

Ashton Park / The Fairways / Woolton Views

Common Corridor Ventilation Report

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Quality Management

Revision	Date	Comment	Author	QA & Technical Review	Approver
R00	22/01/2020	For support of the fire strategy and for initial comments	Charlie Hopkin	James Kelland / Max Rapenne	Andrew Basford
R01	21/04/2022	Updated simulations to incorporate reduced size to mechanical shaft and dampers	Jiang Huang	Andrew Basford	David Maeso
R02	02/08/2022	Investigate Option 1 of the proposed ventilation provisions	Jiang Huang	Ian Fu	David Maeso
R03	26/09/2022	Revised modelling for Option 1 of the proposed ventilation provisions	Jiang Huang	Ian Fu	David Maeso

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1 INTRODUCTION

OFR consultants have been appointed by Livv Housng Group to further investigate ‘Option 1’ of the ventilation proposal documented in Section 3.2.1 of the fire strategy, Document reference: ‘200421-R00-MA19124-WP3-WAFTA_Fire Strategy_DF_CIC’). Recently, R02 of this report, a feasibility study on Option 1 of the ventilation proposals was completed by OFR for Ventro Group and it was deemed unfeasible without providing the recommended amendments to the ventilation provisions. Livv Housing is the new Client for this revision of the report (R03), who wish to further investigate and adopt the additional recommended provisions to option 1 of the ventilation proposal. The recommendations of the feasibility study include adding an extra window AOV to serve the lobby (on every floor) and increasing the extraction rate to 4m³/s. Further details are documented in Section 2 of this report.

Option 1 was previously a concept ventilation method proposed by OFR in 2020 for this project, but the CFD modelling was not carried out because the client adopted Option 2 of the proposed concept ventilation method, which has been modelled and documented in revisions R00 and R01 of this CFD report. More recently, Ventro group instructed a feasibility study on Option 1 and it was unfeasible without additional provisions; the feasibility study is documented in revision R02 of this report.

Previously, OFR consultants were appointed by the Knowsley Housing Trust (KHT) to provide fire engineering advice in relation to the refurbishment of the Ashton Park / The Fairways / Woolton Views residential developments in Liverpool. For the purposes of brevity only, the report refers exclusively to ‘Ashton Park’, but its content remains applicable to both The Fairways and Woolton Views. All three residential developments have a similar common corridor arrangement and the analysis of the change in design for Ashton Park will apply to all three developments.

The initially proposed Option 1 ventilation method is shown in Figure 1. The system makes use of the existing partition separating the two corridors with a lift lobby. The provisions include two independent mechanical extraction systems, where each is provided with a mechanical extract shaft at the remote end of the corridor with natural inlet air provided by an AOV adjacent to the lift lobby.

The revised Option 1 ventilation method is shown in Figure 2. The system operates on a similar principle as the initial proposal, but a lobby window AOV is to be provided on every level.

A mechanical ventilation system within the common corridors is proposed for the design, due to the developments featuring common corridor travel distances which are greater than those recommended in BS 9991 [1]. The system is intended to support means of escape by returning the corridor to tenable conditions within a reasonable timeframe following smoke contamination during the initial escape of occupants. The system is also intended to support firefighting by maintaining tenable conditions within the stair during fire and rescue service operations.

To determine whether the proposed system can be expected to achieve a suitable level of performance and to inform the outline specification for the system, a computational fluid dynamic (CFD) based fire and smoke modelling assessment has been undertaken, with the results of the analyses detailed herein. This document is not intended to operate as a standalone document and should be read in conjunction with the fire strategy.

1.1 Basis of Assessment

The BS 7974:2019 [2] code of practice provides a framework for a range of fire engineering approaches to be adopted in the fire safety design of buildings. The framework summarises a design process which considers:

- Undertaking qualitative design review and setting fire safety objectives;
- Performing quantitative analyses of the design problem in the context of the defined objectives; and
- Comparing the results of the analyses against acceptance criteria, to determine whether the design is able to achieve an adequate level of safety.

BS 7974 notes that this approach to design can be used in conjunction with other standards (such as BS 9991 [1] and BS 9999 [3]) and may also be used to support alternative approaches. BS 7974 states that for any given functional requirement, the method of quantitative analysis can be either deterministic or probabilistic, and the acceptance criteria can be either absolute or comparative. For the analyses detailed herein, a performance-based deterministic assessment has been undertaken to adopt absolute acceptance criteria, where these criteria are derived from the recommendations of PD 7974-5 [4] and PD 7974-6 [5]. Elsewhere, direct reference is given to published and peer-reviewed literature, where details of all referenced literature can be found in Section 7.

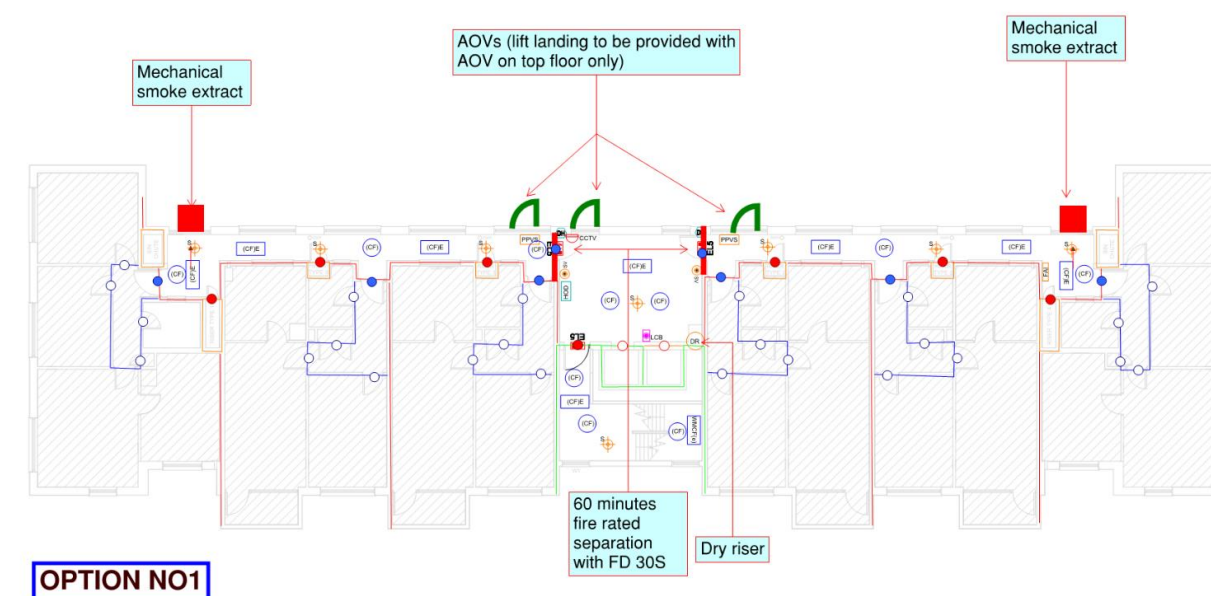


Figure 1: Initial Option 1 of proposed ventilation provisions, Extract from the fire strategy reference document.

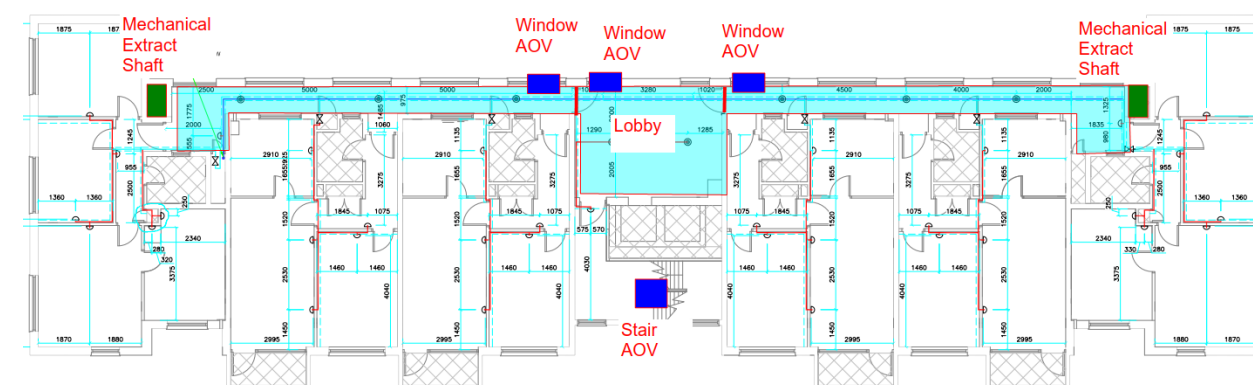


Figure 2: Revised Option 1 proposed after revision R02 of this report.

