Study Report

No. 185

Soot Yield Values for Modelling Purposes – Residential Occupancies

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Preface

This is the report prepared during research into soot yield values used for modelling.

Acknowledgments

This work was funded the Department of Building and Housing.

Note

This report is intended primarily for regulatory authorities, researchers and fire engineers.

SOOT YIELD VALUES FOR MODELLING PURPOSES – RESIDENTIAL OCCUPANCIES

BRANZ Study Report 185 **A. P. Robbins and C. A. Wade**

Reference

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Abstract

The Department of Building and Housing (DBH) has convened a working group to develop a fire engineering framework for performance-based design specifying design fire scenarios, design fire characteristics and acceptance criteria. They have been reviewing a number of case study examples on sample buildings, generally compliant with C/AS1 to test proposed fire design scenarios and input parameters. Handbook values for the smoke yield (the mass of smoke/soot produced per mass of fuel burned) based on flexible polyurethane foam have been assumed for design fires involving 'upholstered furniture'. It is suspected that the predictions for the concentration of smoke are significantly higher than would be experienced in practice, and as a result these are contributing to the buildings failing the proposed acceptance criteria relating to visibility.

The objectives of the research were to:

1. Conduct a sensitivity analysis on the smoke yield parameter when used with two commonly used fire models (BRANZFIRE and FDS) by simulating a well documented experiment and varying the input smoke yield between 0.05 and 0.2 kg/kg.
2. Compare model predictions for the optical density (which is related to smoke concentration and visibility) with the selected experimental data described in a report by the National Institute of Standards and Technology (NIST) (Bukowski et al 2007; Peacock et al 2002).
3. Present the results and make a recommendation on an appropriate smoke yield (kg/kg) to be included in the design fire specifications to be published by the DBH.

For the range of smoke/soot yields considered in this study (0.05 – 0.20 g/g) both FDS and BRANZFIRE provided generally conservative predictions of smoke optical density for the flaming upholstered armchair located within a manufactured home, described in detail in this report.

In modelling the same experiment, a soot/smoke yield of 0.05 g/g generally provided the closest but conservative agreement with the experimental measurements of smoke density.

With a soot/smoke yield of 0.20 kg/kg the models over-predicted the smoke optical density by up to a factor of 10. For the upholstered armchair used in this experiment, assuming a handbook value for soot yield based on 'flexible polyurethane foam' did not provide a good prediction of smoke optical density.

Recommendations based on the results of this research included selection of a design fire value for soot/smoke yields derived from optical measurements taken during flaming combustion of full-sized items of upholstered furniture. In these measurements the upper 95th percentile value of the smoke yield based on 24 items of upholstered furniture (with outlying data points removed) was 0.07 kg/kg.

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1. INTRODUCTION

1.1 Motivation

The Department of Building and Housing (DBH) has convened a working group to develop a fire engineering framework for performance-based design specifying design fire scenarios, design fire characteristics and acceptance criteria. They have been reviewing a number of case study examples on sample buildings, generally compliant with C/AS to test proposed fire design scenarios and input parameters. Handbook values for the smoke yield (the mass of smoke/soot produced per mass of fuel burned) based on flexible polyurethane foam have been assumed for design fires involving 'upholstered furniture'. It is suspected that the predictions for the concentration of smoke are significantly higher than would be experienced in practice, and as a result these are contributing to the buildings failing the proposed acceptance criteria relating to visibility.

1.2 Objective

It was proposed to:

1. Conduct a sensitivity analysis on the smoke yield parameter when used with two commonly used fire models (BRANZFIRE and FDS) by simulating a well documented experiment and varying the input smoke yield between 0.05 and 0.2 kg/kg.
2. Compare model predictions for the optical density (which is related to smoke concentration and visibility) with the selected experimental data described in a report by the National Institute of Standards and Technology (NIST) (Bukowski et al 2007; Peacock et al 2002).
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1.3 Scope

Representative software packages were selected for field model and zone model approaches to fire modelling, being FDS and BRANZFIRE respectively.

A single building layout with a flaming upholstered armchair fire was used for the comparison of model and experiment results. The building was a small single-storey residential occupancy (Bukowski et al 2007; Peacock et al 2002).

One set of experiment data was used for comparison with model predictions.

2. SUMMARY LITERATURE REVIEW

2.1 Background

Tenability criteria for life safety for occupants during fire evacuation may involve calculation of visibility through smoke. Visibility is determined by the concentration of carbon/soot in the smoke layer and the path length through the smoke from the viewer to a target object, as well as the characteristics of the target.

A study by Jin (1978) found that the product of visibility (V) and average extinction coefficient (k_{avg}) is a constant for a given object and lighting condition. The data correlated to a value of 3 for light-reflecting signs and 8 for light-emitting or illuminated signs (Mulholland 1995),

The visibility is therefore given by:

$V = 3\ k_{avg}$ metres (reflective signs)

$V = 8\ k_{avg}$ metres (illuminated signs).

Optical density (OD) is the conversion of extinction coefficient from natural log to base 10 units such that $OD = k_{avg} / 2.3$.

When attempting to model smoke development and visibility through smoke, the production of soot from the fire is expressed as the mass of soot generated per mass of fuel burned. This quantity is referred to as the soot yield with units kg/kg.

The DBH working group suggested the following design values for smoke/soot yield. The post-flashover values were taken as twice the pre-flashover value.

Table 1. DBH working group proposals for soot yield values (Wade et al 2007)

Pre-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	**Post-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})**	**Description**
0.20	0.40	100% polyurethane
0.11	0.22	50% polyurethane, 50% wood
0.015	0.030	100% wood

2.2 Smoke Related Building Performance Criteria

Performance criteria have generally been expressed either as a visibility distance or as an optical density. A summary of published suggested smoke related building performance criteria are presented in Table 2.

Table 2. Summary of published smoke related building performance criteria

Limit for Visibility (m)	Limit for Optical Density (1/m)	Comment	Reference
0.8	~1.2		(Babrauskas 1979)
5	~0.2	For small enclosures with short travel distances	(Buchanan 2001; Jin 1978, 1981; Jin and Yamada 1990; Purser 2002)
10	0.08	For large enclosures with long travel distances	(Jin 1978, 1981;Jin and Yamada 1990; Purser 2002)
10	~0.1	For all rooms other than small enclosures	(Buchanan 2001)
10	~0.1		(Smith 1982)

2.3 Published Modelling with Soot Yield

There are a small number of published studies investigating the influence of soot yield values on model optical density values or smoke detector activation compared to experiment results. Such research typically uses a single soot yield value, and sensitivity analyses have typically not been performed thoroughly.

Hultquist (2000) reported on simulating visibility in the CFAST zone model for three experiments: a hospital bed in a large enclosure, a propane burner in a small enclosure and a wood stack fire in an enclosure linked to a staircase. Good agreement for predicted optical density with the experiments was achieved for the first two, and over-prediction for the third. CFAST uses H/C and CO/CO_2 ratios instead of species yields directly for input.

Brammer (2002) used an average smoke yield value of 0.10 kg/kg for use in modelling (using FDS) two two-storey house fires (approximately reaching 600 kW in 500 s and 900 kW in 500 s), using Cardington house experiment results for comparison. In general, there was reasonable agreement between the trend of the model and the experiment results. There was good agreement between the model and experiment values between approximately 300 and 500 s. However for the first 300 s, the model over-predicted the experiment results. This initial over-prediction of the optical density followed on to impact the under-prediction of the smoke detector activation times.

Hamberg (2004) extended Brammer's study by conducting further simulations with BRANZFIRE using soot yields of 0.05 and 0.23 kg/kg. She found that a soot yield of 0.05 kg/kg gave the closest agreement to the measured value of smoke optical density.

Wade and Collier (2004) modelled the light extinction coefficient in the ISO 9705 room using BRANZFIRE for a propane gas burner over the range 50 – 250 kW with reasonable agreement. The smoke/soot yield for the propane burner was taken as 0.01 kg/kg.

Another recent study by Thomas (Thomas 2007; Spearpoint, personal communication 2007) where he simulated Cardington house fire experiments using soot yields of 0.2 down to 0.131 kg/kg for an upholstered chair in the BRANZFIRE zone model also resulted in a large over-prediction of smoke optical density and corresponding under-prediction of smoke alarm activation times.

2.4 Published Smoke Yield Values

A summary of published and proposed average smoke yield values for flaming combustion of combinations of materials, natural materials and solid and foamed synthetics are presented in Table 3, Table 4 and Table 5, respectively.

Table 3. Summary of published and proposed average smoke yield values associated with flaming combustion of combinations of materials

Pre-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	Post-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	Description	Reference
		Using whole data set for mattresses and upholstered furniture	From analysis of data from (CBUF 1995) [a]
0.097	-	95th percentile	
0.30	-	99th percentile	
		Using data set without outlier for mattresses and upholstered furniture	From analysis of data from (CBUF 1995) [a]
0.073	-	95th percentile	
0.96	-	99th percentile	

Notes:

[a] Derived from optical measurements – details of analysis are included in Appendix A.

Table 4. Summary of published and proposed average smoke yield values associated with flaming combustion of natural materials

Pre-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	Post-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	Description	Reference
0.015	0.03	100% wood	(Wade et al 2007) [a]
0.015	-	Wood	(Karlsson and Quintiere 2000)
0.015	-	Durmast oak	(Guillaume 2006)
0.015	-	Red oak	(Tewarson 1988)
0.015	-	Brush	(Guillaume 2006)
0.020	-	100% wool	(Wade 2001) [b]
0.008	-	Pure new wool	(Guillaume 2006)

Notes:

[a] These are values proposed by the DBH working group based on examination of literature.

[b] Floor covering materials in cone calorimeter tests.

Table 5. Summary of published and proposed average smoke yield values associated with flaming combustion of synthetic solids and foams

Pre-Flashover Soot Yield Value (kg_{soot}/kg_{fuel})	**Post-Flashover Soot Yield Value** (kg_{soot}/kg_{fuel})	**Description**	**Reference**
0.230	-	Polyurethane	(Karlsson and Quintiere 2000)
0.131- 0.227	-	Polyurethane flexible foams	(Tewarson 1988)
0.104- 0.130	-	Polyurethane rigid foams	(Tewarson 1988)
0.052	-	100% polyamide	(Wade 2001) [a]
0.028	-	PVC flooring	(Wade 2001) [a]
0.140	-	PVC	(Karlsson and Quintiere 2000; Tewarson 1988)
0.172	-	Pure PVC	(Guillaume 2006)
0.040	-	Nylon	(Wade 2001) [a]
0.075	-	Nylon	(Karlsson and Quintiere 2000)
0.160	-	Polystyrene	(Karlsson and Quintiere 2000)
0.164	-	Polystyrene	(Guillaume 2006)
0.18 – 0.21	-	Polystyrene foams	(Tewarson 1988)
0.022	-	PMMA	(Karlsson and Quintiere 2000; Guillaume 2006)
0.105	-	ABS	(Guillaume 2006)
0.060	-	Polyethylene – solid	(Guillaume 2006)
0.06	-	Polyethylene	(Tewarson 1988)
0.056- 0.102	-	Polyethylene foam	(Guillaume 2006)
0.059	-	Polypropylene	(Guillaume 2006)
0.091	-	Polyester	(Tewarson 1988)
0.091	-	Polyester-1	(Guillaume 2006)
0.089	-	Polyester-2	(Guillaume 2006)
0.003	-	PTFE	(Guillaume 2006)
0.042	-	ETFE	(Guillaume 2006)

Notes:
[a] Floor covering materials in cone calorimeter tests.

