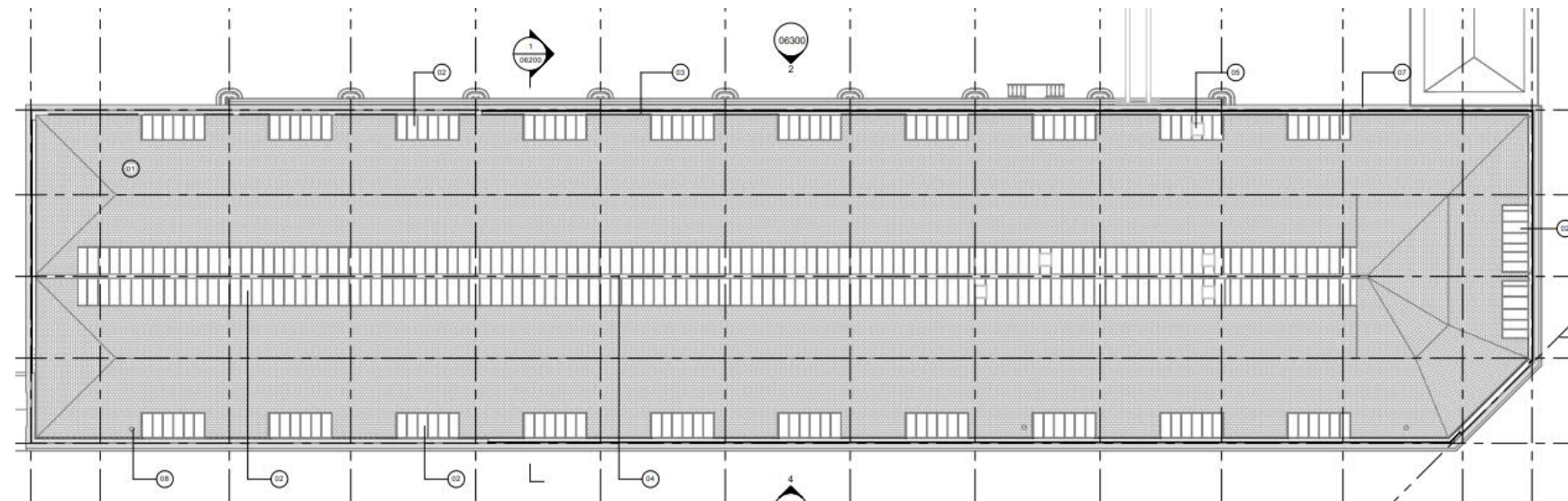


Figure 5-1 - Power Hall roof plan - existing rooflight configuration – courtesy of Carmody Groarke Architects

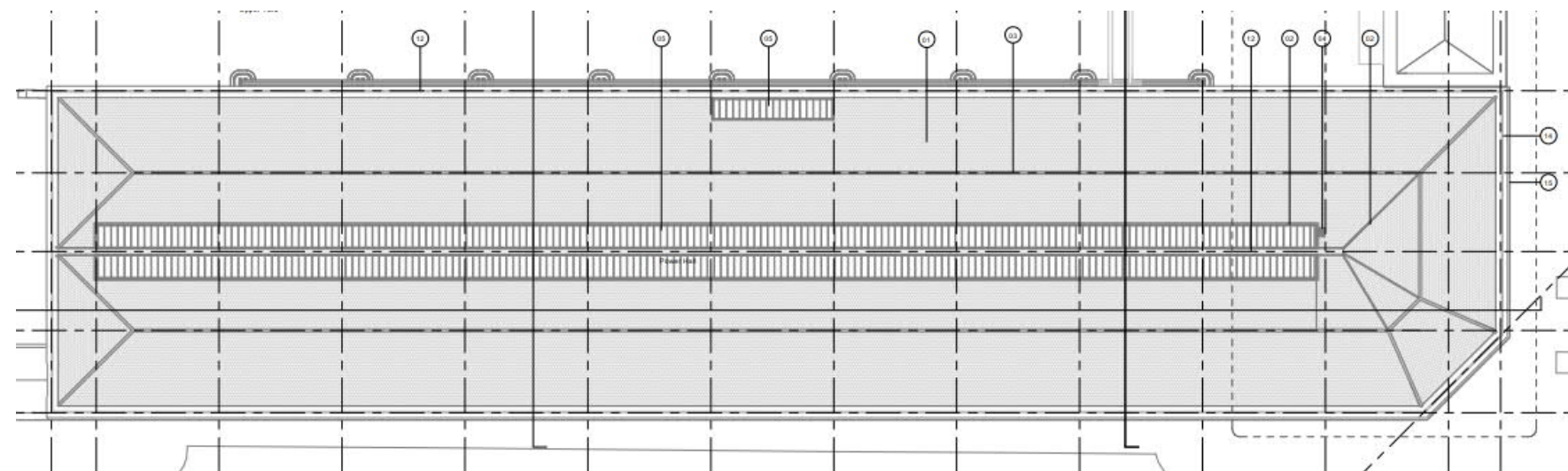
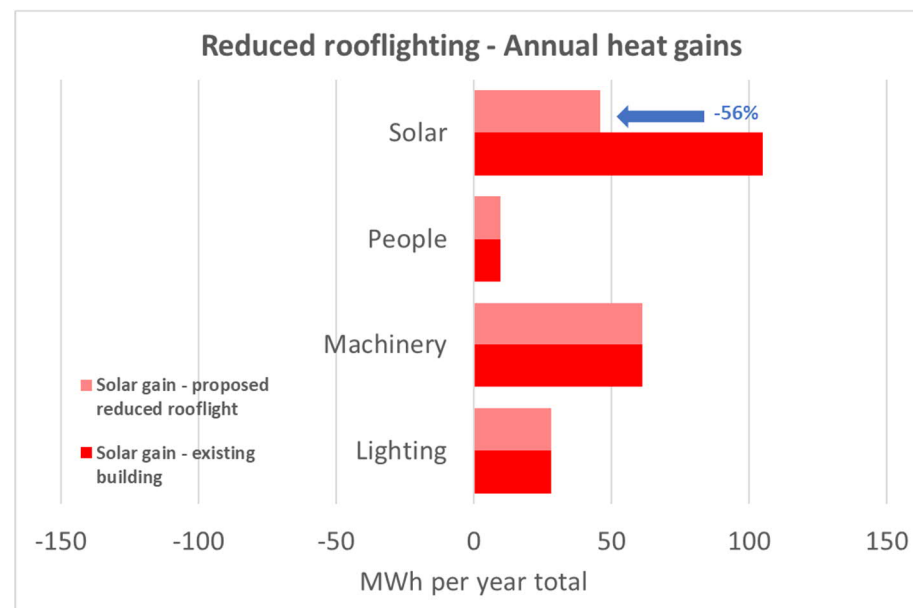


Figure 5-2 - Power Hall roof plan - proposed rooflight configuration – courtesy of Carmody Groarke Architects

5.2.2 Natural ventilation

The reduction on rooflight area will significantly limit the overheating risk within the building.

