1. Fire Engineering Assessment of Cooker Separation Distances
   1. Introduction
      1. UK Residential design guidance documents, such as AD-B and BS 9991 states that when designing kitchen areas, cooking facilities should be located “remote” from the escape path. Specifically, Section 3.18.b.ii of AD-B requires that “Cooking facilities are remote from the main entrance door and do not impede the escape route from anywhere in the flat”. Section 9.4.2.a of BS 9991 states “Cooking facilities should be sited away from the flat entrance door and the internal escape route”.
      2. As neither of these documents provide a quantification of what constitutes “remote”, it is left to the designer to justify that a particular arrangement of cooking facilities is acceptable. The purpose of this appendix is to provide a quantitative assessment of the location of the cooking facilities on this project to demonstrate that should a cooker fire occur, occupants are able to safely evacuate.
   2. Area of Study
      1. Cooking facilities are deemed to present a hazard to escape as cooking oil, when left on a hob, can auto ignite. This is a common cause of a dwelling fires, with UK fire statistics (2022) attributing “cooking appliances” as the cause of 45% of all dwelling fires.
         * Once autoignition has occurred, the fire has the potential to hinder escape within two ways:
         * By producing a smoke which will fill down from the ceiling and cause untenable visibility, temperature of toxicity conditions to occur within the space (convective output); and
         * By emitting radiant heat from the flames which could harm those trying to escape past the fire (radiative output).
      2. Typically, the smoke produced by a fire will rise and fill across the entire ceiling. As more smoke is produced, the smoke layer will descend evenly across the space, affecting conditions at different heights within the room evenly. As such, the effect of the convective heat output of the fire on escape would be the same regardless of whether the cooking facilities are located “remote” from the escape routes. For this reason, the convective output of the fire is disregarded for the purposes of this study.
      3. As such, this study focusses purely on the radiative output of the fire. Specifically, this study calculates the radiative heat output of the flames of a “reasonable worst case” cooker fire and then assesses whether the radiative heat dose of any occupants expected to escape past the fire is within acceptable limits. If this can be demonstrated, it can be considered that the cooking facilities are located suitably “remote” from the escape routes.
      4. The kitchen areas are provided with a suppression system. Should an oil pan fire occur, it would be expected that this system would activate shortly after ignition. Once ignited, it is expected that the separation distance between the cooking facilities and the escape routes would be of less importance as:
         * The suppression system would quickly control and most likely extinguish the fire, removing the risk posed; and
         * Once activated the sprinkler spray would absorb much of the radiative heat emitted by the fire, significantly reducing the radiative heat flux received on the escape route.
      5. As such, this study focusses solely on the period of time following ignition but prior to activation of the suppression system.
   3. Fire Engineering Approach
      1. Fire Dynamics has developed internal software to assess this problem. The software incorporates a visual interface which allows the user to mark up the relative locations of the cooking facilities and the escape route, the position any obstructions which may shield the escape route from the path of the radiation and the location of any doors which need to be used to reach a place of relative safety. Once this is complete, the software calculates the radiative heat dose an occupant would be expected to receive when attempting an escape (Using Purser’s Fractional Effective Dose concept, as per the method detailed in BS 7974-6). Figure 1 is a flow chart which shows the step by step process the evacuation model follows. The values used in this model are outlined in the sections which follow.

User Inputs Relative Positions of Escape Route, Cooking Facilities, Escape Doors and Walls obstructions

User Defines Fire Heat Release Rate (kW) and Occupant Travel Speed

Escape Distance = Length of Defined Escape Path

Distance Travelled = 0m, Cumulative Radiative FED = 0

Calculate Distance Between Occupant Location and Cooking Facilities

Is Linear Path Between Occupant and Cooking Facilities Blocked by a Wall

Yes

No

Add result to Cumulative Radiative FED

Calculate Radiative FED Contribution for One Second Timestep

No Radiation Received

Calculate Radiative Heat Flux Received (kW/m2)

Occupant Moves Along Escape Route. Escape Distance = Escape Distance - (Occupant Travel Speed / One Second)

Does Escape Distance = 0?