Wade and Collier (2004) estimated smoke yield values from smoke obscuration measurements in a cone calorimeter for a range of wall lining materials. These are presented in Table 6.

Table 6. Smoke yield estimates based on smoke extinction area (SEA) from cone calorimeter

Material	Cone SEA (m²/kg) peak @ 50 kW/m²	Estimated yield = SEA/8790 (kg/kg)
Paper-faced plasterboard	85	0.010
Ordinary plywood	74	0.008
Melamine-faced, HD, non-combustible board	176	0.020
Plastic-faced steel sheet on mineral wool	768	0.087
FR particleboard	80	0.009
PVC wall carpet	488	0.056

Post-flashover fire conditions are characterised by high global equivalence ratio (>1). A correlation for the dependence of the soot yield on the global equivalence ratio was developed by Tewarson, Jiang and Morikawa (1993) as follows.

$$\frac{\Psi_{s,vc}}{\Psi_{s,wv}} = 1 + \frac{\alpha}{\exp(2.5\Phi^{-\zeta})}$$

where:

$\Psi_{s,vc}$ = soot yield under ventilated controlled conditions

$\Psi_{s,wv}$ = soot yield under well-ventilated conditions

Φ = global equivalence ratio

α, ζ = constants dependent on the fuel.

Figure 1 shows the correlation in graphical form showing that, for a wood fuel, a doubling of the pre-flashover soot yield is a reasonable value to apply to the post-flashover (under-ventilated) regime.

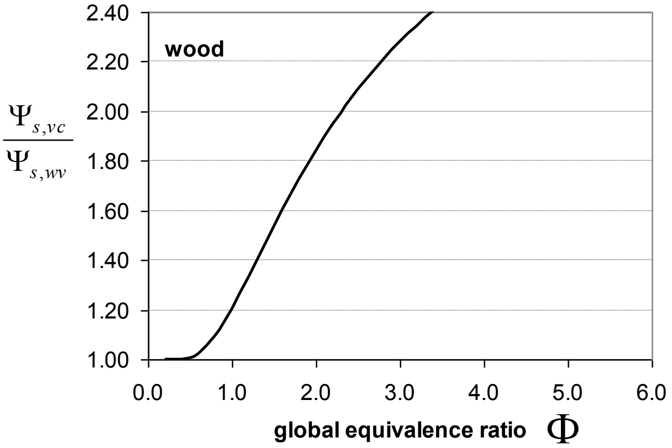


Figure 1. Tewarson, Jiang and Morikawa correlation for wood fuel (extracted from Tewarson et al 1993)

The Fire Code Reform Centre in Australia published fire engineering guidelines (FCRC 1996) that included typical ranges for smoke mass conversion factors (equivalent to soot yield) as shown in Table 7. They also provided a table of typical product yields for well-ventilated flaming combustion shown in Table 8 column 2. We have estimated the corresponding soot yield in column 3.

Table 7. Typical ranges of smoke mass conversion factor (extracted from FCRC 1996)

Material	**Smoke mass conversion factor (kg/kg)**	
	Flaming	Non-flaming
Cellulosic	<0.01-0.025	0.01-0.17
Plastics	<0.01-0.17	<0.01-0.19

Table 8. Typical product yields for well-ventilated flaming combustion

Material	**Mass optical density (m^2/g)**	**Estimated soot yield (kg/kg) [b]**
Timber	0.04	0.012
Polyvinyl chloride (PVC)	0.40	0.121
Polyurethane (flexible)	0.34	0.103
Polyurethane (rigid)	0.30	0.091
Polystyrene	1.0	0.303
Polypropylene	0.24	0.073
Generic building contents [a]	0.30	0.091

[a] Data for the generic building contents may be applied to residential, office and retail premises where there is a typical mixture of combustible contents.

[b] Yield ≈ 2.3 x mass optical density / 7.6.

2.5 Summary of Experimental Work Used for Comparison with Model Results

Experiment results used for comparison with model results are those published for the NIST Test FR 4061 (Peacock et al 2002) for a flaming upholstered armchair located in the living room of a manufactured home (Test No. SDC02). A summary of the experimental set-up is included in the following sections.

2.5.1 Experiment Set-up

The layouts of the manufactured home and the locations of instrumentation used during the test fires are shown in Figure 2. A summary of the instrumentation vertical locations and measurement uncertainty is presented in Table 9. Where multiple vertical sensors were used at one location, the sensors are labelled from the top most sensor to the bottom. A summary of the measured activation criteria for the smoke alarms used in the experiment is presented in Table 10.

The used armchairs (obtained from a rental retailer) used in the series of flaming experiments each had a mass of 28 kg. The composition of the cushioned sections of the wood-framed polyurethane foam upholstered armchair is presented in Table 11. A photograph of a representative armchair used in the test is shown in Figure 3.

The test was ignited using an "electric match", which consisted of an open cardboard match book with a nichrome wire loop through the sulphur ends of the matches. This was designed to provide a small (~2 s) ignition source, which was extended to ~20 s using a folded piece of paper, to ensure the ignition of the surrounding material. The location of ignition was at the front of the join between the seat cushion and the base (Bukowski et al 2007).

Table 9. Summary of instrument vertical locations and measurement uncertainty (adapted from Bukowski et al 2007)

Measurement	Instrument Vertical Positions (mm from ceiling)	Uncertainty
Temperature	20, 300, 610, 900, 1200, 1520, 1820 [a]	± 16ºC [b]
Sample mass	-	± 2 g
Oxygen concentration	900	± 0.6% volume fraction
Carbon dioxide concentration	900	± 0.4% volume fraction
Carbon monoxide concentration	900	± 0.06% volume fraction
Optical density	20,900 [c]	10% [d]

Notes:

[a] One temperature measurement was taken in Bedroom 3 at 1520 mm from the ceiling.

[b] Uncertainty of ±16ºC of peak gas burning temperature was measured. It was noted that additional uncertainty was expected due to variation in ignition and fire growth.

[c] One optical density measurement was taken in Bedroom 3 at 1020 mm from the ceiling.

[d] However, heating of the meters affected the reliability of the computed smoke obscuration. Therefore care should be used when analysing these values.