1.2 Reference Information

This report has been developed based on the drawings by Ridge & Partners architects, listed in Table 1. Should any changes to the design occur, these should be evaluated by a fire engineer to ensure the analysis herein remains applicable.

Table 1: Reference drawings.

Drawing number	Revision	Date	Description
142529/AP/GF1F	-	10/2014	Ashton Park Ground Floor and 1 st Floor layout
142529/AP/2F3F	-	10/2014	Ashton Park 2 nd Floor and 3 rd Floor layout
142529/AP/4F5F	-	10/2014	Ashton Park 4 th Floor and 5 th Floor layout
142529/AP/6F7F	-	10/2014	Ashton Park 6 th Floor and 7 th Floor layout
142529/AP/8F	-	10/2014	Ashton Park 8 th Floor layout
142529/AP/RP	-	10/2014	Ashton Park roof plan
142529/TF/GF1F	-	10/2014	The Fairways Ground Floor and 1 st Floor layout
142529/TF/2F3F	-	10/2014	The Fairways 2 nd Floor and 3 rd Floor layout
142529/TF/4F5F	-	10/2014	The Fairways 4 th Floor and 5 th Floor layout
142529/TF/6F7F	-	10/2014	The Fairways 6 th Floor and 7 th Floor layout
142529/TF/8F	-	10/2014	The Fairways 8 th Floor layout
142529/TF/RP	-	10/2014	Woolton Views roof plan
142529/WV/GF1F	-	10/2014	Woolton Views Ground Floor and 1 st Floor layout
142529/WV/2F3F	-	10/2014	Woolton Views 2 nd Floor and 3 rd Floor layout
142529/WV/4F5F	-	10/2014	Woolton Views 4 th Floor and 5 th Floor layout
142529/WV/6F7F	-	10/2014	Woolton Views 6 th Floor and 7 th Floor layout
142529/WV/8F	-	10/2014	Woolton Views 8 th Floor layout
142529/WV/RP	-	10/2014	Woolton Views roof plan

2 SUMMARY OF VENTILATION PROVISIONS AND CFD ANALYSIS

The results of the CFD assessment indicate that the proposed common corridor ventilation system to achieve a suitable level of performance for both the means of escape and firefighting phases.

The CFD analysis modelled a ventilation system, illustrated in Figure 1, that operates on the following principles:

- A mechanical extract shaft provides a means of exhaust located at the remote end of the corridor; and
- Natural inlet air is provided by a single automatically openable vent (AOV) which opens directly to the outside and is located at the other end of the corridor to the extract shaft.
- A natural outlet is provided by a single AOV which opens directly to the outside and is located within the lift lobby serving the lobby itself. This is to be provided on every level.
- Two independent ventilation systems serve the two corridors, separated by the lift lobby.

The analyses are based on the following outline specification, which OFR Consultants understand to be achievable and in line with Option 1 of the proposed ventilation method.

The modelled ventilation arrangements are shown indicatively in Figure 1, and with the following criteria:

- The mechanical smoke shafts should achieve a volumetric flow rate of 4 m³/s at the point of exhaust, with a geometric free area of 0.7 m² opening into the corridor. (The 0.7 m² shaft and vent opening into the corridor has been advised by the client, the original proposed Option 1 recommended a 0.8 m² shaft and vent).
- The corridor AOVs should be located on the external elevation at the opposite end of the corridor to their respective smoke shaft and should achieve a 0.7 m² geometric free area.
- An additional AOV should be provided at the lift lobby on every level. This AOV should achieve a geometric free area of 1.5m².
- An AOV will be positioned at the head of the stair and will achieve a minimum geometric free area of 1.0 m².

Smoke detection is provided in the common corridors to operate the mechanical extract shafts and associated vents, the AOV in the common corridor and the AOV in the stair. The common corridor AOV and vents into the mechanical shafts will only operate on the floor where the fire is first detected. All smoke vent areas stated in this report are geometric-free areas that assume an unrestricted hole opening.

As a minimum, a Category L5 automatic fire detection system designed to BS 5839-1 [6] will be incorporated into the design and interfaced with the abovementioned smoke extract system components. Smoke detection will be provided in the common corridors to operate the mechanical extract shafts and associated vents; the AOV in the common corridor, lift lobby and the stair. The common corridor and lift lobby AOV and vents into the mechanical shafts will only operate on the floor where the fire is first detected.

In addition to the performance specifications given previously, the mechanical ventilation system is expected to achieve the following specification, derived from the recommendations of BS 9991 [1] and other relevant standards:

- When in a closed position, vents to shafts should either: have a minimum fire and smoke resistance performance of 30 min and a leakage rate no greater than 360 m³/h/m² when tested in accordance with BS EN 1366-2 [7]; or be in accordance with BS EN 12101-8 [8];
- All shafts should be protected shafts (as per the fire resistance specified in the fire strategy), constructed of materials that are classified as non-combustible (Euroclass A1) and lined or faced to limit leakage of smoke or air;
- No services other than those relating to the smoke extract system should be contained within the shafts;
- Fans should be capable of handling gas temperatures of 300 °C for a continuous period of not less than 60 min when tested in accordance with BS EN 12101-3 [9];
- In accordance with BS EN 12101-6 [10], the system shall be designed so that the force on door handles which open into the corridor does not exceed 100 N. BS EN 12101-6 recommends that a maximum pressure differential of 60 Pa may be utilised for design purposes;
- Fans, ducts and AOVs to outside should be sited at a distance away from each other which is sufficient to limit the risk of smoke recirculation; and
- The control equipment for the system should be designed in accordance with BS ISO 21927-9 [11].

This report provides the recommended performance requirements of the system needed to support the fire strategy. The responsibility of the detailed design and commissioning of the ventilation system will reside with the design and installation specialists, where these specialists should provide the full specification of the system and comprehensive operations and maintenance information at handover.

All smoke vent areas stated in this report are geometric free areas that assume an unrestricted hole opening. Corresponding aerodynamic areas should be determined by the design and installation specialists when specifying vents to ensure equivalent aerodynamic performance. The proposed shaft free areas are given for indicative purposes and will also need to be confirmed as appropriate by the design and installation specialists.

3 BUILDING DESCRIPTION AND PROBLEM DEFINITION

Ashton Park is a 9-storey (Ground + 8) existing residential development located in Liverpool. The development is to be refurbished to bring the design closer to contemporary fire safety standards.

As the building is less than 30 m in height, and in line with the expectations of guidance given in BS 9991 [1], sprinkler protection is not intended to be provided as part of the fire strategy. The building includes common corridor travel distances up to approximately 21 m (Figure 3), greater than the 7.5 m single direction of travel recommended in BS 9991 for buildings not incorporating sprinkler protection.

This revised update to option 1 of the proposed ventilation system adopts a protected lobby ventilated via a window AOV, as previously illustrated in Figure 2. Due to the extended travel distances to the stair door, a mechanical ventilation system is proposed. The system is provided with an extract shaft at the remote end of the common corridor with a window AOV adjacent to the lift lobby acting as the supply air. The two ventilation systems of the left and right corridor will operate independently.

Ashton Park is to adopt a 'stay put' evacuation strategy (sometimes referred to as 'defend-in-place'), where occupants are expected to be safe to remain within their flats but may evacuate following instructions from the fire and rescue service or of their own volition. The system is therefore intended to facilitate means of escape by supporting the evacuation of occupants other than those in the flat of fire origin after the initial escape of occupants from the flat of origin. The design should also be able to provide adequately safe conditions in the corridor for the fire and rescue service during firefighting and maintain tenable conditions within the stair during fire and rescue service operations.

To demonstrate the proposed solution's effectiveness in meeting the acceptance criteria (as described in Section 5), a total of three modelling scenarios have been considered, based upon the above problem definition which addresses both means of escape and firefighting tenability. These scenarios are described further in Section 4.4. All fire scenarios have been assessed using CFD-based fire and smoke modelling within the Fire Dynamics Simulator (FDS) software [12], [13], discussed in Section 4.1.