A support solution on the overheating reduction is to integrate a natural ventilation strategy together with the refurbishment of the glazed elements.

The possibility of naturally ventilating the building will sit on the Project view of using passive strategies holistically integrated within the historic context: natural ventilation will not only help on offsetting internal gains, but will provide better comfort and a healthier environment for the occupants and the building historic elements.

The three main type of natural ventilation can be classified as:

- Single sided ventilation
- Cross ventilation
- Stack ventilation

Due to the shape of the building, single sided ventilation is not effective (high ratio W/H ≈3.5).

The stack ventilation would require automatic openings/stacks on the pitched roof, which represents a more significant impact on the building's heritage.

The cross-side ventilation represents a more viable option for the Power Hall, as there are existing window apertures on in both the south and north façade.

The following table and charts summarise the results from different thermal analysis assessing 3 different scenarios (no natural ventilation – cross ventilation – stack ventilation).

Overheating metric	Results				
	Current climate		Future climate		
	No vent	Cross vent	No vent	Cross vent	Stack vent
CIBSE TM52 compliance check	PASS	PASS	FAIL	PASS	PASS
% occupied hours where internal temperature > 25°C	25%	15%	38%	26%	18%
% occupants uncomfortable on hottest day	75%	64%	93%	89%	83%

The cross-side ventilation presents an optimum compromise between the contribution on offsetting the overheating and the integration within the new glazed partitions.

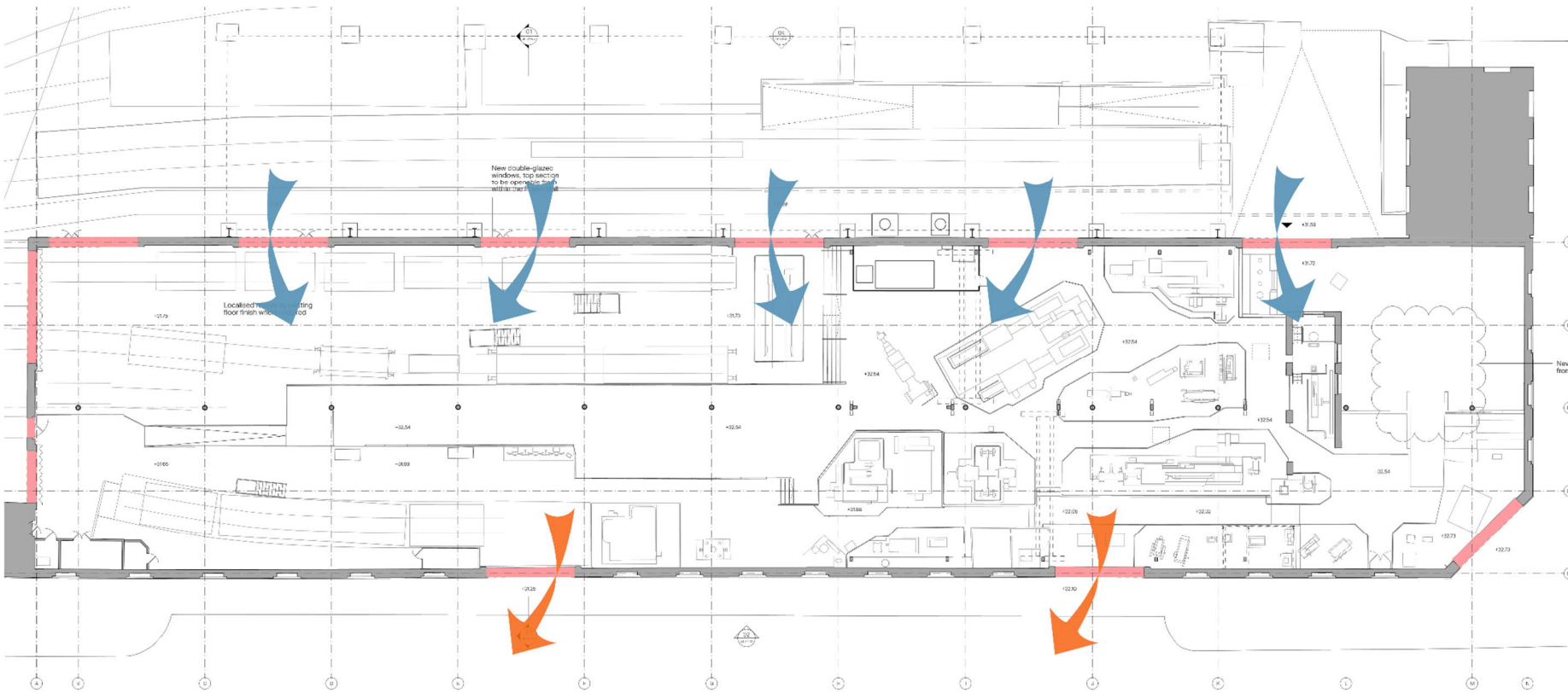
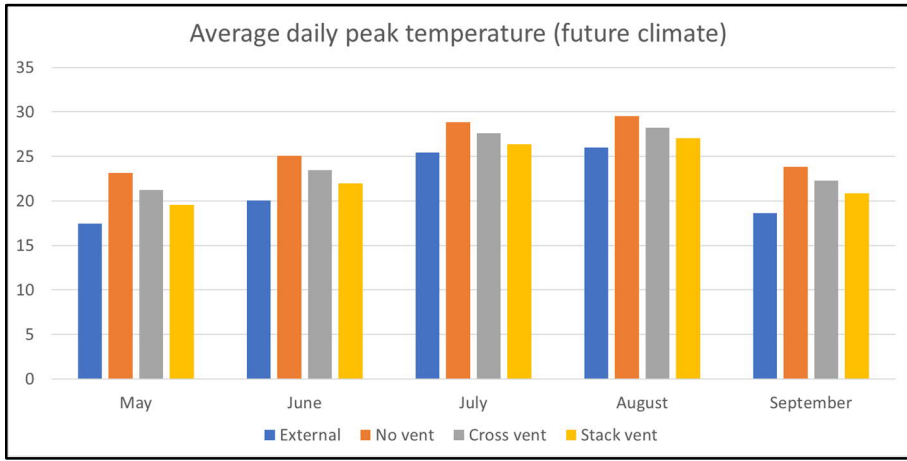
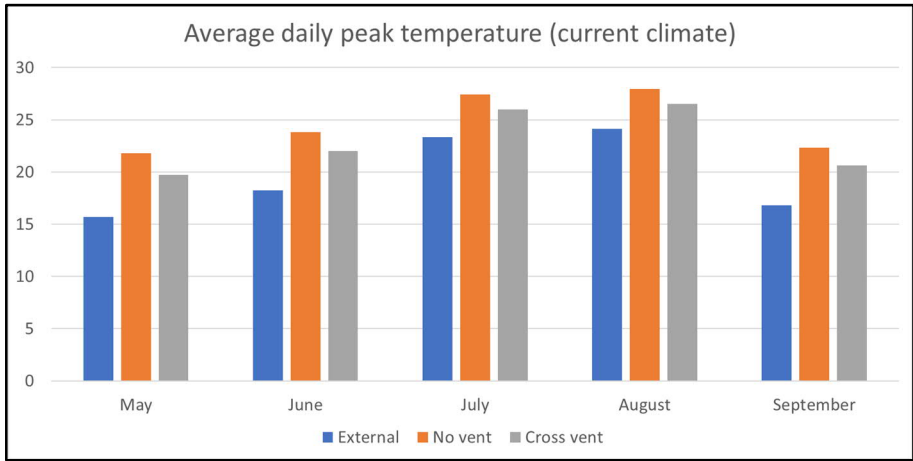