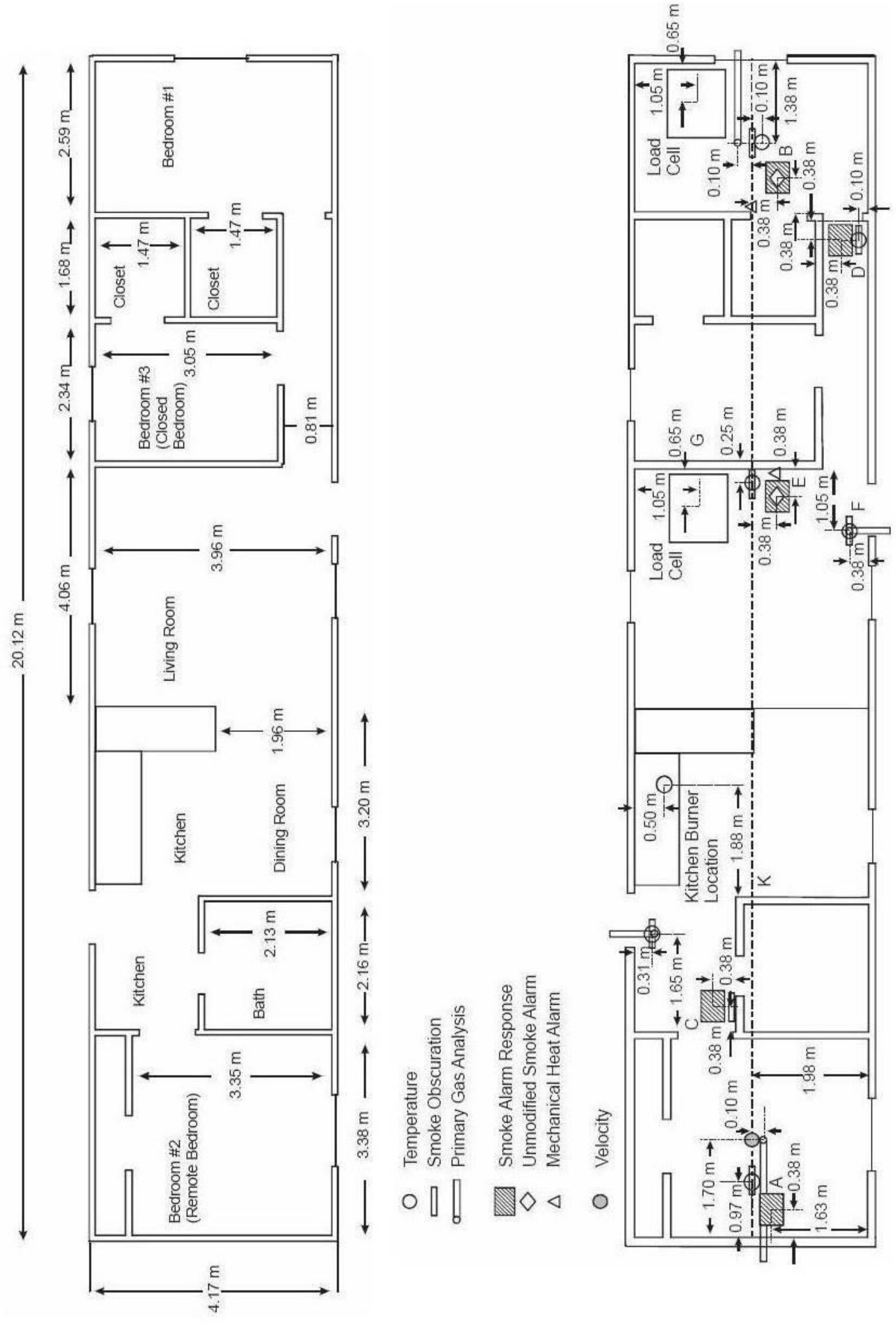


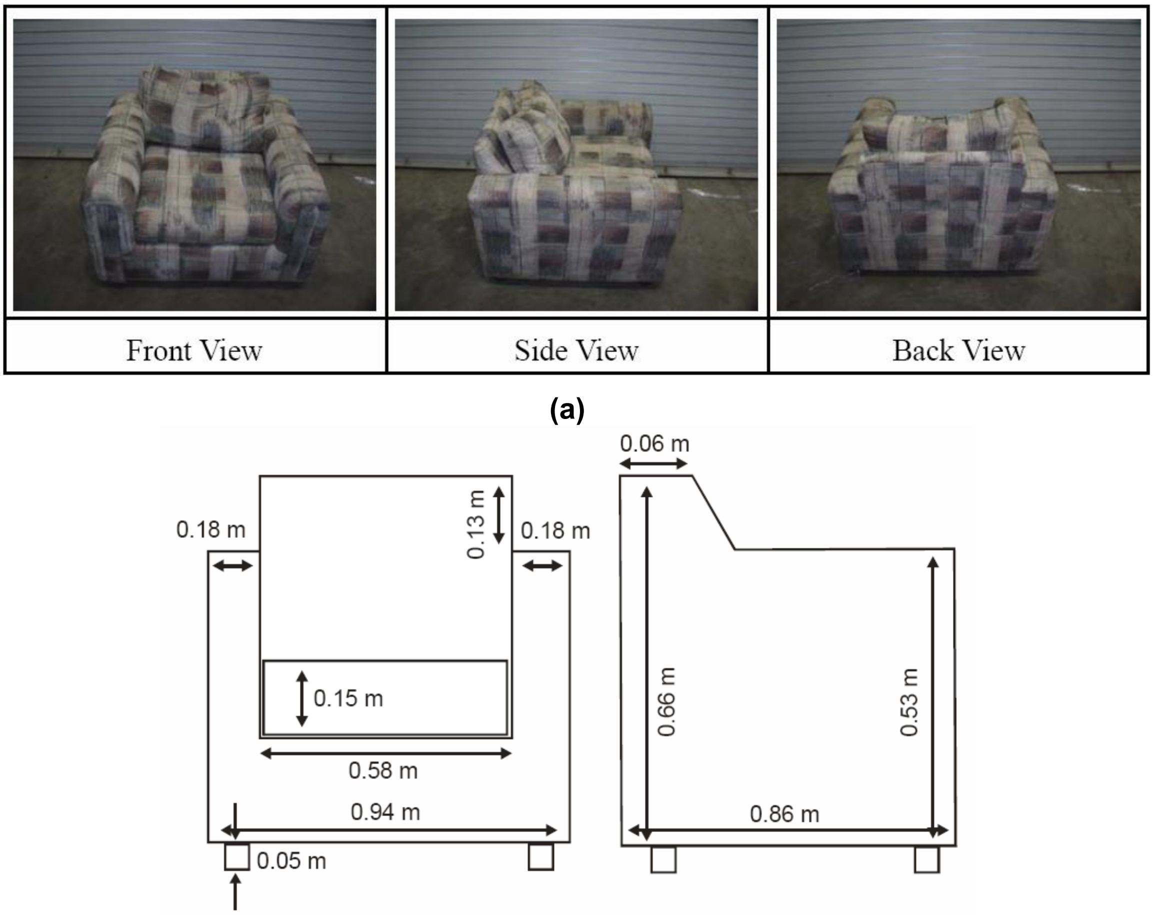
Figure 2. Dimensions and locations of instrumentation for the manufactured house (extracted from Bukowski et al 2007)

Table 10. Measured experiment smoke alarm activation criteria (Bukowski et al 2007)

Alarm Type	Sensitivity (%/m)
Ionization	4.13 ± 1.2 4.23 ± 1.7
Photoelectric	6.76 ± 4.3

Table 11. Composition materials of upholstered armchair with wooden frame (adapted from Bukowski et al 2007)

Section of Armchair	Polyurethane Foam	Polyester Fibre	Felted Textile Fibre of Unknown Composition
Seat cushion	79%	21%	-
Back cushion	-	100%	-
Remaining cushion	28%	-	72%



(b)

Figure 3. (a) Photographs and (b) dimensions of the upholstered armchair tested (extracted from Bukowski et al 2007)

2.5.2 Summary of Experimental Results

Experimental results for temperatures, optical densities and gas concentrations are included with model results in Section 3 (Figure 9 – Figure 22). The heat release rate used as a model input was based on the experiment results for the mass of the burning specimen lost during the test (Figure 4), which was converted to a mass loss (and heat release) (Figure 5) for modelling purposes.

At 186 s, the armchair self-extinguished. Therefore this was taken as the end of the test for modelling purposes. The test did not reach flashover conditions – the peak heat release rate did not exceed 200 kW. Therefore only pre-flashover conditions are considered here with regard to the selected model inputs for soot and carbon monoxide (CO) yields.

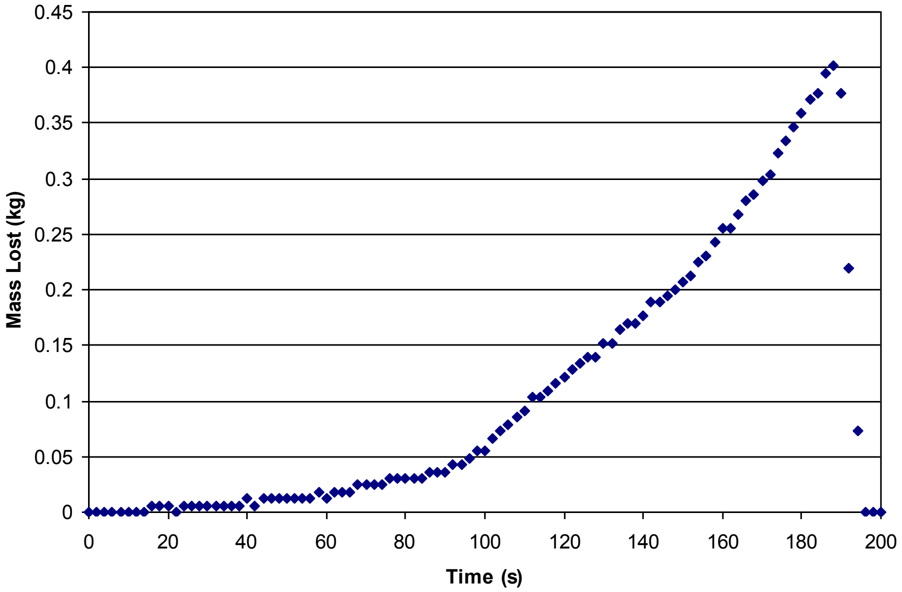


Figure 4. Armchair mass lost versus time (adapted from Test No. SDC02, Peacock et al 2002)

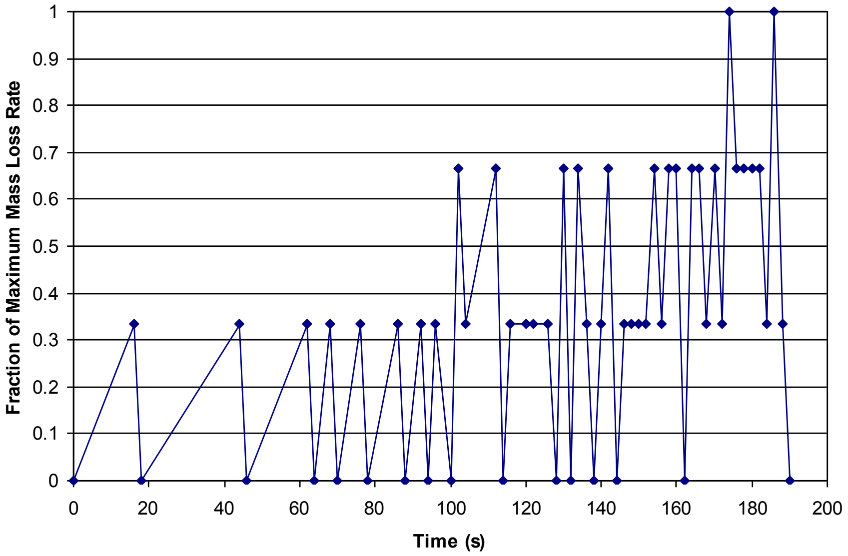


Figure 5. Armchair mass loss rate as a fraction of the maximum mass loss rate for the test versus time (using data from Test No. SDC02, Peacock et al 2002)

3. MODELLING

Two modelling approaches were used: a zone model approach (BRANZFIRE Version 2007.2 with additional input values for pre- and post-flashover carbon monoxide yields) and a field model approach (FDS Version 4.0.2).

3.1 Scenarios

Model scenario assumptions:

- Flaming armchair fire is modelled as a vent on the top seat cushion with:
  - Constant fire area
  - Mass loss rate based on experiment data Test No. SDC02, NIST Test FR 4061 (Peacock et al 2002)
  - Heat release rate = mass loss rate (Figure 5) x net heat of combustion (see Table 12 for value).
- All surfaces are inert, so there is no potential additional heat released from sources other than the armchair.
- In FDS, the 'INERT' surface description is used, which assumes the surface remains at ambient temperature with no heat transfer throughout. In BRANZFIRE, surfaces are described as 'concrete' throughout, with a density of 2300 kg/m³, a thermal conductivity of 1.2 W/m.K and an emissivity of 0.5.
- In BRANZFIRE, the fire is assumed to be in the centre of the room of fire origin. The McCaffrey plume model is assumed.
- Temperature, visibility, extinction coefficient, and volume fractions of oxygen, carbon dioxide and carbon monoxide are recorded at locations as close as grid spacing allows to the experiment setup (Figure 2 and Table 9). Parameter values are also recorded for the vertical planes intersecting the points of interest.
- Smoke detectors were set for the bounding upper and lower sensitivity values determined for the NIST Test FR 4061 (Peacock et al 2002) instruments. (Table 16, included in Appendix E). Smoke detectors were included in the modelling approaches; however the results of the comparisons are not included in this report.
- Sensitivity of grid spacing and soot yield parameters only are considered. (Table 13 and Table 14) The minimum grid spacing used for the FDS approach was limited by the available computing facilities.

A summary of the model scenarios considered is presented in Table 14.