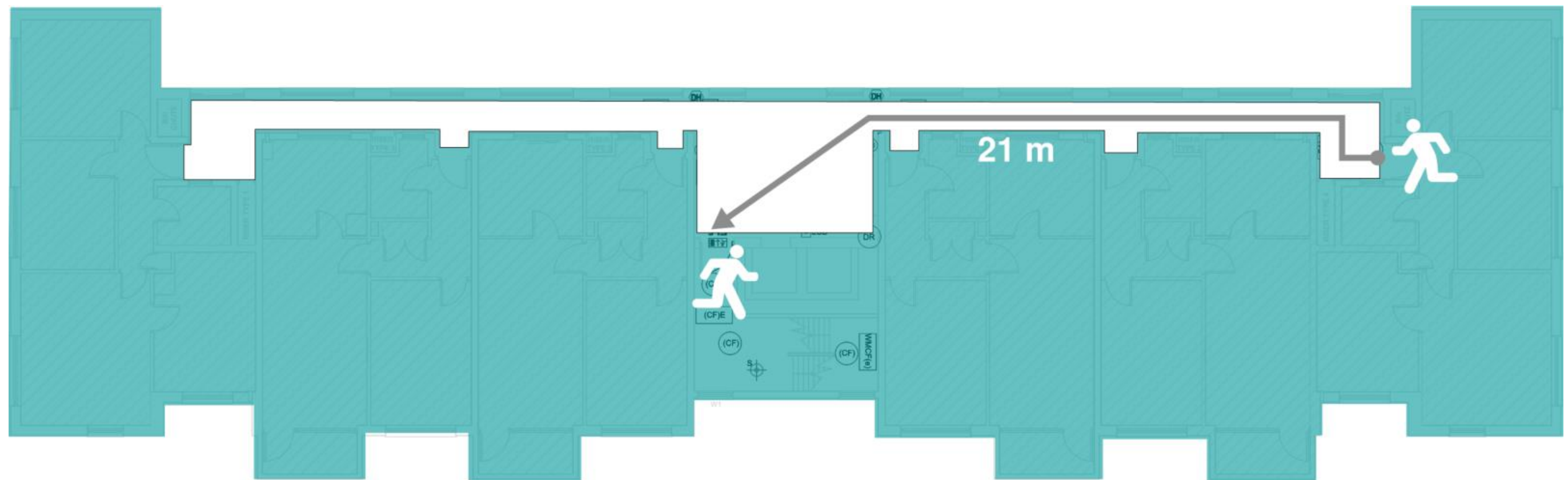


Figure 3: Worst-case extended travel distance in residential common corridor (single direction of travel).

4 MODELLING METHODOLOGY

4.1 Modelling Tool

The fire and smoke modelling documented in revision R00 of this report used FDS version 6.7.3. The revised fire and smoke modelling documented in revisions R01-R03 of this report utilised FDS version 6.7.5. This is an open-source CFD modelling package developed by the National Institute of Standards and Technology (NIST) specifically for use in fire modelling applications. FDS solves the incompressible form of the Navier-Stokes equations, by default using a very large eddy simulation (VLES) turbulence model. This is solved on structured cartesian grids. The FDS documentation includes verification and validation guides [14], [15] to support applications of the tool.

4.2 Design Fire Properties

Table 2 provides a summary of the key design fire properties used as part of the modelling. A 1.0 MW medium growth rate t^2 fire and a 3.8 MW steady-state non-sprinklered fire have been simulated for the means of escape and firefighting phases, respectively.

Table 2: A summary of design fire properties.

Parameter	Value	Comment
Maximum HRR	MOE: 1.0 MW FF: 3.8 MW	1.0 MW is a conservative fire size for means of escape, as it considers a 300 s initial evacuation period for the timeline given in Section 4.6. In their assessment of residential fire incident data, Hopkin et al. [16] propose that a 95 th percentile design fire be adopted for deterministic analyses, suggesting a maximum HRR of 3.8 MW for fires in flats. In comparison, 2.5 MW is the maximum fire size considered in BRE document BD 2410 [17].
Heat release rate per unit area (HRRPUA)	MOE: 510 kW/m ² FF: 521 kW/m ²	In a review of design values for HRRPUA, Hopkin et al. [18] propose that a HRRPUA range of 320 kW/m ² to 570 kW/m ² is reasonable for residential design from previous experimental studies. Fleischmann [19] provides guidance on HRRPUA for use in fire safety design, where it is recommended that non-storage fires be simulated with a HRRPUA ranging from 500 kW/m ² to 1000 kW/m ² . This range is intended to accommodate different HRRs and cell sizes. The adopted HRRPUA values have therefore been selected to sit within these two ranges.
Area of fire	MOE: 1.4 m by 1.4 m (2.0 m ²) FF: 2.7 m by 2.7 m (7.3 m ²)	Determined from the HRR and HRRPUA.
Soot yield	0.1 kg/kg	A conservative soot yield for a polyurethane fire [20]. The selected yield implies smouldering combustion but with a fire size commensurate with flaming combustion. Relatively, BRANZ Study Report 185 [21] recommends a 95 th percentile soot yield of 0.07 kg/kg for residential occupancies.
Effective heat of combustion	20 MJ/kg	This is the recommended pre-flashover design fire value from C/VM2 [22]. It is broadly derived from Robbins and Wade [21], representing a polyurethane fire.
Radiative fraction	0.35	This is the FDS value for 'all other species' and the recommended pre-flashover design fire value from C/VM2 [22] for general building contents.
Growth rate	MOE: Medium ($\alpha = 0.012 \text{ kW/s}^2$) FF: Steady state	A medium growth rate is adopted from the recommendations of Hopkin et al. [16], approximately equating to a 95 th percentile design fire.

4.3 Geometry and Surface Properties

During both means of escape and firefighting, door openings have been modelled with a ‘fully-open’ clear width of 0.8 m and a height of 2.0 m, based upon the door dimensions for the design (as per the drawings summarised in Section 1.2) along with the selected cell size of 0.1 m (see Section 4.5). This is a conservative representation of firefighting operations, as in practice the doors may regularly be opening and closing and in some instances may only be partially open to allow for the laying of the firefighting hose and equipment. For example, in comparison, Kent Fire & Rescue Service (KFRS) Guidance on Firefighter Tenability and CFD Analysis [23] outlines a recommended door opening for the stair door of 0.2 m during the firefighting phase. For flats incorporating protected entrance halls, doors from the room of fire origin to the entrance hall are simulated as fully open throughout.

Corridors and flats have been modelled with a representative floor to ceiling height of 2.4 m.

For the means of escape phase, the stair enclosure and opening of the stair door have not been modelled for the following reasons:

- The stair conditions are simulated under more onerous conditions during the firefighting phase;
- With the conservative means of escape timeline (detailed in Section 4.6), a 5 s delay from the time of initial detection and a 30 s time for the extract rate to reach full capacity, it would be expected that the stair door would open and close for initial occupant egress prior to the system being fully active. Thus, the modelling of the stair door opening would have a limited impact on the simulated corridor clearance;
- With respect to smoke potentially entering the stair during the initial means of escape, any demonstrated clearance will be influenced by the conservatism of the modelling timeline and assumptions on the time it takes for the stair door to open and close relative to the system activation and ramp-up time; and
- In these circumstances, the observed performance for stair smoke ingress would be no worse than other system types, including guidance-based natural provisions.

To support the requisite fire size, a natural inlet is provided to the flat of fire origin. The flat incorporates a natural low-level vent (1.8 m wide by 0.8 m high) to allow for enough oxygen to reach the fuel bed to sustain a 1.0 MW HRR, consistent with the approach adopted in BD 2410 [17]. The low-level location of the vent allows for the provision of oxygen whilst minimising smoke and heat losses from the flat during the development of the fire. During the firefighting phase, a 2.7 m wide by 1.5 m high window breakage is adopted from the outset, necessary to sustain a 3.8 MW maximum HRR for the defined reaction.

Table 3 provides the surface properties adopted for the modelling geometry. All wall and object construction has been modelled as 15 mm thick gypsum plaster surfaces based on properties defined by Quintiere [24] and slabs/ceilings have concrete properties from Peacock et al. [25], resulting in a more representative estimation of temperature losses at the boundaries than if default inert properties were adopted.

4.4 Modelling Scenarios

One fire scenario has been modelled for the means of escape (MOE) phase and two fire scenarios have been modelled for the firefighting (FF) phase. These two phases consider two separate modelling timelines, discussed further in Section 4.6.