Figure 5-3 - Cross-side natural ventilation concept



6.0 REFURBISHMENT OF THE RAINWATER SYSTEM

The refurbishment of the rainwater system will consist mainly in:

- A new gutter installation, based on the existing layout, with the intent to repair the existing damages, water leaks and sediments.
- The connection of the new gutter to the existing cast iron down pipes.

ASSUMPTIONS

The rainfall intensity is estimated using statistical rainfall data related to the frequency of reoccurrence of storms of specific intensity and duration. This figure should be chosen with due regard to the nature and use of the building, and appropriate to the degree of risk that can be accepted. A conservative approach was taken in our design, using the following assumptions:

Refer to BS EN 12056-3 Figure NB.4	
Parameter	Unit
Storm event duration	2 min
Return period	500 years
Margin for future climate	20%
Rainfall intensity	0.0768l/s/m2

The rainwater pipe capacities were calculated using the following assumptions:

Refer to BS EN 12056-3 Section 6.1.1 Table 8		
Parameter	Unit	Notes
Pipe diameter, parapet	110mm	No.13
Pipe diameter, valley	150mm	No.5
Pipe filling degree	0.33	This figure should be used unless local regulations state otherwise

RESULTS

Based on the assumptions listed in this document, it can be concluded that;

- the proposed gutter cross-sections will have enough capacity to support the rainwater run-off
- the existing quantity of downpipes have enough capacity to support the rainwater run-off

For the construction details of the gutter, refer to the Design Access Statement documentation