Table 12. Summary of scenario single-value inputs

Parameter	Value	Units
Carbon monoxide yield	0.04 [a]	kg_{CO}/kg_{fuel}
Soot yield	0.20 [a]	kg_{soot}/kg_{fuel}
Net heat of combustion	20 [a]	MJ/kg_{fuel}

Note: [a] (Wade et al 2007)

Table 13. Summary of parameters selected for sensitivity analysis

Parameter	Values Considered
Grid spacing (for FDS)	0.30, 0.15, 0.10, 0.0625 (m)
Soot yield	0.20, 0.18, 0.15, 0.10, 0.05 (kg_{soot}/kg_{fuel})

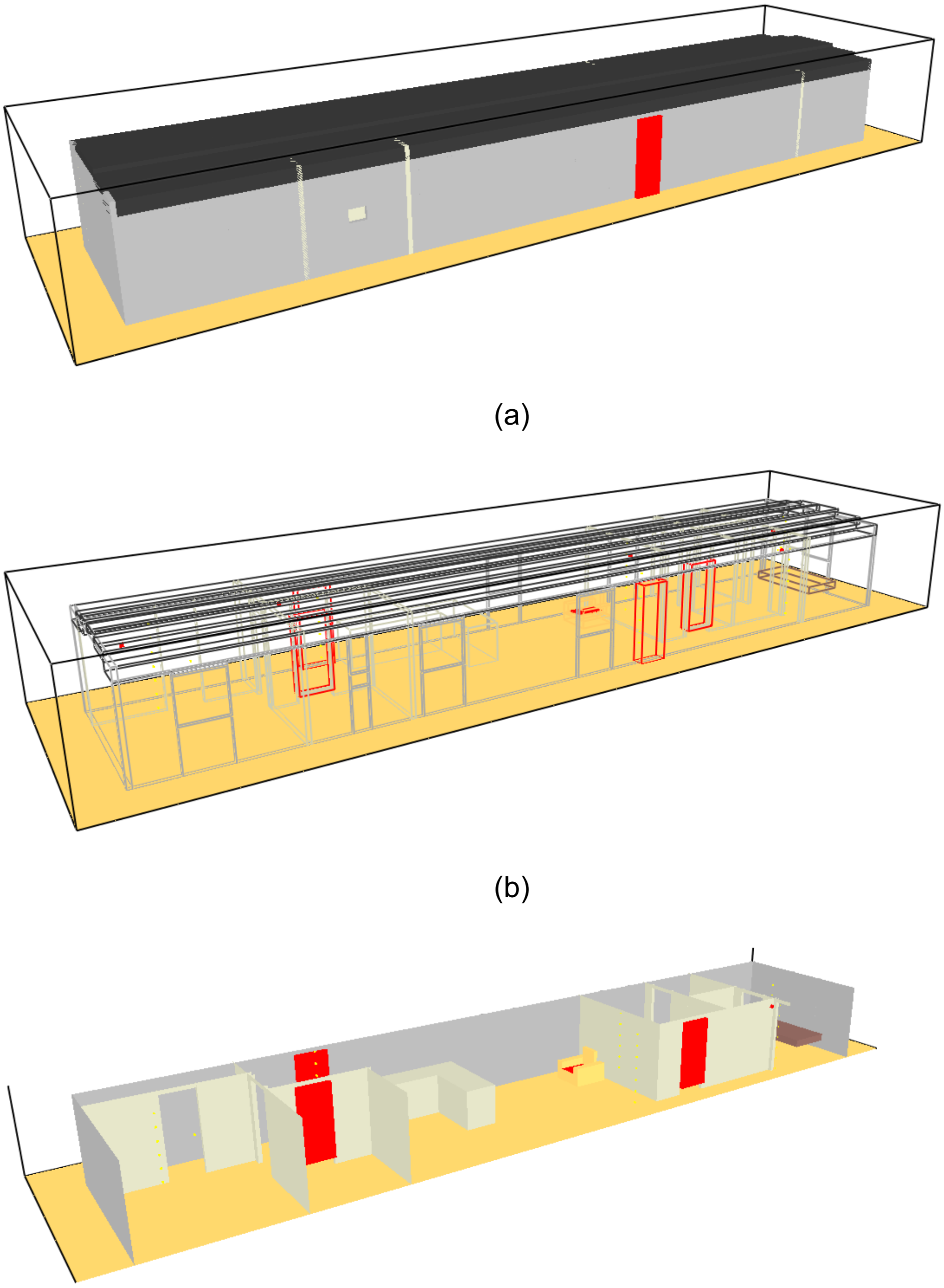
Table 14. Summary of scenarios considered

Scenario Number	Grid Spacing (for use with CFD approach only) (m)	Soot Yield (kg_{soot}/kg_{fuel})	Comparison with Experiment Parameter(s)
1	0.30	0.10	Temperature
2	0.15	0.10	Temperature
3	0.10	0.10	Temperature and Optical Density
4	0.0625	0.10	Temperature
5	0.10 [a]	0.20	Optical Density
6	0.10 [a]	0.18	Optical Density
7	0.10 [a]	0.15	Optical Density
8	0.10 [a]	0.05	Optical Density

Note: [a] the choice of grid spacing was based on comparison of the results for temperatures between the model scenarios 1 to 4 and experiment Test No. SDC02 NIST Test FR 4061 (Peacock et al 2002). The analysis of these comparisons is included in Appendix D.

Model parameters recorded:

- Visibility
- Extinction coefficient
- Temperature
- Smoke detector activation
- Volume fraction of oxygen, carbon dioxide and carbon monoxide.



(a)

(b)

(c)

Figure 6. Smokeview representations of the modelled manufactured house

Figure 7. Smokeview representation of the modelled living room with armchair (the vent is located on the seat cushion of the armchair)

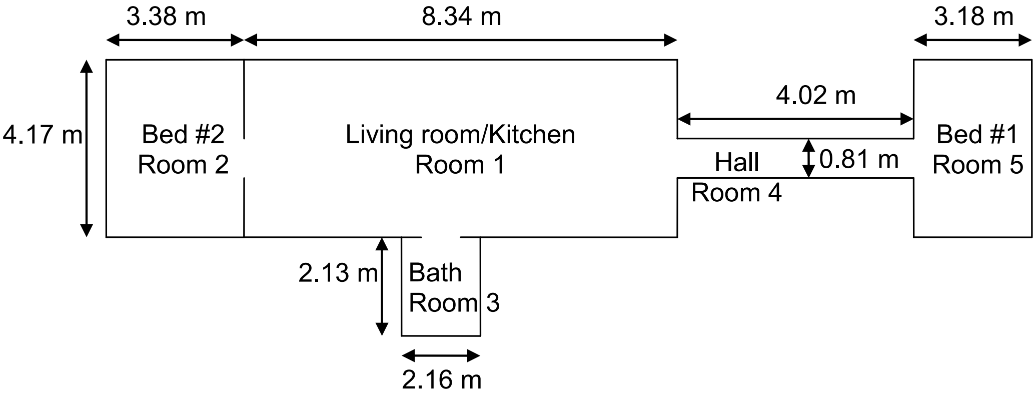


Figure 8. Schematic of the layout of the manufactured house used in BRANZFIRE

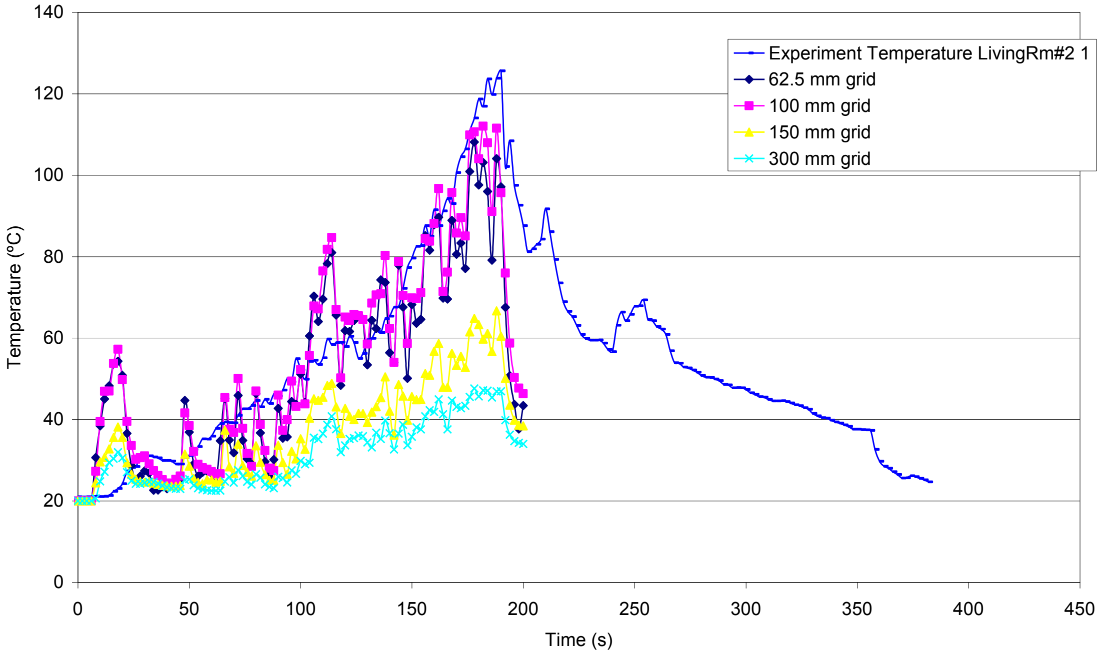
3.2 Model Results

A summary of the model results are included in Appendix B for FDS, Appendix C.6 for BRANZFIRE, and Appendix D for a comparison of model results from FDS and BRANZFIRE.