Table 4 provides a list of the fire scenarios considered and Figure 4 provides the flat location of the scenarios. The selected fire scenarios are considered representative worst-cases of a typical common corridor ventilation arrangement, for the reasons described in Table 4

4.5 Mesh Configuration

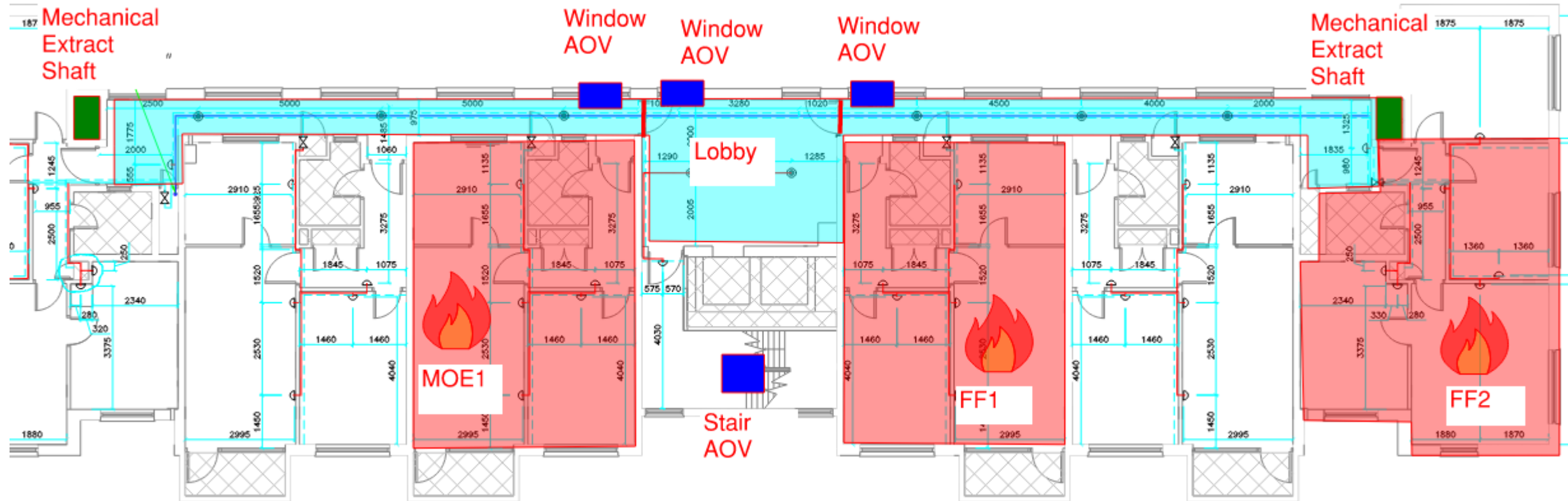
All scenarios have been modelled with a uniform mesh with cell size (δx) of 0.1 m. A discussion on mesh sensitivity is included in Appendix I. The discussion considers the numerical parameters of the modelling, in particular the characteristic fire diameter (D^*) and the plume resolution index ($D^*/\delta x$), as well as discussing the predictive capabilities, uncertainties and biases of the FDS model.

Table 3: Geometry surface properties.

Parameter	Materials	
	Concrete [25]	Gypsum plaster [24]
Surface	Slabs and ceiling	Walls and other obstructions
Thickness	100 mm	15 mm
Density	2280 kg/m ³	1440 kg/m ³
Specific heat	1.04 kJ/kg/K	0.84 kJ/kg/K
Thermal conductivity	1.8 W/m/K	0.48 W/m/K
Emissivity	0.9	0.9

Table 4: Matrix of simulated fire scenarios.

Scenario	Floor	Fire location	Comment
MOE1	1 st	Corridor midpoint	Provides the greatest potential for smoke spread along the full corridor length, as well as smoke accumulation outside of the ventilation system flow path.
FF1	1 st	Near stair	The worst case for potential smoke contamination of the stair during firefighting.
FF2	1 st	End of corridor	The furthest distance from the stair provides the worst case for travel distances which firefighters may have to traverse in sub-optimal conditions.



1st Floor

4.6 Timelines

Figure 5 and Figure 6 show the two separate timelines adopted for the means of escape and the firefighting phase simulations, respectively. The timelines are not intended to represent real time events and associated durations.

The means of escape timeline takes into consideration the evacuation of occupants from the flat of fire origin, where the common corridor is expected to return to tenable conditions (as outlined in Section 5.1) so that occupants in other flats accessing the common corridor can still safely evacuate (if required). The firefighting timeline is concerned only with firefighter tenability (described further in Section 5.2) following the means of escape phase.

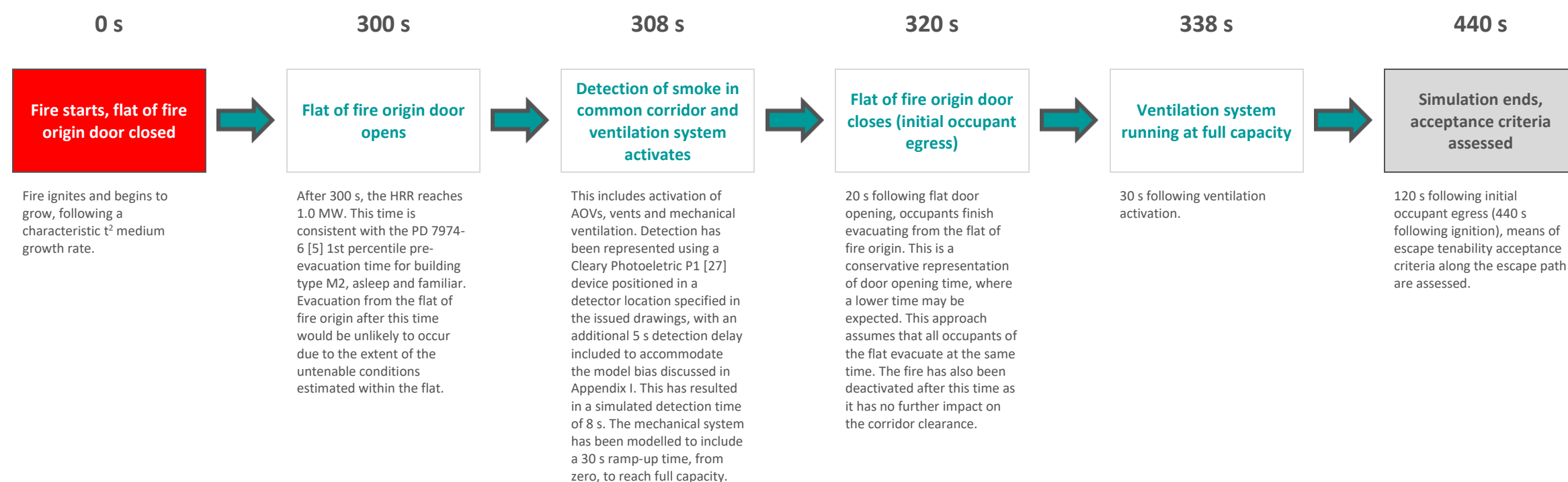


Figure 5: Means of escape timeline.



Figure 6: Firefighting timeline

5 ACCEPTANCE CRITERIA

5.1 Means of Escape

The modelling acceptance criteria are premised upon the tenability thresholds recommended in PD 7974-6:2019 [5] and other relevant guidance, where specified. The following tenability criteria are proposed for the means of escape stage of the analysis:

- The conditions in the common corridor need to improve following initial occupant egress, so that the common corridor is navigable by other occupants. A two-minute smoke clearance time has been applied. This is consistent with an approximated 'quick' pre-movement time in single-family dwellings [29] and is shorter than the pre-movement time of 300 s considered in the means of escape timeline, providing a more stringent expectation of the common corridor system's smoke clearance capacity;
- Whether a space is navigable is measured by attainment of a visibility of at least 10 m at a height of 2.0 m above the finished floor level (FFL) and temperatures below 60 °C. The temperature limit of 60 °C represents a conservative acceptance limit for means of escape, as it assumes an environment with high humidity. The 10 m visibility parameter (as measured to a light reflective surface) is a distance limit representing an approximate value which persons unfamiliar with a building would be prepared to travel. Given the residential nature of the building, it can be assumed that most occupants are familiar with the building and, therefore, it should be noted that the 10 m visibility parameter is conservative;
- PD 7974-6:2004 [30] discusses the impact of toxicity on evacuation, specifying that the concentrations of mixed smoke irritants will not impair or prevent escape if a visibility of at least 5 m can be maintained. Given that this is less than the 10 m visibility limit specified above, toxicity tenability thresholds are inherently addressed through the visibility limits employed; and
- With respect to velocity, BR 368 [31] states that "airspeed through any inlets also serving as escape doors must be less than 5 m/s to avoid adverse effects on people escaping through those doors". In its discussion on tenability and velocity, BR 368 also states that "measurements of the subjects' actual walking speeds show that it was not seriously impeded below 10 m/s". Given these observations, a 5 m/s velocity criterion has been adopted for general corridor tenability and velocities in the immediate vicinity of vents should not exceed 10 m/s.