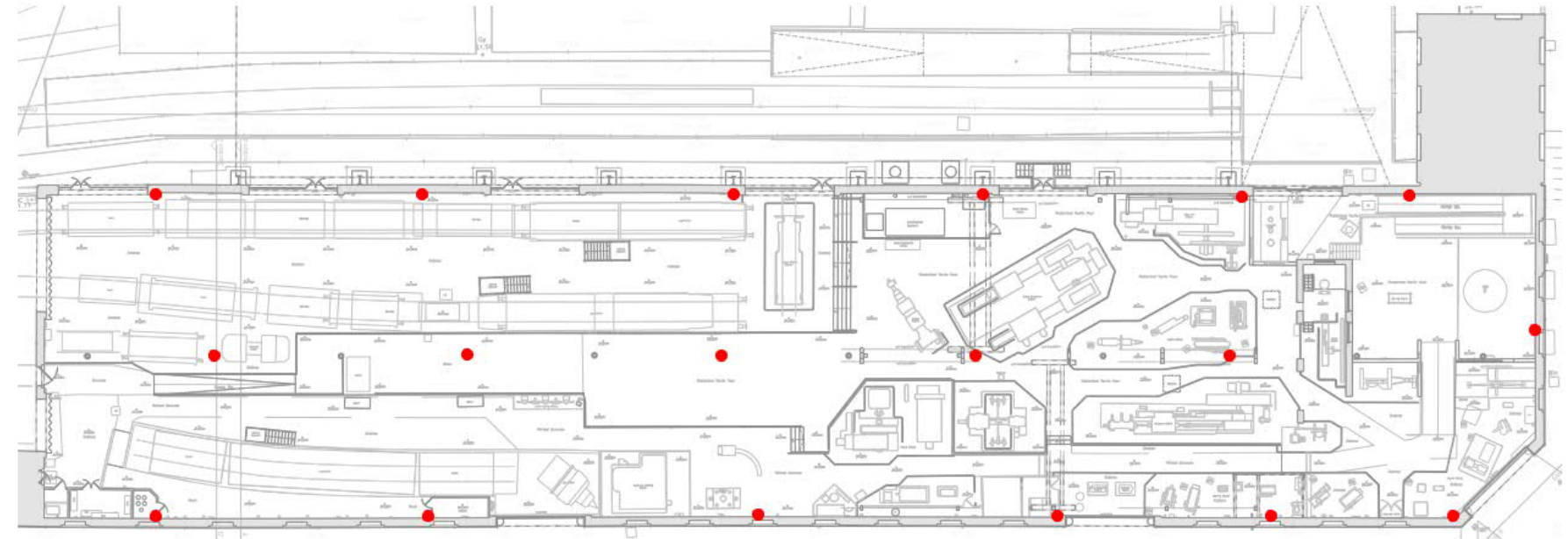


Figure 6-1 - existing rainwater downpipe position to be re-used

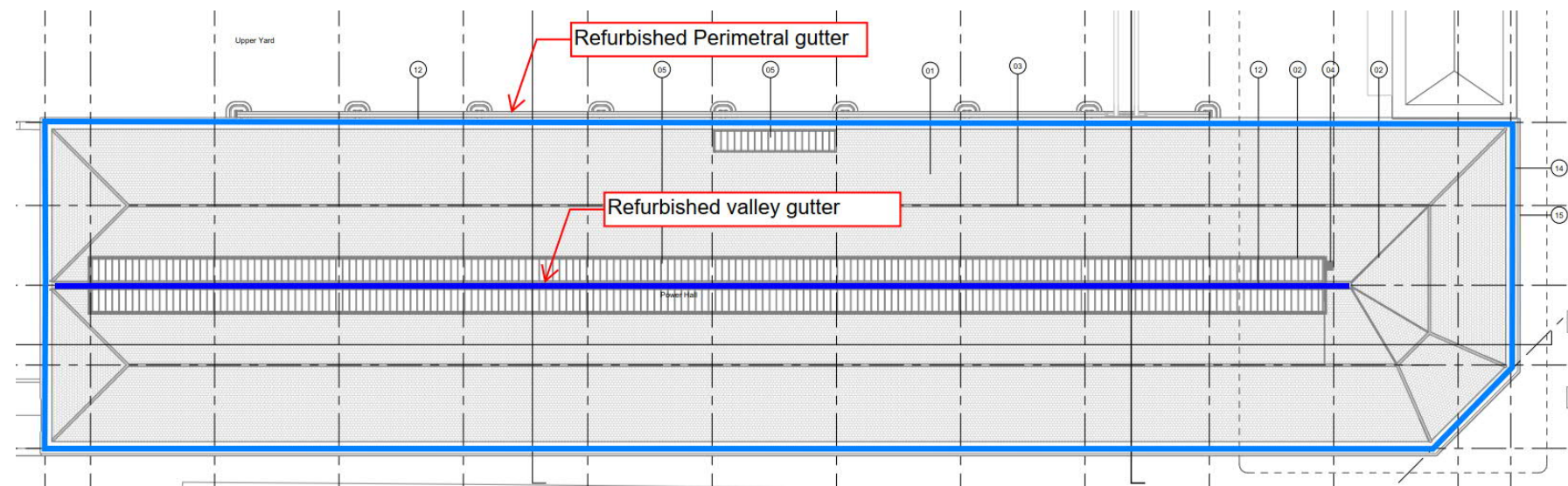


Figure 6-2 - Rainwater system - roof areas served by each gutter

7.0 PROPOSED LIGHTING SYSTEM

The existing light fittings in the Powerhall are all understood to be fluorescent type lighting. These are all suspended from the roof structure with a mixture of larger clear reflector pendants for general lighting and spun metal reflector luminaires for area specific exhibition lighting.

The presence of the internal scaffolding represents a good opportunity to replace and provide new lighting throughout the Powerhall as part of this phase of the works. This means new high efficiency LED luminaires can be installed throughout the building to reduce the building's energy demand which aligns with the general decarbonisation objective of the building and wider site.

The objective is to create an atmospheric but uniformly lit space that provides safe pedestrian access throughout the hall. Local dedicated exhibition lighting will be used to highlight exhibits, the extent of which is to be agreed with the new gallery interpretation during the Work Package 4.

Following the client brief as well as relevant CIBSE and SLL (Society of Light and Lighting) LG design guidance the design criteria for general lighting in the main exhibition space is 50 lux minimum average illuminance and 0.4 uniformity on the pedestrian areas. Dedicated lighting will be provided in the plant areas using robust fittings to minimum 200 lux illuminance to allow for safe maintenance of equipment.

The primary luminaire type proposed in the exhibition area is to be a pendant style fitting that will suspend from the pitched roof section. The exact fixing detail is to be coordinated but is currently proposed to be fixed from the purlins. This style of fitting has been chosen to closely match the style of some of the existing fittings and to keep in keeping with the space's heritage. A sample image is shown in Figure 7-1.

Following detailed light modelling with various arrangements a grid arrangement with 2 fittings per pitch section is proposed as shown in Figures 7-2 and 7-3. This meets the target design criteria and provides a uniform reflected ceiling arrangement that ties in with the roof structure spacing and form.