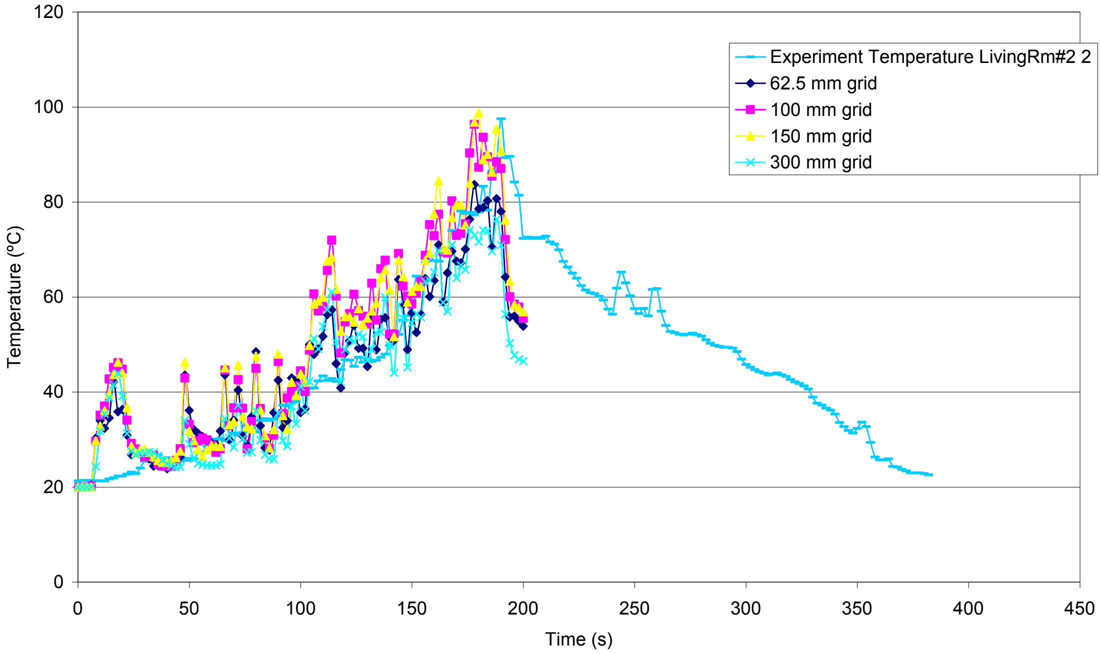
3.2.1 Grid Spacing

An example of the comparison of model and experiment temperature results near to the fire (in Living Room, Location E of Figure 2) for the range of grid spacing considered is shown in Figure 9. Then an example for temperature results remote from the seat of the fire (Bedroom#1, Location B of Figure 2) is shown in Figure 10. A summary of the comparison of model and experiment results for other locations and variables is included in Appendix B.9.

In summary, of the grid sizes considered, the 100 mm uniform grid size in each direction was found to produce results closest to the experiment temperature results. Therefore this grid was used for Scenarios 5 to 8, where the sensitivity to soot yield value was considered.



(a)


120
100
80
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Temperature (ºC)
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Time (s)
Experiment Temperature LivingRm#2 2
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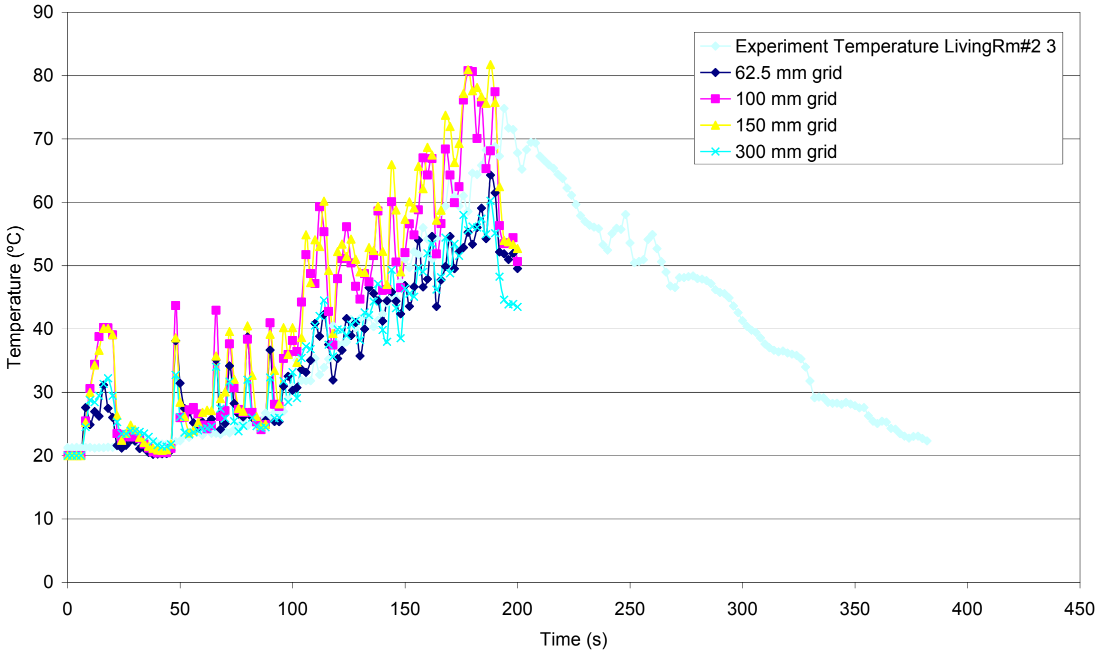
100 mm grid
150 mm grid
300 mm grid

(b)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Temperature (ºC)
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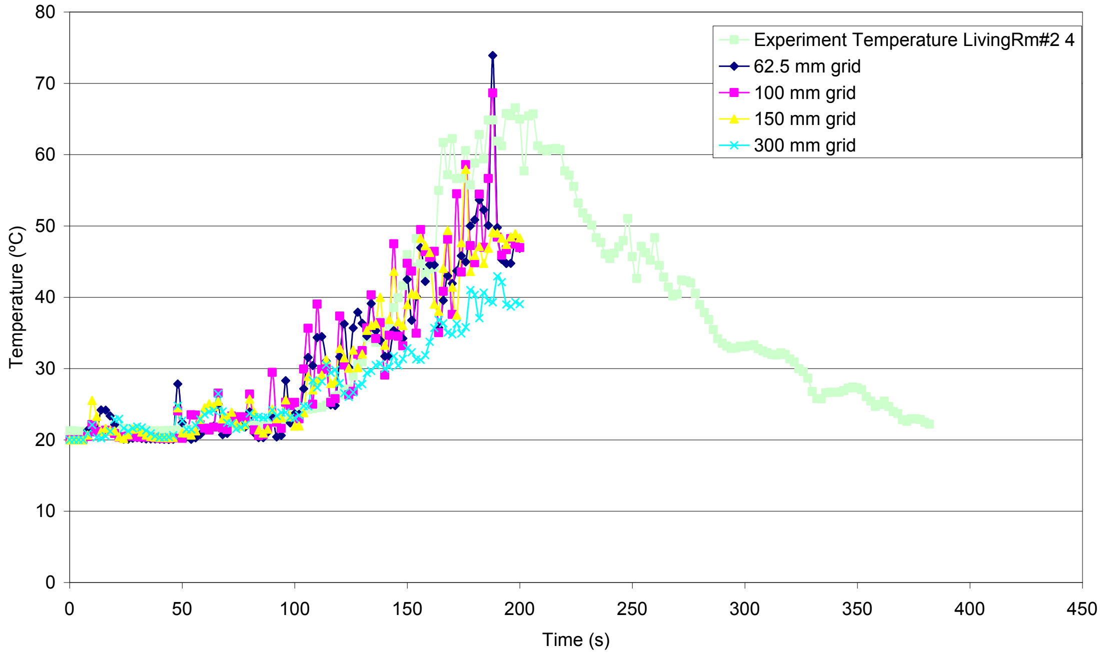
Time (s)
Experiment Temperature LivingRm#2 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(c)


80
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Temperature (ºC)
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350
400
450
Time (s)
Experiment Temperature LivingRm#2 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(d)


60
50
40
30
20
10
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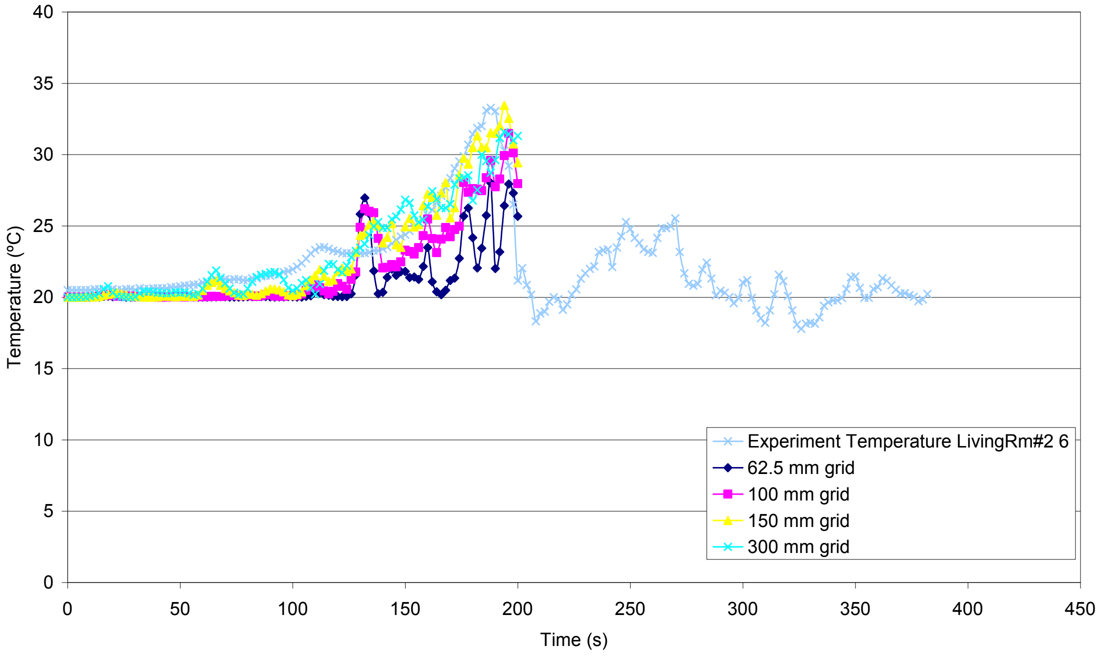
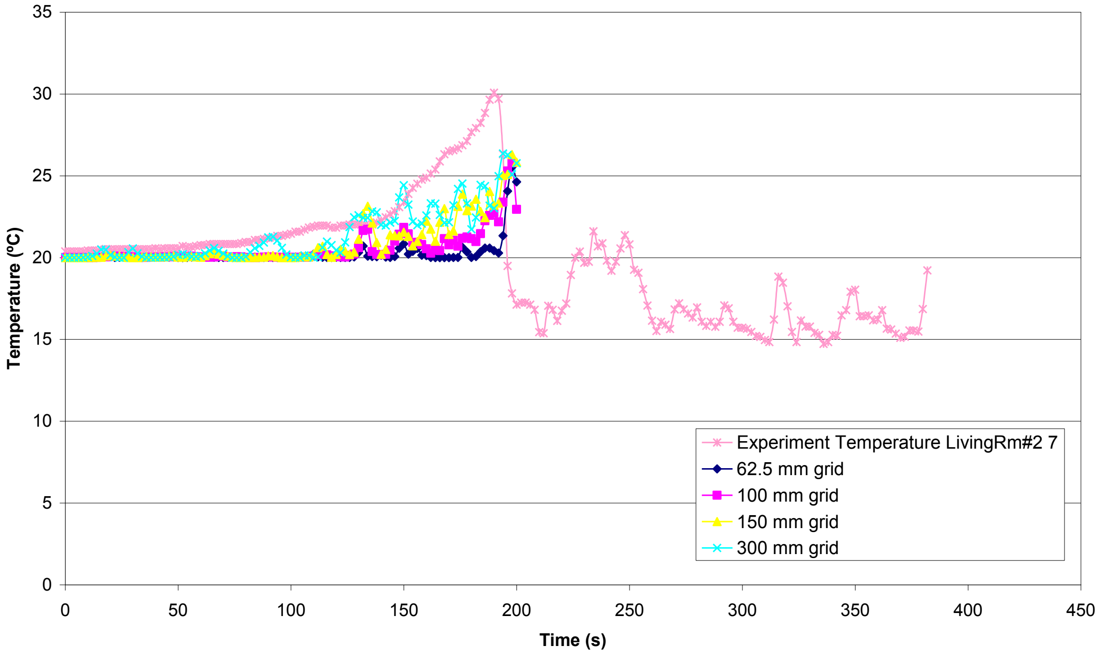
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#2 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