No

Does Remaining Travel Distance = 0?

Yes

If Required, Calculate Distance From Cooker to Escape Door and Calculate FED Contribution For Door Opening Time. Add Result to Cumulative FED

Cooking Facilities are Sufficiently “Remote” From Escape Route

No

Yes

Is Cumulative FED >=1?

Cooking Facilities are not Sufficiently “Remote” From Escape Route

Figure 1: Flow Chart of Fire Dynamics Internal Software

* 1. Assumed Fire Size
     1. In the research paper “Modelling the thermal radiation from kitchen hob fires”, Spearpoint, Hopkin and Hopkin provide a summary of the key fire test data where the maximum heat release rate of the fire is recorded. This is reproduced in Table 1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Experiment ID** | **Hob energy and power output (kW)** | **Oil type and initial mass** | **Pan material, diameter and depth** | **Hob/kitchen arrangement** | **Maximum HRR *Qmax*(kW)** |
| Hamins et al. -  Test 1 | Electric 1.4 +/- 0.3 | Corn oil 187 g | Stainless steel, 10 cm dia., 5 cm deep | Open | 73 +/- 20 |
| Hamins et al. -  Test 2 | Electric 1.4 +/- 0.3 | Corn oil 187 g | Stainless steel, 10 cm dia., 5 cm deep | Open | 101 +/- 20 |
| Hamins et al. -  Test 3 | Electric 2.0 +/- 0.3 | Corn oil 4000 g | Stainless steel, 25 cm dia., 18 cm deep | Open | 472 +/- 20 |
| Hamins et al. -  Test 11 | Electric 1.4 +/- 0.3 | Peanut oil 186 g | Stainless steel, 10 cm dia., 5 cm deep | Open | 100 +/- 20 |
| Hamins et al. - KSG15 | Gas 1.5 | Corn oil 4140 g | Stainless steel, 25 cm dia., 18 cm deep | Enclosure | 3500 |
| Chow and Ni, Tests B1-B3 | Electric 3 | Vegetable oil  blend 450–500 g | Stainless steel, 25 cm dia., 18 cm deep | Open | 33 +/- 2 |

Table 1: Summary of Fire Test Data with Calculated Maximum Heat Release Rates

Of these tests, the Hamins et al KSG15 has a much greater heat release rate as the test allowed for the spread of fire to adjacent kitchen surfaces (i.e. cabinets, extraction hoods). As the flats in question are provided with suppression systems, this is not expected to occur in this instance so this result can be disregarded.

* + 1. The next largest result, Hamins et al Test 3, includes for 4000g (4.5L) of cooking oil. This is representative of an old fashioned chip pan catching fire. Whilst this fire size is considered to be unrepresentative of the majority of pan fires (most cooking does not take place in an old fashioned chip pan, such pans tend to be replaced by standalone deep fat fryer units today), the recorded figure of 476kW has conservatively been taken to be the heat release rate of the fire for the purposes of this assessment.
  1. Calculation of Received Radiative Heat Flux
     1. In the research paper “Modelling the thermal radiation from kitchen hob fires”, Spearpoint, Hopkin and Hopkin found that the most accurate hand calculation for radiative heat flux from a cooker fire is to adopt a point source model, where the received heat flux is given as:

where:

= radiative heat flux received (kW/m2)

= radiative heat output of the fire (kW)

= radial distance to the receiver (m)

= angle between the emitter and the receiver.

* + 1. As the worst-case results would be obtained where the angle between the emitter and the receiver is fixed at 0°, for the purposes of this assessment this calculation can be simplified to:
    2. It should be noted that is the radiative heat output only. As per Drysdale, the radiative fraction of the fire is assumed to be 1/3rd of the total heat output (i.e. = 476/3 = 158.66666666666666kW).
  1. FED Calculation
     1. The FED for radiative heat is calculated at each timestep using Equation 10 of BS 7974:6 (below).

where:

= Fractional Effective Dose at timestep.