Figure 7-1 - Lighting fitting type considered for the new lighting strategy

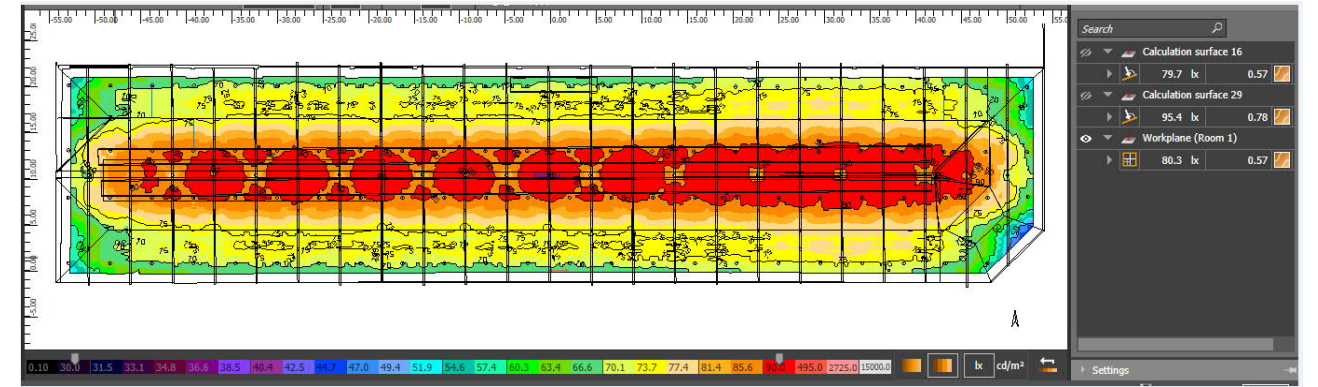


Figure 7-2 - Light distribution heat map for the new proposed lighting scheme

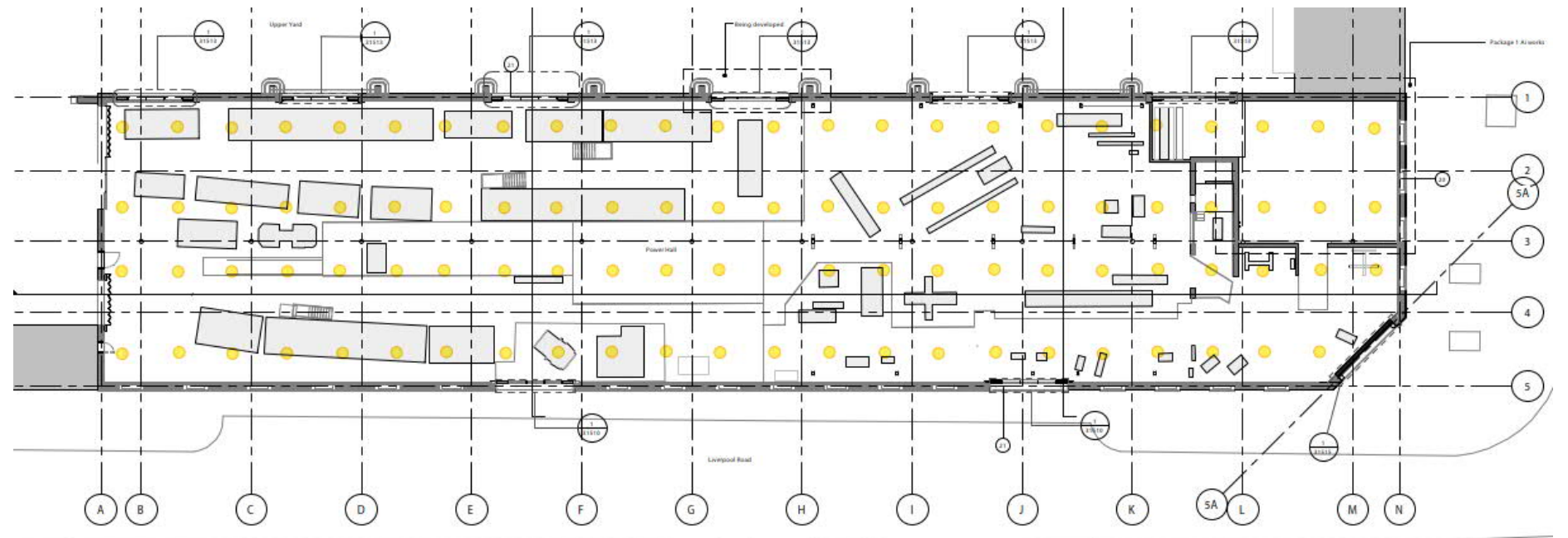


Figure 7-3 - Power Hall proposed new lighting strategy - concept layout

8.0 PROPOSED SERVICES AT HIGH LEVEL

The roof repairment works represent a convenient chance to refurbish the existing electric services installed at high level. The presence of a free-standing internal scaffolding for the roof and truss repairments, will allow for safer and more rapid works on these services as well.

8.1 Existing services

At high level the existing services consist mainly of:

- Lighting fixtures (refer to the above paragraphs)
- Exposed galvanised containments and conduits
- Exposed cables directly clipped on the timber elements
- Fire alarm system
- Wi-fi system
- Gas, steam, and water pipes

The status of these services is generally poor, with evidence of multiple installations in the past, without a comprehensive logic on how to minimise the distribution routing across the building.

There are evident signs that some systems have reached the end of their lifespan, which will require a prompt re-installation in few months anyway.

In addition, most of these services will be redundant as result of the major MEP renovation within the work package 1A:

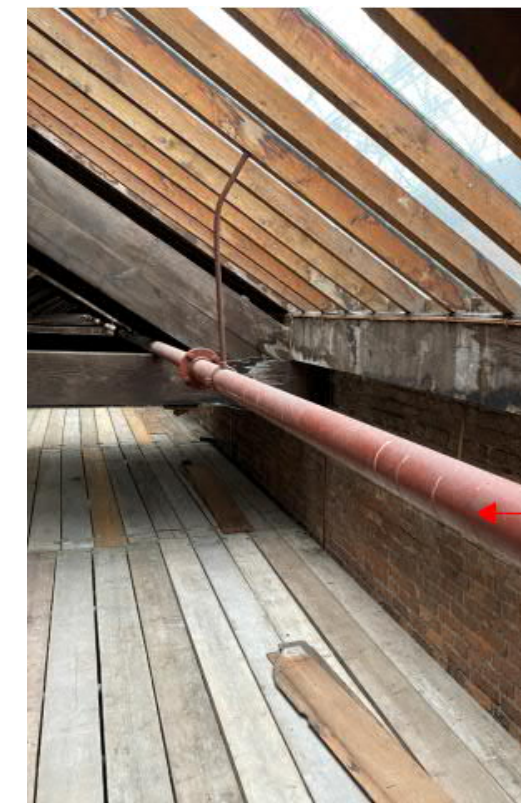
- The existing steam and gas pipes will not serve any system.
- The existing fire alarm will be substituted with a more modern and discreet aspirating type, that will minimise the visual impact.
- Existing lighting wiring will be obsolete with the new scheme lighting presented above, which will require a new wiring strategy.

It is then proposed to strip-out all the redundant services at high level for:

- Taking advantage of the current scaffolding, that will significantly simplify the operation.
- Harmonise the services distribution serving the new system (lighting, wi-fi, fire alarm, etc...) within an holistic strategy on reducing the impact on the listed heritage..



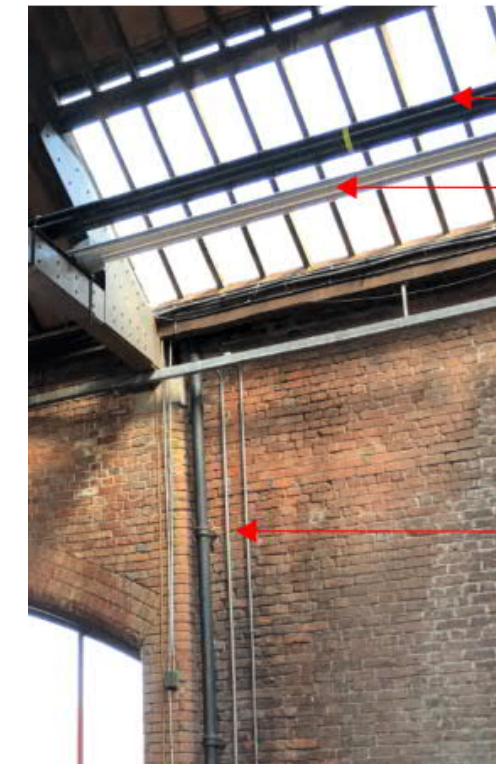
- Water pipe - to be changed
- Exposed cables for fire alarm and emergency lighting - to be removed
- Pending cables - to be removed



- Gas pipe - redundant - to be removed



- Exposed wiring - to be removed
- Open trunking - to be removed



- Gas pipe - north side - redundant - to be removed
- Steam pipe - north side - redundant - to be removed
- Exposed conduits - to be removed

8.2 Proposed services

The presence of the internal scaffolding is a good chance to rationalise the services distribution at high level. The new strategy shall provide a more uniform and lean distribution at high level, enclosing the cables in defined routes in order to limit the visual impact and the direct cable clipping on the historic elements (trusses and purlins).

The new proposed main distribution routes for services will run on the walls at high level just below the truss beam level. These will be predominately for electrical services and will generally be run in metallic containment. This containment will be stacked as to minimise the height of services. Final branches will be made off these primary distribution routes to serve final zones and equipment.

As the lighting is suspended from the pitched roof small section metal trunking is proposed to run along the vast majority length of the building. This will run between the void between the rafter and inner face of the roof build up. The light fittings will then be fed by local tap offs from this trunking.