5.2 Firefighting

The firefighting acceptance criteria are premised upon the recommendations of PD 7974-5 [4] and the underlying principles contained within BS 9991 [1]. Conditions in both the common corridor and stair need to be maintained such that they remain tenable for the full duration of the simulated firefighting phase, for the limits specified below:

- Temperatures along the common corridor retreat path, i.e. between the flat of fire origin and stair door, should not exceed 210 °C at 1.5 m above FFL. PD 7974-5 states that exposure to extreme conditions (210 °C) for up to 1 min might be tolerable if the outcome is to save life. However, damage to personal protective equipment can occur under these conditions. In comparison, Donnelly et al. [32] note in their work on 'thermal environment for electronic equipment used by first responders' that 260 °C could be tolerated for up to 5 min. Donnelly et al. also discuss experiments which considered skin temperatures measured inside the sleeves of turnout gear, where it was found that when subject to elevated temperatures reaching 260 °C the onset of third-degree burns did not occur until after 18 min; and
- Provisions are necessary to ensure that the stair remains free from substantial smoke and heat ingress in the event of a fire within a flat. This is of importance where only one staircase serves the building and occupants of the non-fire affected floor may be directed to evacuate by the fire and rescue service. For this, tenability criteria have been adopted consistent with that of means of escape (Section 5.1), where visibility through the full height of the stair, above and below the fire affected floor, should be maintained above 10 m and temperatures maintained below 60 °C.

5.3 Methods of Observing Results and Criteria

As part of the CFD analyses, temperature and visibility have been measured within the common corridor. This is typically presented in the form of contour plots in the z-plane (horizontal) at $z = 2.0$ m above FFL for means of escape and $z = 1.5$ m above FFL for firefighting. Temperature and visibility have also been measured in the stair in the x and y planes using a similar approach (e.g. through the stair door centreline). A full presentation of the results for each scenario is given in Appendix II.

Scales used in the presentation of contour plots have been selected to align with the acceptance criteria detailed in Sections 5.1 and 5.2, i.e. to align with the ranges of tenability acceptance criteria specified in PD 7974-5 [4], PD 7974-6 [5] and BR 368 [31]. The adopted scales and relevant bounds are described in Figure 7.

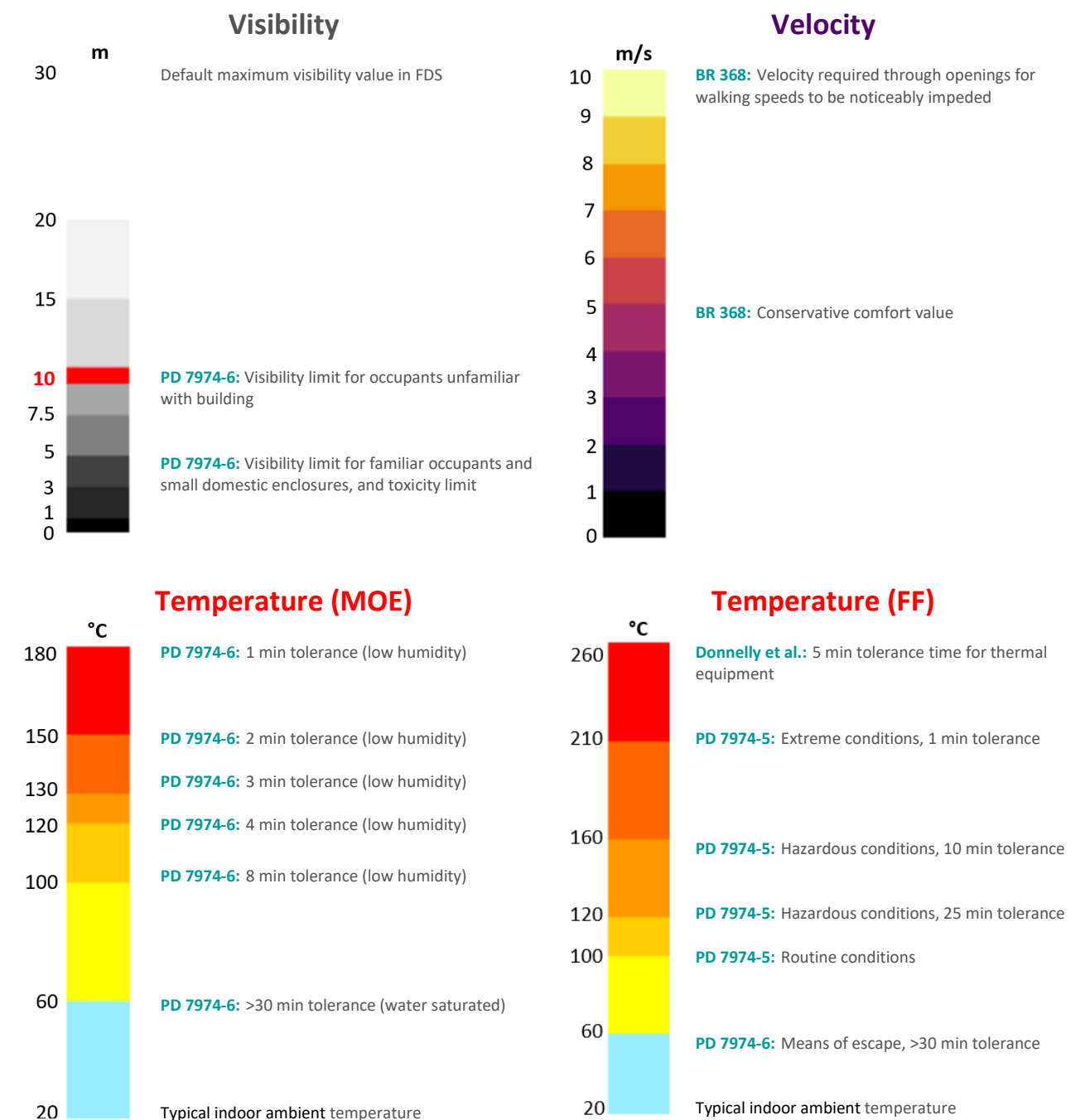


Figure 7: Contour plot scales adopted for the presentation of results.

6 RESULTS DISCUSSION AND CONCLUSIONS

6.1 Means of Escape

The full simulation results for the means of escape phase can be found in Appendix II. These results present contour plots of the visibility, temperature and velocity within the corridor at three different time intervals, presented in the horizontal plane at a height of 2.0 m from FFL.

The corridor is shown to return to tenable conditions within 120 s (Figure 8) following the escape of occupants from the flat of fire origin. In the lift lobby, residuals of smoke still exist after 120s, but it is mostly above 10m visibility at $t = 120$ s and visibility of the lobby returns to above 10 m visibility limit after another 60 s. This is considered acceptable because visibility within the lobby is always above 5 m after $t = 120$ s, therefore it is considered that toxicity is unlikely to impact on occupants passing through the lobby, as discussed in the acceptance criteria in Section 5.

6.2 Firefighting

As above, the full simulation results for the firefighting phase can be found in Appendix II. These results present contour plots of visibility, temperature and velocity through the stair and in the common corridor at a time of 200 s (i.e. the end of the simulation). Stair conditions are observed in a vertical plane through the stair door and the height of the stair. For clarity, only conditions on the floor of fire origin and one storey above are shown but the full stair height has been simulated. For the corridor contour plots, these are presented in the horizontal plane at a height of 1.5 m from FFL.

The visibility conditions are shown in Figure 9, at $t = 200$ s, the stair core remains free of smoke for the duration of the simulation. Similarly, in FF2, the stair core remains free of smoke. This meets the acceptance criteria for the protection of the stair core.

The temperatures within the flat reach in excess of 800 °C. Within the corridor, only the regions in the immediate vicinity of the flat door exceed 210 °C at 1.5 m above FFL, which is considered reasonable given the simulated flat conditions. Temperatures are maintained below the criterion along the firefighter retreat path between the flat of fire origin and the stair door, as shown in Figure 10.

The simulated conditions occur when the stair and flat doors remain fully open, with the maximum HRR remaining at 3.8 MW for a 2 min period following the arrival of the fire and rescue service. This is a conservative representation of fire and rescue service operations, where it would be expected that the deployment of water (such as prior to the full opening of the flat door) would reduce the temperature and buoyancy of smoke both within the common corridor and the flat of fire origin, as well as significantly reducing the HRR of the fire.

6.3 Conclusion

CFD analysis has been performed for Option 1 of the ventilation proposal. For the proposed ventilation provisions, it does not the acceptance criterion detailed in Section 5.1 for both means of escape and firefighting phase.