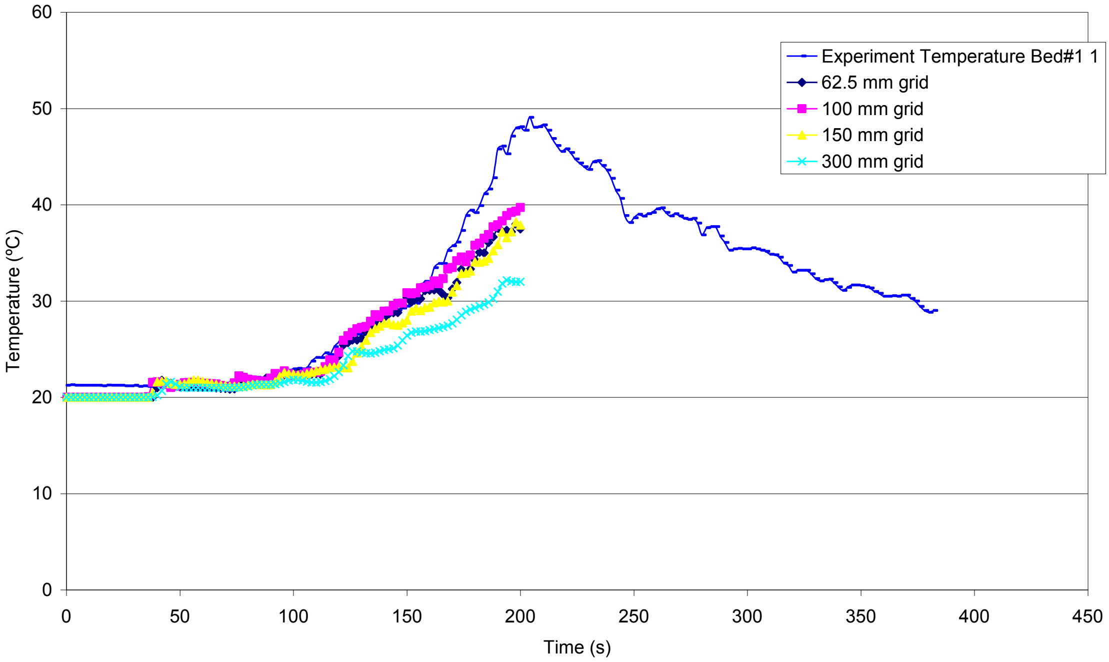


(f)

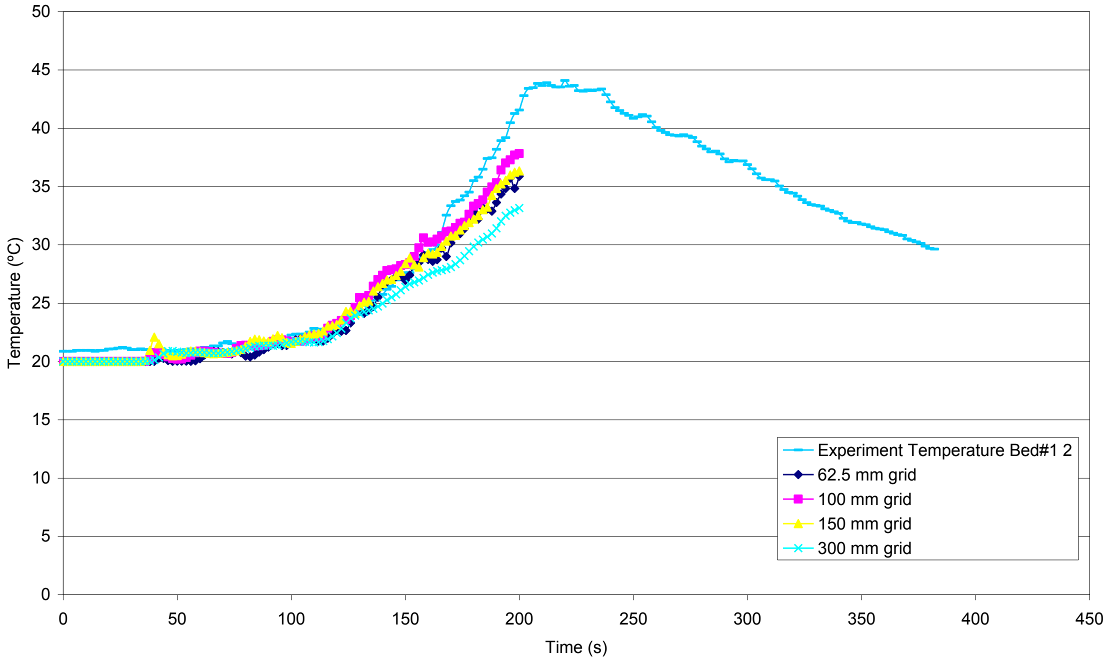


(g)

Figure 9. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing, for Living Room #2 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 1
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(a)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45
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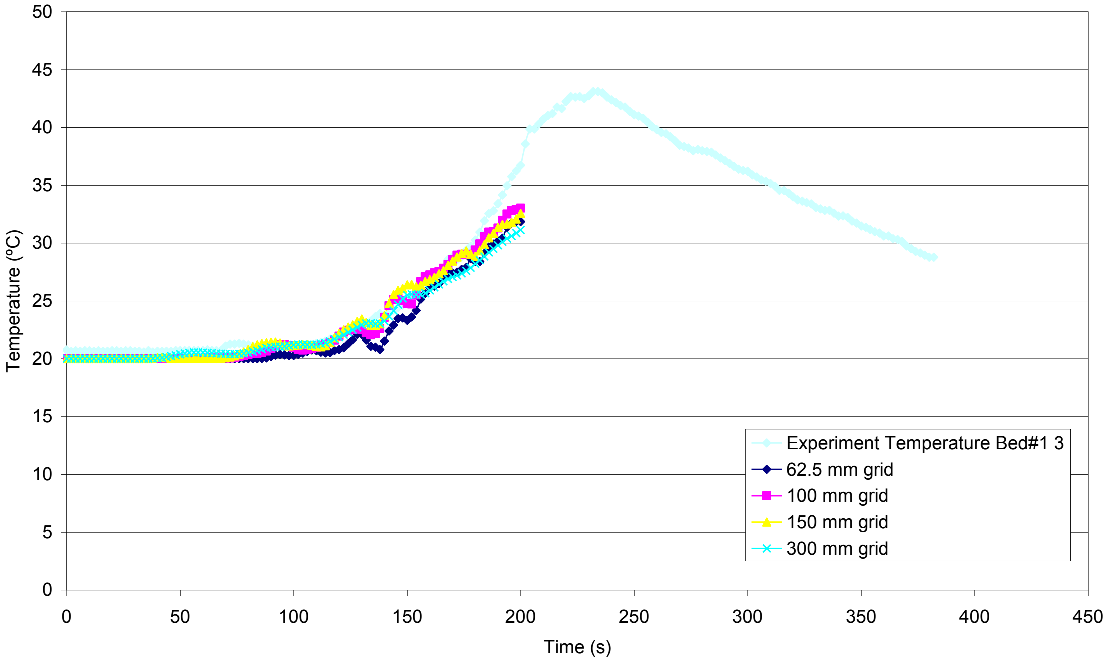
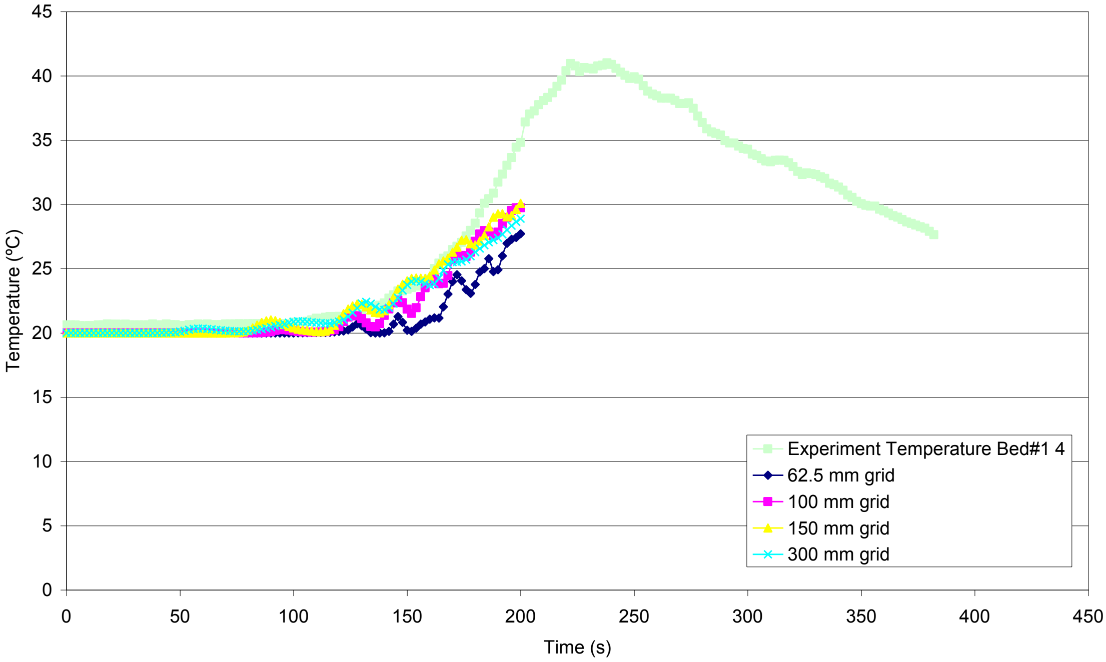
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