= Tolerance time for the level of radiative heat flux imposed at this timestep (minutes)

= Tolerance time for the smoke temperature imposed at this timestep (minutes)

= length of timestep (one second, or 1/60 minutes).

* + 1. is calculated using Equation 7 of BS 7974:6:

where:

= Tolerance time for the level of radiative heat flux imposed (minutes)

= Radiant heat exposure endpoint for exposed skin (taken to be 1.33(kW.m2)4/3min. This is the minimum value for severe skin pain as per Table 2 of BS 7974:6

= Measured radiative heat flux (kW/m2)

* + 1. This calculation is undertaken at each time step (FED Contribution). The total FED Contributions from each time step are then added to give a Cumulative FED. If the Cumulative FED is greater than or equal to “1” then the occupant is considered exposed to an unacceptable radiative heat dose.
  1. Other Assumptions
     1. It is assumed that the occupants walk at a speed of 1.2m/s, as per CIBSE Guide E and BS 7974:PD6.
     2. When drawing the escape route, it is assumed that an occupant is 0.5m wide, which is the mean value for U.S adults given on page 2837 of the SFPE handbook.
     3. The time taken for an occupant to open a door and escape through is taken to be 11 seconds. This is the 95th percentile value for “All Apartments” taken from Table 2 of “Estimating Door Open Time Distributions for Occupants Escaping from Apartments” by Hopkin et al. This figure is considered to be sufficiently onerous to account for all eventualities.
     4. **Insert a justification for door opening time used.**
     5. It is assumed that the occupant receives a radiative heat dose for the entire time they are escaping through the door.
  2. Measured Route
     1. A drawing showing the escape route, cooker location and wall obstruction locations is provided in Figure 2.

A blue line drawing of a house

Description automatically generated

Cooker Location

Start of Escape Route

Wall Obstruction

Escape Route

Figure 2: Diagram of Software Inputs

* 1. Results of Calculation
     1. The results of the calculation are provided in Table 2.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Time** | **Distance Travelled along Escape Route (m)** | **Distance from Cooker Fire (m)** | **Radiative Heat Flux Received (kW/m2)** | **FED Contribution From Time Step** | **Cumulative FED** |
| 0 | 0 | 3.72 | 0 | 0 | 0 |
| 1 | 1.2 | 3.69 | 0.92 | 0.0111 | 0.0111 |
| 2 | 2.5 | 2.66 | 1.77 | 0.0267 | 0.0378 |
| 3 | 4.61 | 1.58 | 4.99 | 0.106 | 0.1438 |
| 4 | 7.75 | 1.6 | 4.92 | 0.1039 | 0.2477 |
| 5 | 9.89 | 1.12 | 9.94 | 0.2651 | 0.5128 |
| 6 | 11.09 | 1.95 | 3.29 | 0.061 | 0.5738 |
| 7 | 13.68 | 2.58 | 1.87 | 0.0288 | 0.6026 |
| 8 | 16.79 | 3.62 | 0.96 | 0.0118 | 0.6144 |
| 9 | 18.91 | 2.91 | 1.47 | 0.021 | 0.6353 |
| 10 | 21.15 | 2.74 | 1.67 | 0.0248 | 0.6601 |
| 10.54 | 22.44 | 2.71 | 1.71 | 0.0138 | **0.6738** |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Table 2: Result of Calculation

* 1. Conclusion
     1. It can be seen from the results that under “reasonable worst case” conditions, the maximum FED an occupant could be expected to receive is 0.674. As this is less than “1”, this can be considered to be an acceptable dose of radiative heat. The factor of safety in this result is considered to be sufficiently large to allow for any uncertainties in the inputs.
     2. Given this, it is our view that it has been quantitatively demonstrated that in this instance, the cooking facilities are sufficiently “remote” from the escape routes.
     3. **FED>1. Revise parameters and try again.**