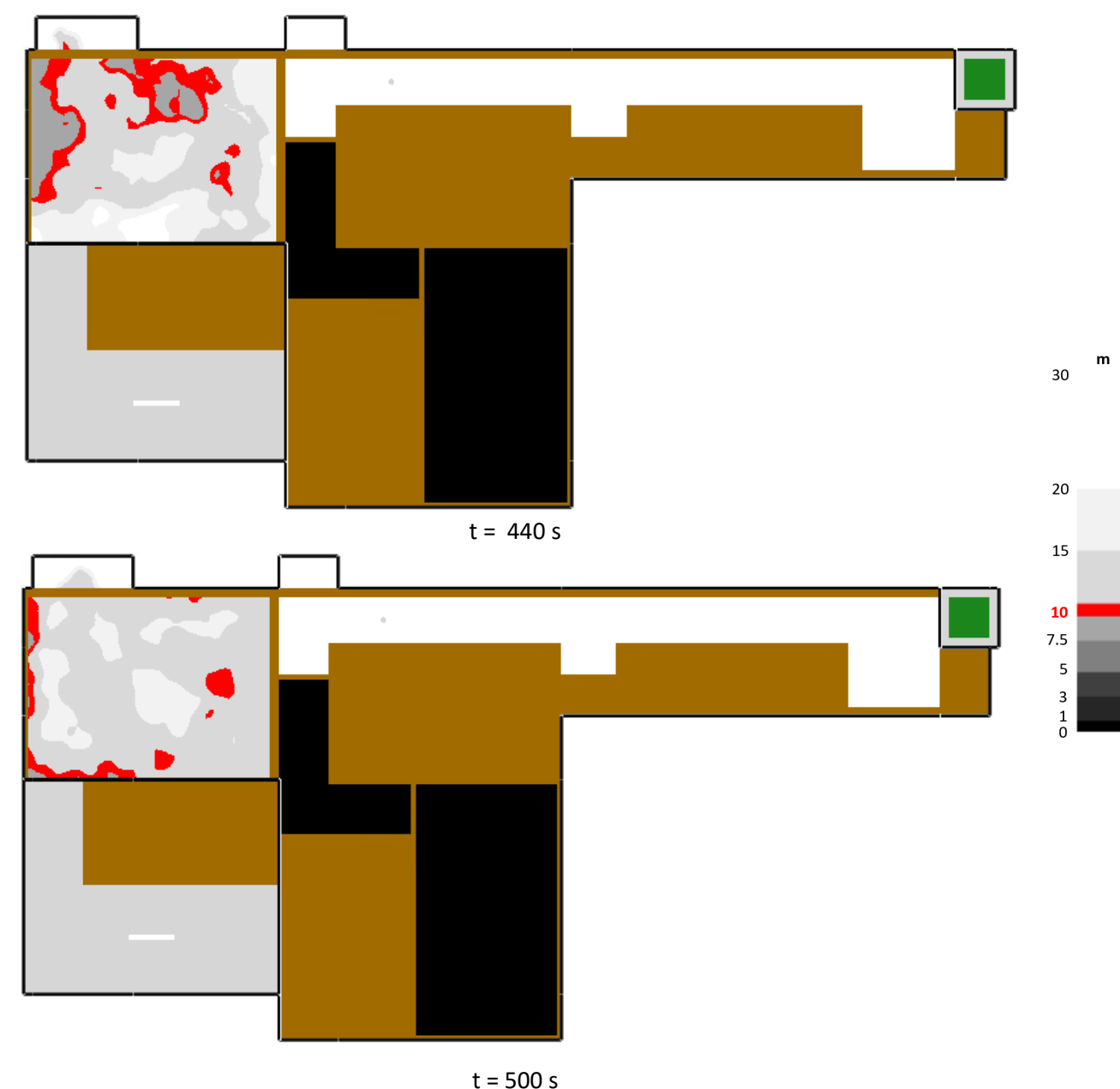


Figure 8: Visibility within the corridor at $z = 2.0$ m, Scenario MOE1..

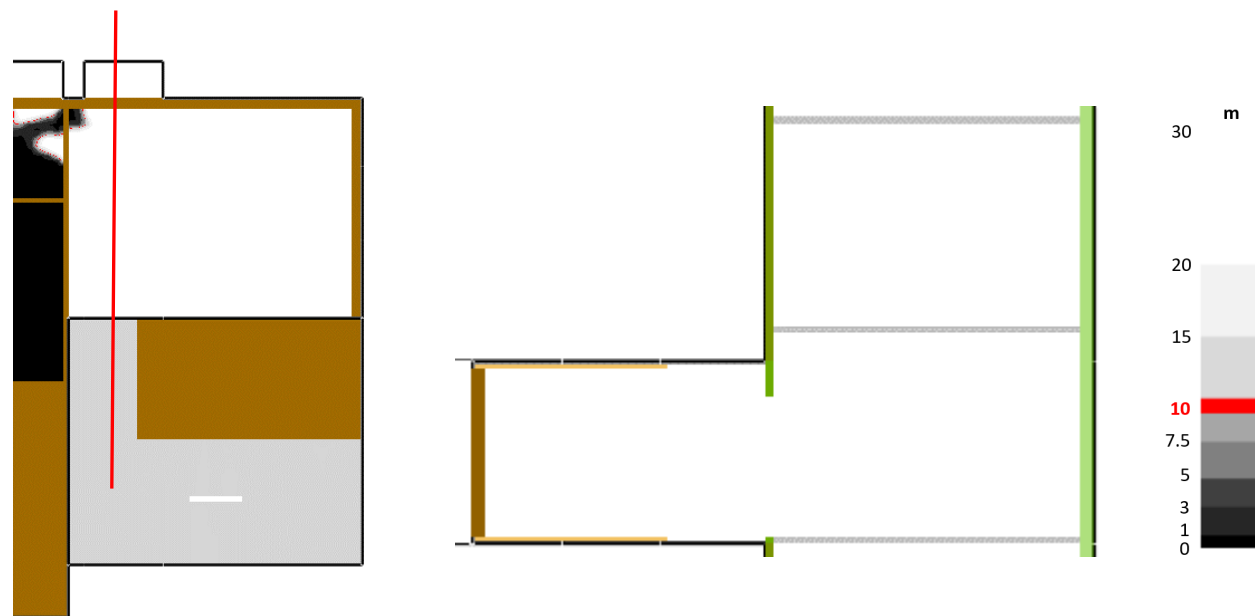


Figure 9: Visibility within the stair in the horizontal and vertical plane (indicated by the red line), Scenario FF1, $t = 200$ s.

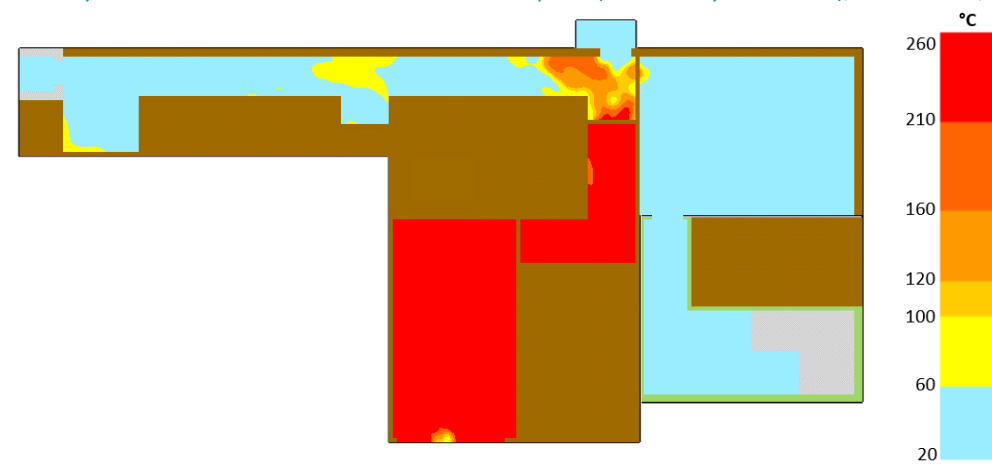


Figure 10: Temperature within the corridor at $z = 1.5$ m, Scenario FF1, $t = 200$ s.

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CORRIDOR VENTILATION REPORT APPENDIX I – MESH SENSITIVITY

Numerical Parameters

The mesh size (δx) used for the fire can be compared to the characteristic fire diameter (D^*) and plume resolution index ($D^*/\delta x$). Research document NUREG-1824 [33] included a series of sensitivity analyses carried out for FDS where suitable $D^*/\delta x$ values typically ranged from 4 to 16, with the upper bound representing practical computational limits. These values were deemed in the examples to adequately resolve plume dynamics, along with other geometrical characteristics. Relevant test series and associated numerical parameters of the FDS validation guide [15] have been reproduced in Table I 1.