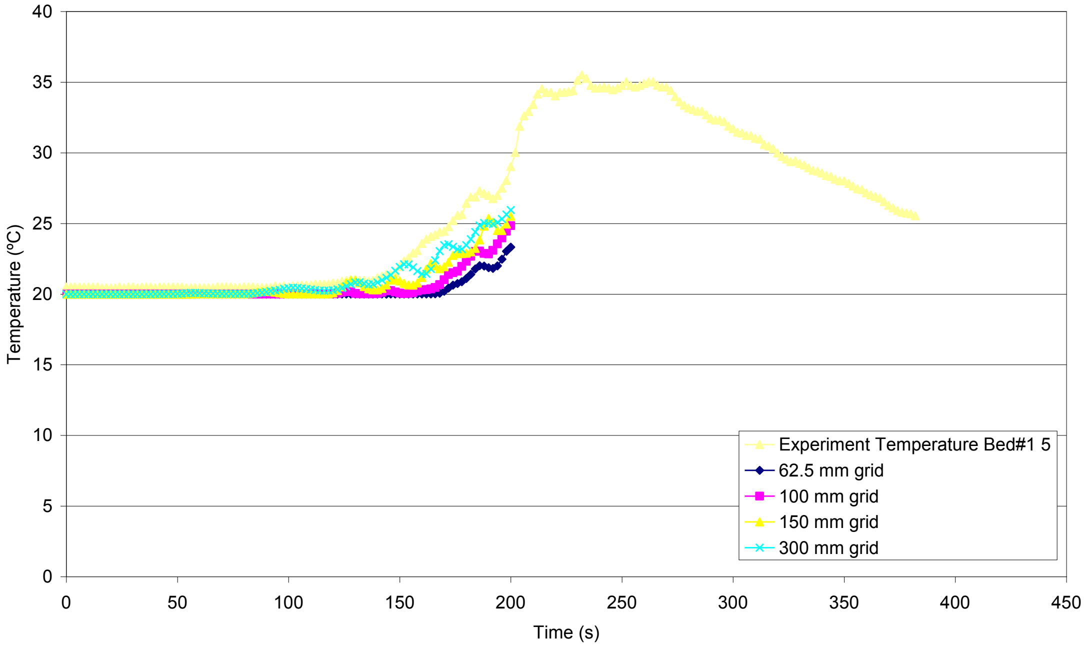
(b)


Temperature (°C)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Bed#1 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

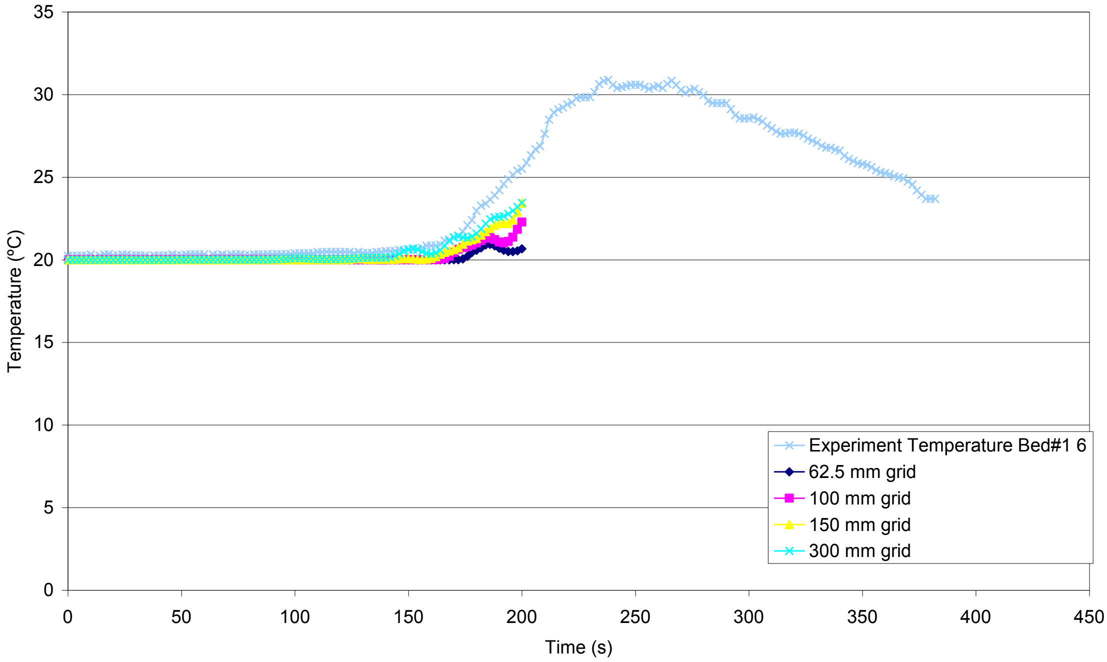
(c)


Temperature (°C)
Time (s)
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Bed#1 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

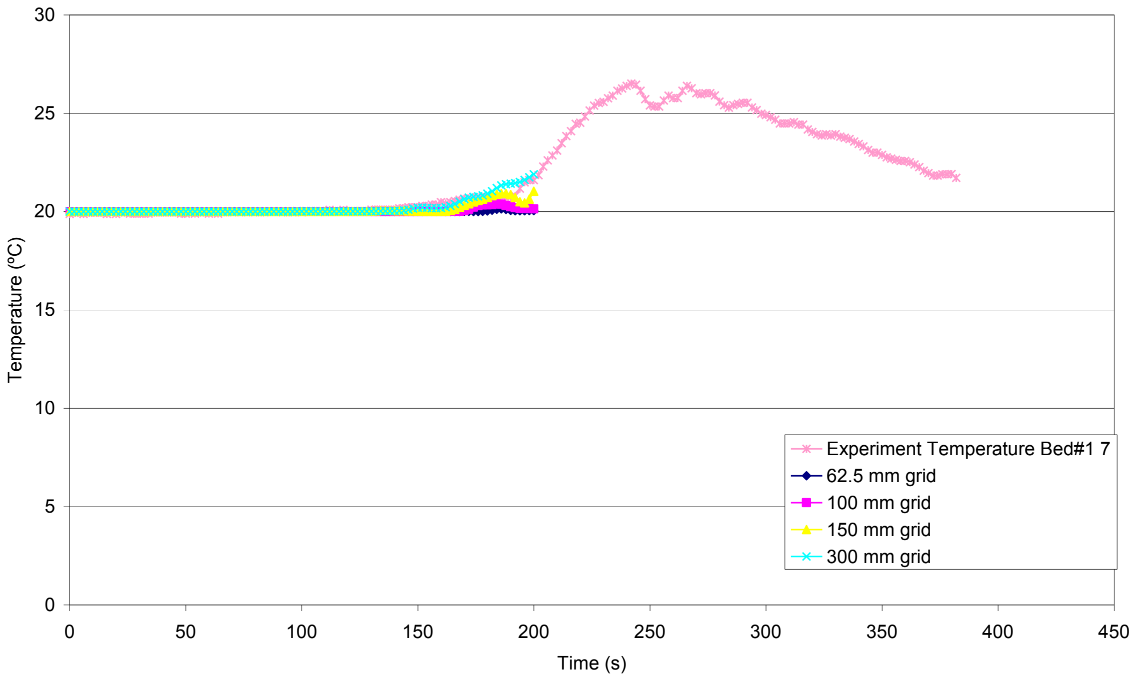
(d)


40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)


35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 6
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(f)



(g)

Figure 10. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #1 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling

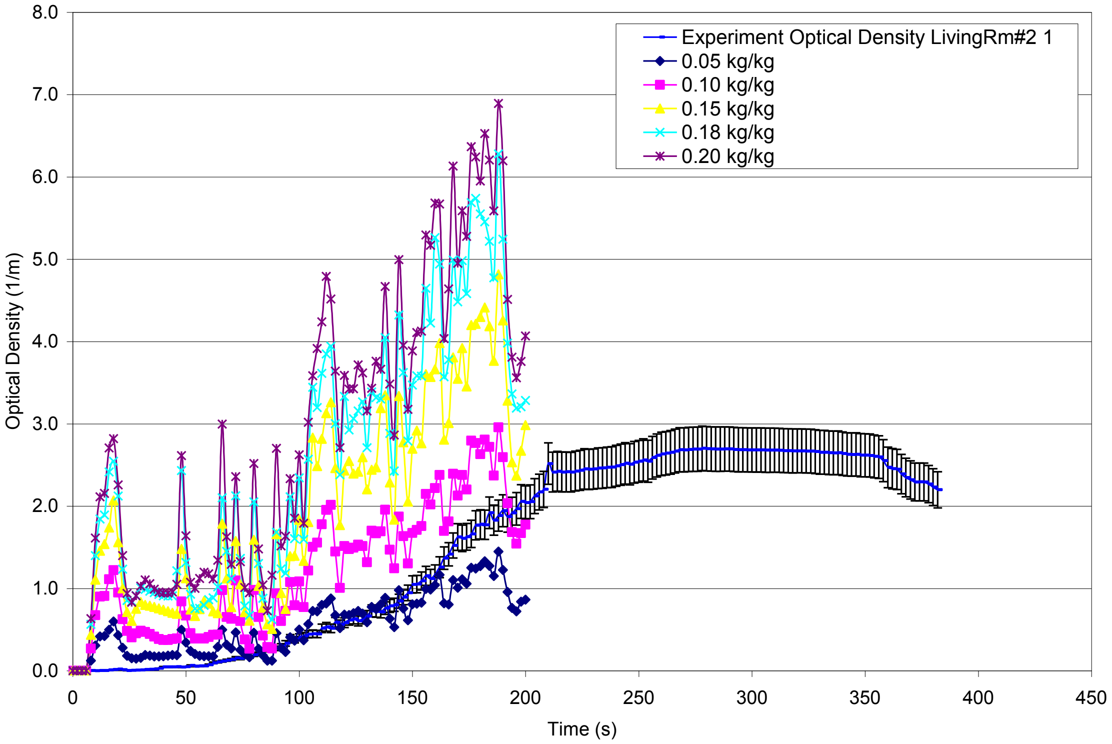
3.2.2 Optical Density

Model results using FDS for the range of soot yield values (Scenarios 2 and 5 to 8) are shown in Figure 11 to Figure 16 for each of the rooms (as shown in Figure 2) in the manufactured home, where experimental data was available.