These general principles are demonstrated in Figures 8-1 and 8-2.

Some of the high-level containment is required to provide a new route for LV supplies from the Powerhall LV panel to serve the curatorial building and existing toilet block. These buildings were originally served from the Powerhall so the new cables will joint onto in the north west corner within the reappropriated plant area.

The plant area will also require supports for pipework and containment which is to be supported using a ground mounted frame system. Some services are to run in a floor void via a set of trenches.

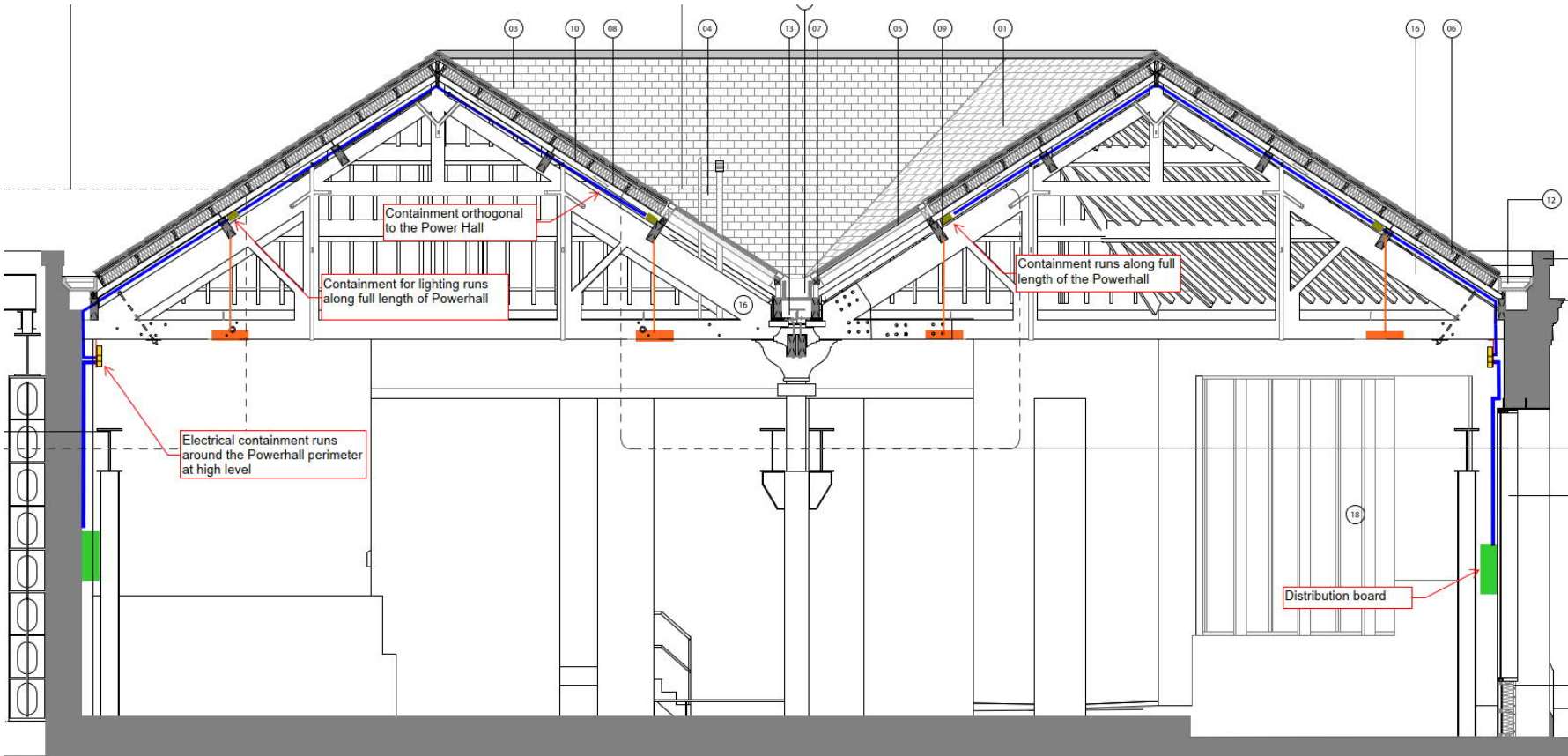


Figure 8-1 – Proposed containment distribution Principles - Section

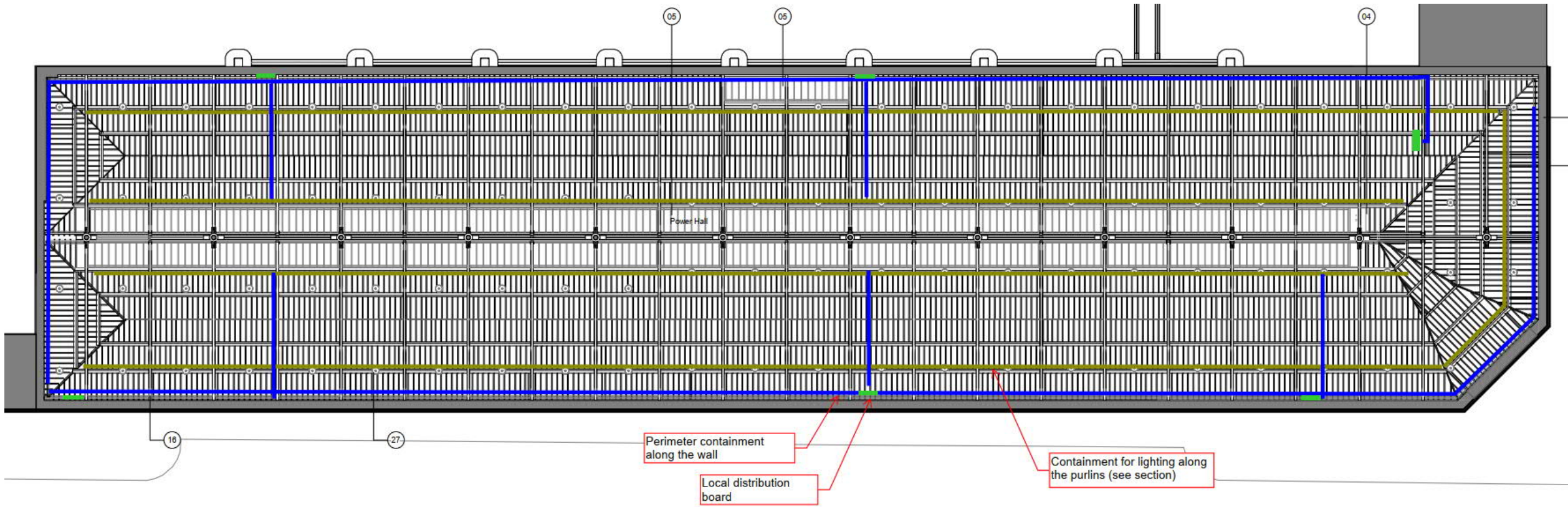


Figure 8-2 – Containment Principles Layout

9.0 LIGHTNING PROTECTION SYSTEM

Buildings with prominent roofs are often targets for lightning strikes. This phenomenon should be considered carefully for historic buildings as it involves an additional risk of damage to historic fabric. Although lightning protection is not a legal requirement, insurance companies and Public Trustees may require these buildings to have lightning protection.