The modelling has been undertaken with a uniform cell size of 0.1 m. A maximum fire size of 1.0 MW and 3.8 MW modelled with a 0.1 m uniform cell achieves a $D^*/\delta x$ value of ~ 10 and 16, respectively, which is within the NUREG-1824 recommended range as well within or greater than the ranges of the ATF Corridor Experiment and the NIST/NRC Compartment experiments test series. McDermott et al. [34] have also indicated that “ $D^*/\delta x \approx 10$ has historically been considered adequate grid resolution.” Hopkin et al. [35] observed nominal deviation in the observed corridor clearance time between 0.05 m and 0.1 m cell sizes. The selected 0.1 m cell size for this assessment is therefore considered adequate.

Model Uncertainty and Model Bias

The FDS Validation Guide includes discussion and calculations of model uncertainty and model bias factors. The model uncertainty represents the relative standard deviation of simulation data compared to experimental test data (σ_m) for certain quantities of interest, and the bias factor highlights overall trends and biases of FDS’s predictive capabilities. The relevant measures of uncertainty and bias factors are shown in Table I 2, where a value greater than one represents a general ‘over-estimation’ by the model relative to the experimental test series, and a value less than one represents ‘under-estimation’. From this it can be observed that FDS typically overestimates temperatures, entrainment and smoke obscuration compared to the experimental data. These are the three, core metrics of interest in this assessment. FDS is shown to underestimate the smoke detector activation time and therefore a detection delay has been incorporated into the modelling (discussed in Section 4.6). As such, there is a requisite confidence in the tool’s capability to investigate the given design problem with an appropriate degree of conservatism.

Table I 1: Relevant FDS Validation Guide scenarios and equivalent parameters for this assessment.

Test series	D^*	$D^*/\delta x$	Comment
ATF Corridor Experiments	0.3-0.7	3-7	A series of experiments with long unventilated hallways and a connecting stairway.
NIST/NRC Compartment Experiments	0.6-1.3	5-11	A series of experiments which considered naturally ventilated and mechanically ventilated compartments, with fire sizes of 350 kW to 2.2 MW.
Ashton Park	1.0-1.6	10-16	Geometry and fire parameters adopted for modelling (not contained within the FDS Validation Guide).

Table I 2: FDS model uncertainty and bias.

Quantity	σ_m	Bias
Hot gas layer temperature, forced ventilation	0.19	1.14
Hot gas layer temperature, natural ventilation	0.07	1.04
Hot gas layer depth	0.05	1.04
Ceiling jet temperature	0.12	1.04
Plume temperature	0.18	1.15
Velocity	0.09	0.99
Smoke detector activation time	0.27	0.61
Entrainment	0.05	1.13
Smoke obscuration	0.10	1.08

CORRIDOR VENTILATION REPORT APPENDIX II – SIMULATION RESULTS

MOE1

Visibility:

Temperature:

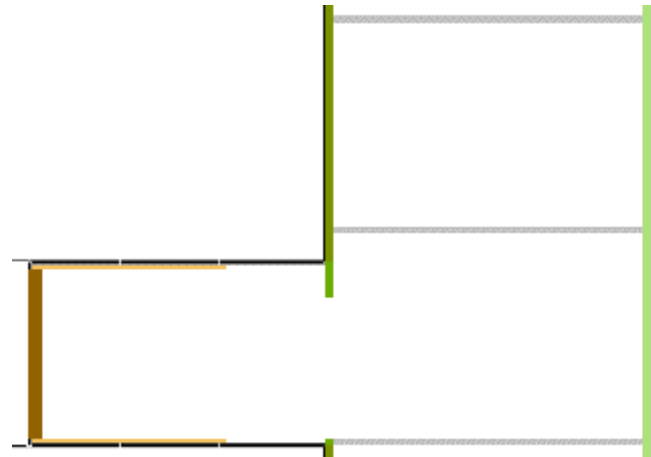
Velocity:



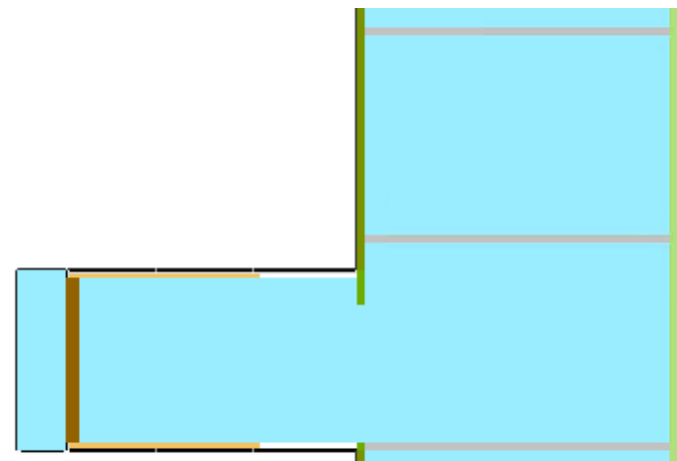
Figure II 1: Contour plots for Scenario MOE1.

FF1
 vertical plane
 simulation time = 200 s
 140 s following flat door opening, acceptance criteria assessed

Visibility:



Temperature:



Velocity:



^(a) Note: Visibility has not been assessed within the corridor during firefighting.

Corridor ^(a)
 $z = 1.5$ m
 simulation time = 200 s
 140 s following flat door opening, acceptance criteria assessed