9.1 Lightning strike damages

Despite thunderstorms are more likely in the south of England, climate change studies indicate that the number and power of lightning storms is likely to increase over this century across the Country. As a result, lightning strikes are likely to become more common in the future.

The most usual direct damages can occur to the roof structures, with limited risk of fire, however lightning strikes can create voltage surges which in turn can cause an electrical system to shut down, malfunction, or even a complete burn out of wiring and equipment. The more vulnerable items are alarms, controls, sound reproduction systems, computers, telephones, and electronic components.

About 60% of insurance claims for lightning damage to historic buildings are for damage to electrical wiring and equipment. While indirect damages are more common than structural damage, it is important to note that it is far less costly. Repairing structural damage is on average three times more expensive.

9.2 Risk assessment

The design of a lightning protection system is guided by *BS EN 62305 Protection against lightning. Physical damage to structures and life hazard*, for which a risk assessment shall be carried out to assess the need of installing a new system.

The BS EN 62305 risk assessment is concerned with both possible risks to people, damage to the structure and its contents, and protection against electrical surges which can also cause damage through sparking and fire. The complex calculations are based on the BS EN62305 three-way matrix of sources of damage, types of damage, and types of risks. BS EN 62305 defines four classes of protection (I, II, III and IV for minimum and maximum values of lightning currents). An important part of the standard risk assessment is the loss of cultural heritage: the architectural and historic importance of the building and its contents needs to be included in the risk assessment.

9.3 Power Hall proposal

refurbishment works are proposed to be carried out both for the super-structure and for the electrical building infrastructure.

A new transformer/Main distribution room is under construction within the Power Hall, as part of the Work Package 1A. The new electrical infrastructure is part of the wider Decarbonisation strategy that targets to reduce the carbon footprint via the site electrification.

This infrastructure, together with the other electrical systems proposed to be installed as part of this application (fire alarm, general lighting, low voltage distribution) represent a sensible system to protect from the risk of lightning as the entire new operations of the building (steam for historic working machines, heating via heat pumps, etc...) will depend by the electrical system.

Two independent risk assessments have been carried out to evaluate the advice to provide lightning protection. The risk assessments took into consideration several aspects, including:

- Dimensions and use of building
- Types and characteristics of the equipment to be protected
- Construction details such as floor surfaces, roof types and wall materials
- Infrastructure for power, telecommunications and data
- Earthing systems
- Risk of fire and the current fire protection
- Risk of people injury
- Risk of loss of public services
- Risk of loss of economic values
- The historic significance of the building and its contents and their value ('potential loss of significance')

In parallel the assessment considered:

- The installation and visual implications for installing this system on a Grade II listed building
- The additional installation and maintenance costs related with it.

CONCLUSIONS

The risk assessments concluded that it is recommended to provide a Class III lightning protection system, mainly to preserve the new electrical infrastructure and the refurbished roof structure.

The Science Industry Museum has acknowledged the recommendation, confirming the need of protecting the new equipment and the building fabric elements.

It is then proposed to implement a new lightning protection system on the Power Hall, with the main target to minimise the installation and visual impacts that may affect the historic and architectural significance of the listed building. For more details on this point, refer to the Design Access Statement document and the Heritage Impact Assessment.

10.0 FIRE ALARM SYSTEM

The roof repairs will involve the strip out of some existing services at high level. This will be necessary so the refurbishment works can be carried out on the structural elements, but also to take advantage of the internal scaffolding that will significantly simplify any major works at high level.

It is also worth noting that the existing systems have been installed in different phases during the past, without a homogeneous distribution strategy, resulting in multiple cabling and exposed services that cause an objective aesthetic impact over the building heritage.

Phase 3B of the Power Hall refurbishment works represent an ideal opportunity to design and install a new fire alarm system for the building, with the clear objectives to:

- Better integrate the new system within the revised services distribution strategy
- Provide a new, reliant, easy to maintain, and visually low impacting system to comply with the revised fire strategy of the building.

10.1 Fire alarm system types

There are four different main types of fire detectors, each of them with advantages and disadvantages related with the type of building to be installed on:

- Point detectors
- VESDA / aspirating smoke detection
- Linear heat detection
- Laser beam detection

Point detectors

The point detector-based system is probably the most common fire alarm system across commercial and civil applications. The system is reliant and robust, with limited false alarms. It consists in fire, heat and smoke detectors installed across the building, each of them to cover a circle area of approx. 7.5m radius. This system will require a significant number of detectors in the Power Hall, due to building shape and area. The maintenance will be also demanding, as each detector needs to be tested regularly.

The visual impact of the system may not well integrate with the wider refurbishment strategy of reducing the system interference with the internal elements of the building.

VESDA/aspirating smoke detection

This system will consist in aspirating pipe laid at high level across the building, connected to aspirating units that constantly take air samples to detect smoke.

Sampling pipework are required to be installed which may be visible, but less intrusive than point detectors. The system can be maintained at low level with an significant reduction in maintenance costs and risks.

Linear heat detection

This solution will mainly consist of heat sensitive cables installed across the space. Heat sensing cables can detect heat anywhere along their length and are designed for use in commercial and industrial applications.

Linear heat detection is cost-effective and can be easily installed with, or in place of, conventional heat detectors, however it will require parts to be replaced every time it activates, through fire or accidental damage. Cabling would be visible and the response time would be greatly increased due to the height of the space.

Laser beam detection

The Optical Beam Smoke Detector works on the principle of light obscuration. The photosensitive element of the Optical Beam Smoke Detector sees light produced by the Transmitter in a normal condition. In case of fire, smoke will alter this signal, producing the related alarm.

Although less visually intrusive and less maintenance demanding, beam detection can be susceptible to clouding and mist, sensitive to building movement. Environments that create smoke and steam (as in the Power Hall) can be problematic.

10.2 Proposal for the Power Hall

The Power Hall building presents peculiar characteristics that better suit some fire alarm systems more than others. The internal height makes the maintenance complicated for all the systems with detection installed at high level. In addition, the large space will require multiple detection points for the correct coverage.

Considering the pro's and con's listed before, it is proposed that a new aspirating fire detection system is installed within the Power Hall.

Close coordination with the Specialist Designer and Installer will be carried out to minimise the visual impact of the system.

The initial studies over a possible system layout are summarised on the pictures below: the aspirating tubes will run at high level, concealed on the roof structure, with local capillary sampling tubes installed every 10m on the roof pitch.

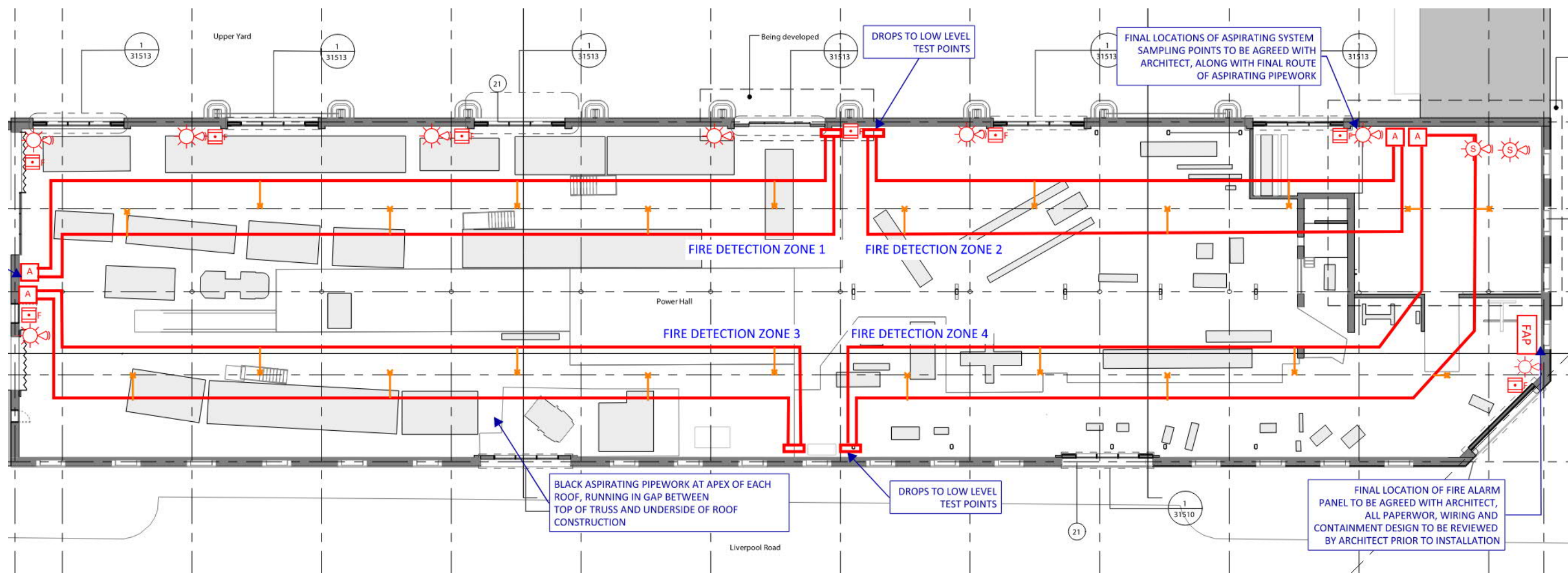


Figure 10-1 - Aspirating fire alarm system - proposed concept layout

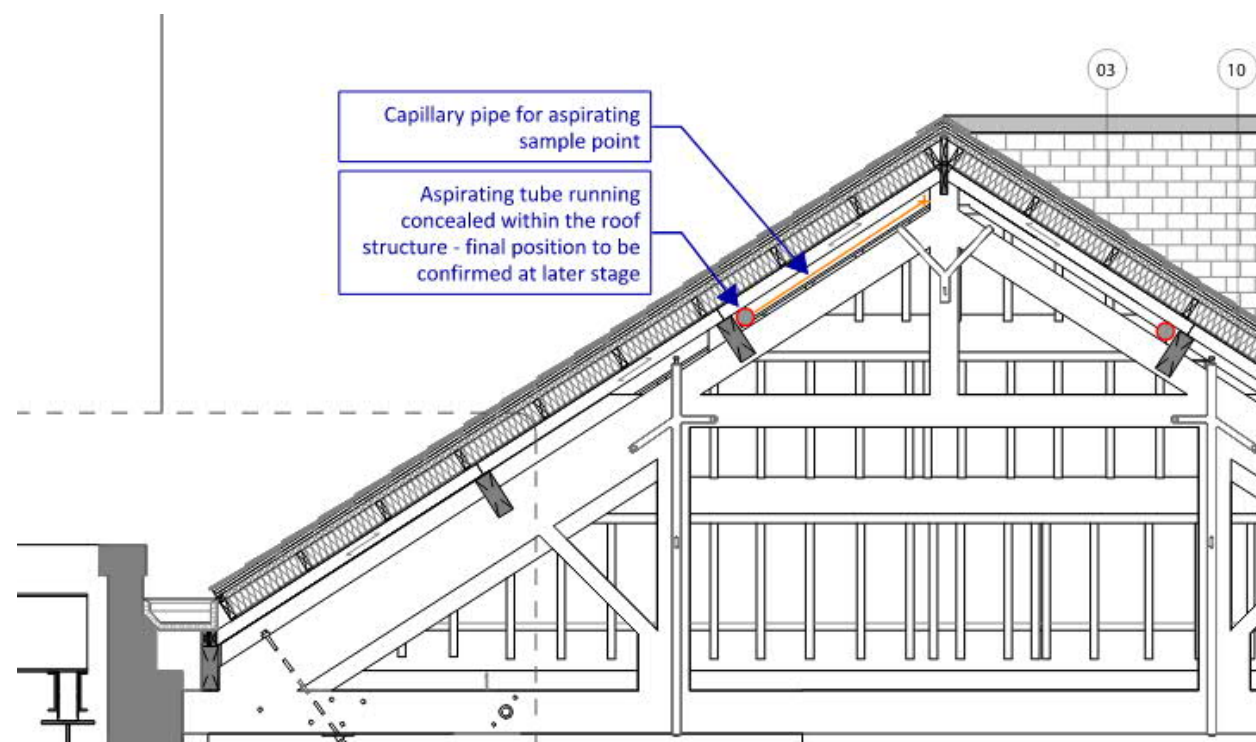


Figure 10-2 - Aspirating fire alarm system - section detail