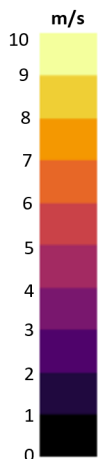
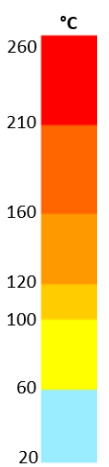
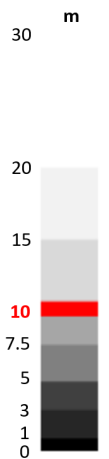
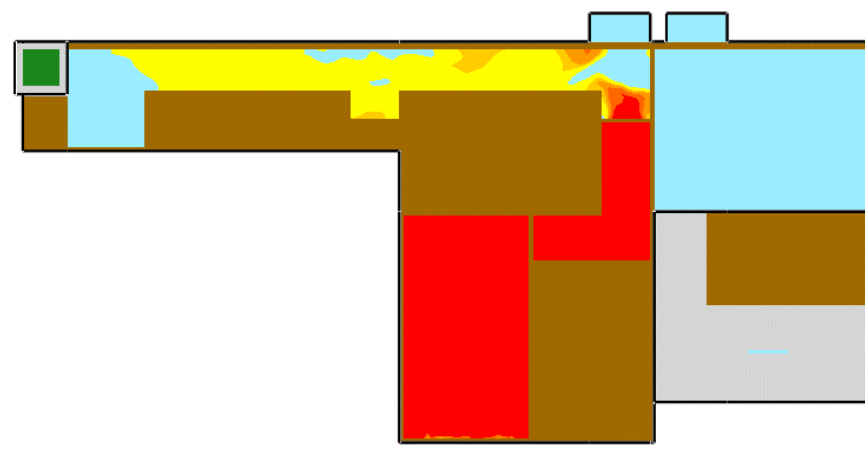
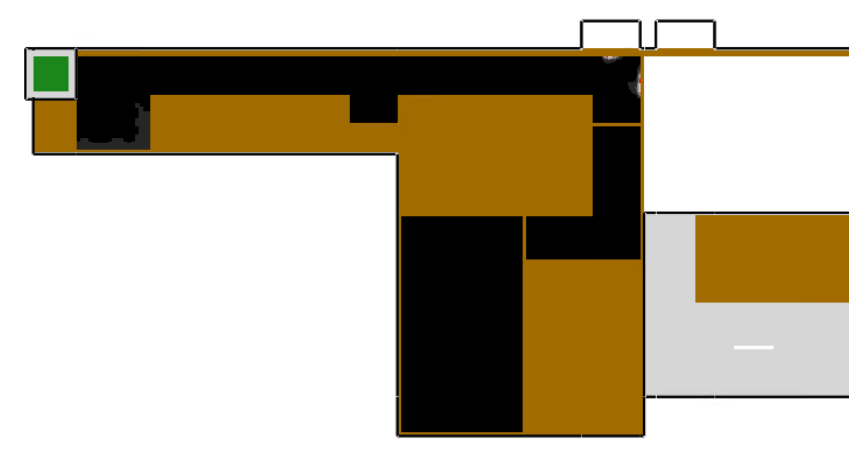
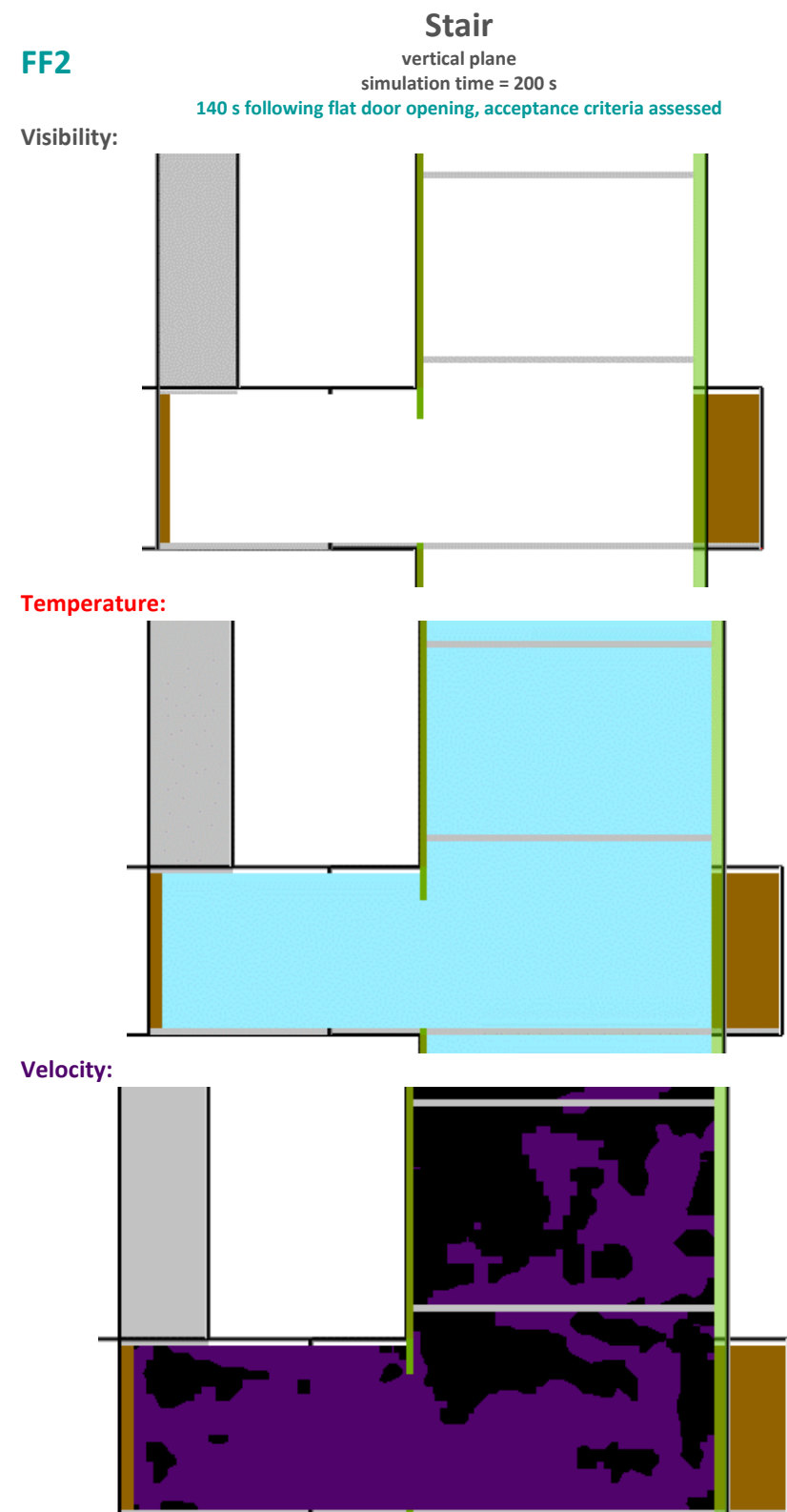


Figure II 2: Contour plots for Scenario FF1.



^(a) Note: Visibility has not been assessed within the corridor during firefighting.

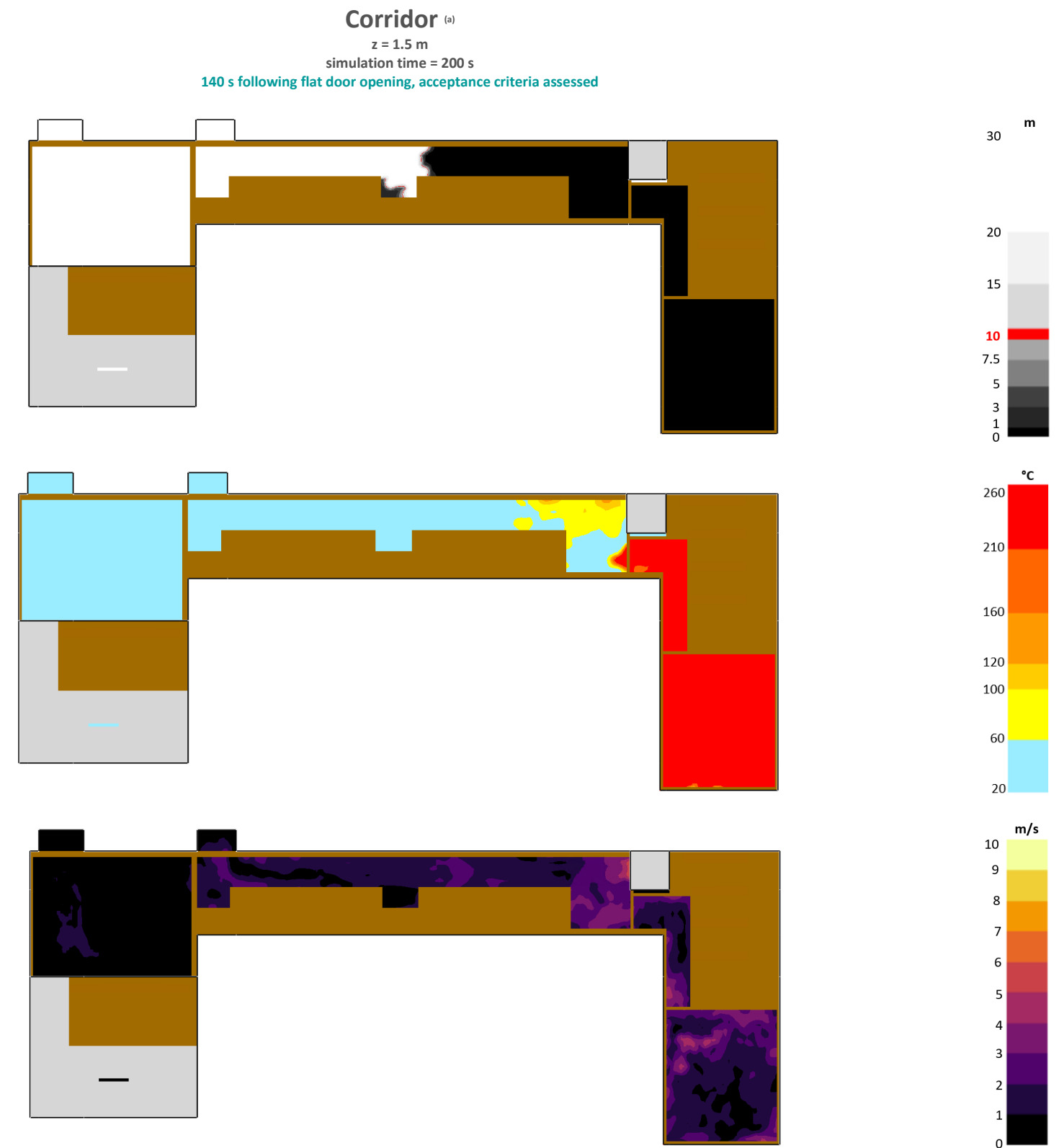


Figure II 3: Contour plots for Scenario FF2.

Our History

2015

- Established in the UK by Simon Lay & Sam Liptrott after their experience working for major global multi-discipline engineering consultancies
- Founding principle that every project deserves access to high quality fire safety solutions

2016 – 17

- Established offices in London and Scotland
- Awarded Google HQ in London in competitive tender
- Appointed to support major contractors
- Commenced work on projects in Europe and India
- Year 1 revenue reached £0.9M

2017 – 18

- Expanded to Bath and Oxford
- Reached team size of 25
- Internal research team appointed to deliver research into high-rise fire safety by CTBUH
- Completed on-site delivery of first major projects
- New governance and legacy model established which ensures that business is wholly owned by staff
- Year 2 revenue reached £1.9M

2018 – 19

- Established a presence in Leeds & Barcelona
- Team expanded to 50 (now reached over 60)
- Developed an in-house team for on-site delivery support
- Published over 30 peer reviewed technical papers
- Year 3 revenue reached £4.9M

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