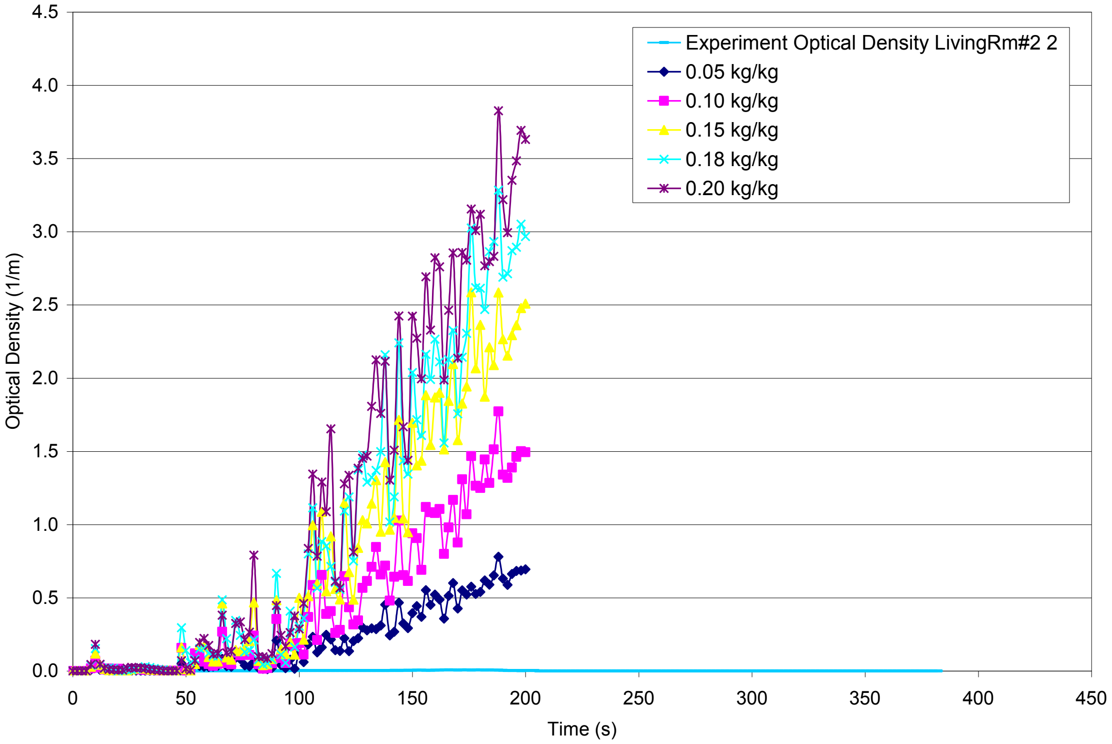
Similarly, model results using BRANZFIRE for the range of soot yield values (associated with Scenarios 2 and 5 to 8) are shown in Figure 17 to Figure 22, for each of the rooms (Figure 2) in the manufactured home where experimental data was available. The experimental measurements shown in these figures, numbered as 1 and 2, correspond to measurements taken at 20 mm and 900 mm below the ceiling respectively.

The error bars shown in Figure 11 to Figure 22 are based on the reported experiment uncertainty, as summarised in Table 9.

3.2.2.1 FDS

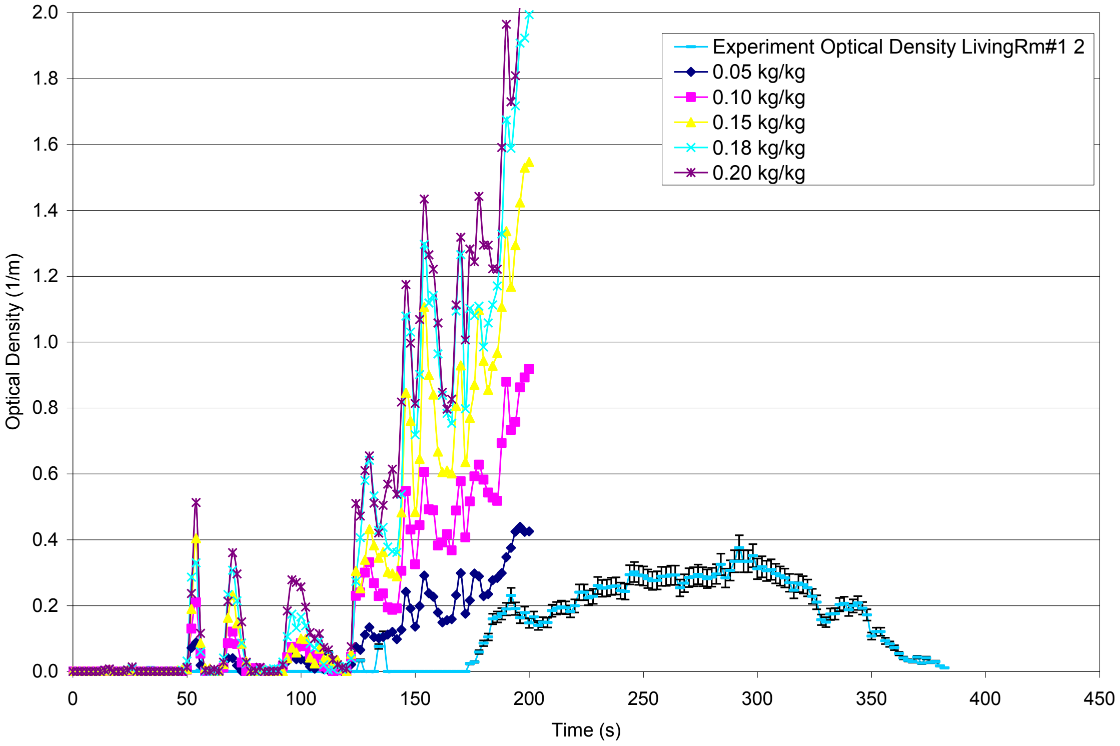


(a)

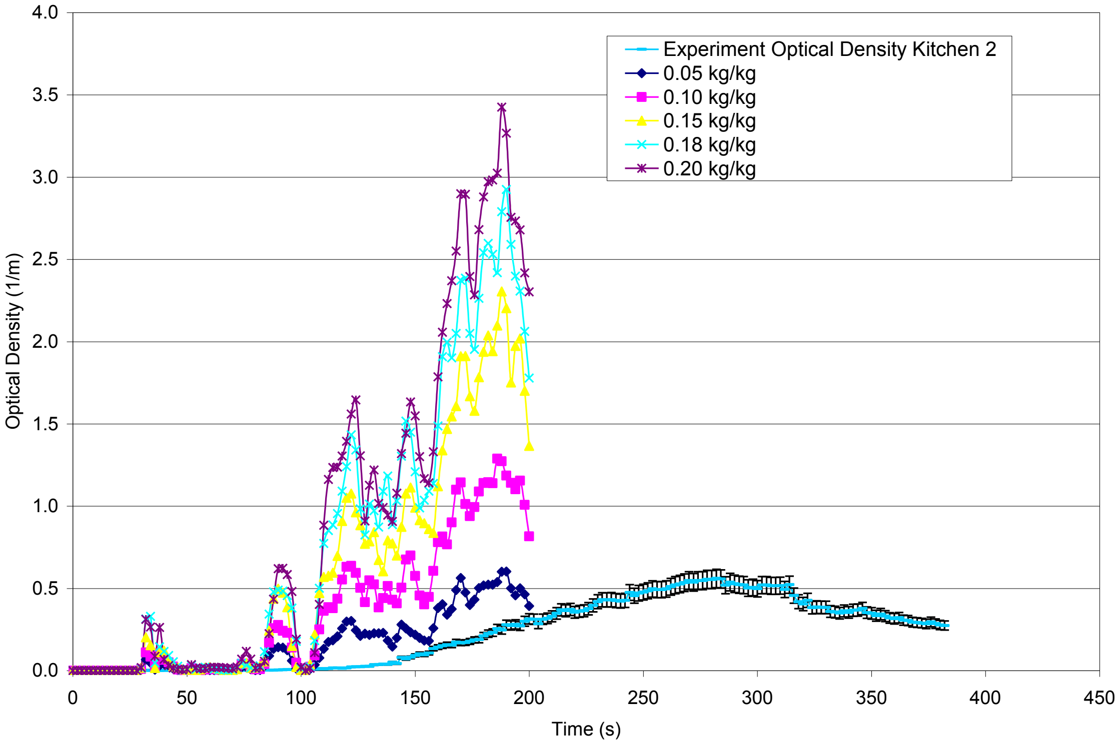


(b)

Figure 11. Experiment and model results, using FDS 100 mm grid spacing, for Living Room #2 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

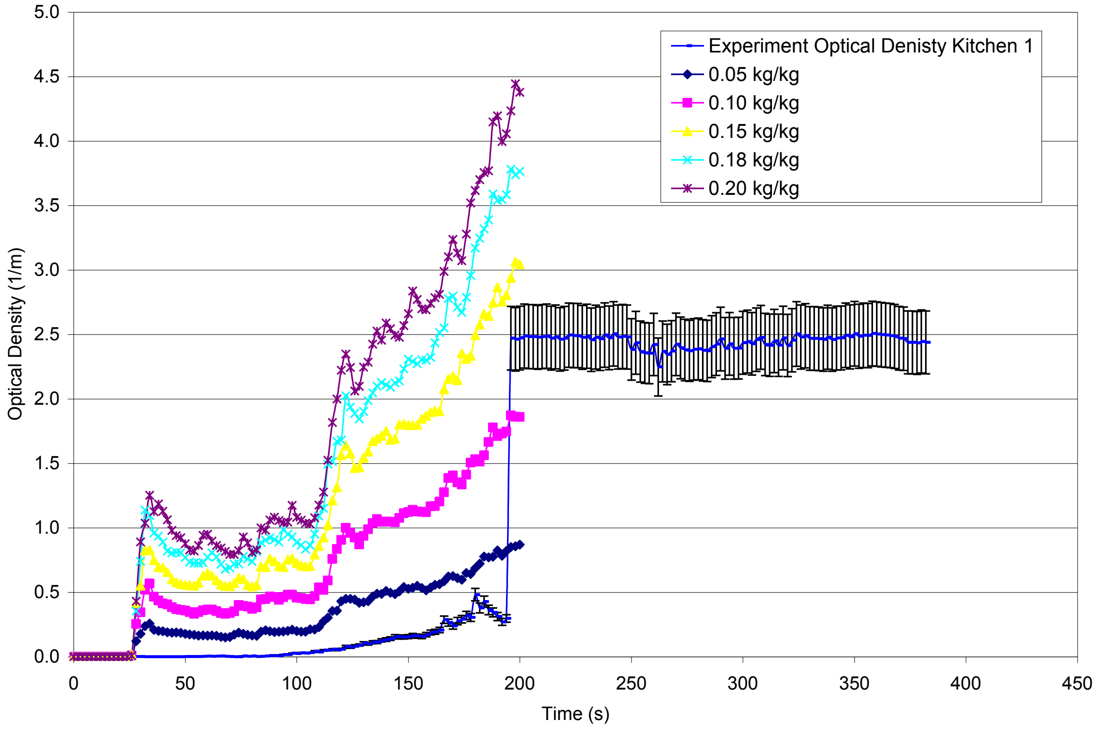


(a)

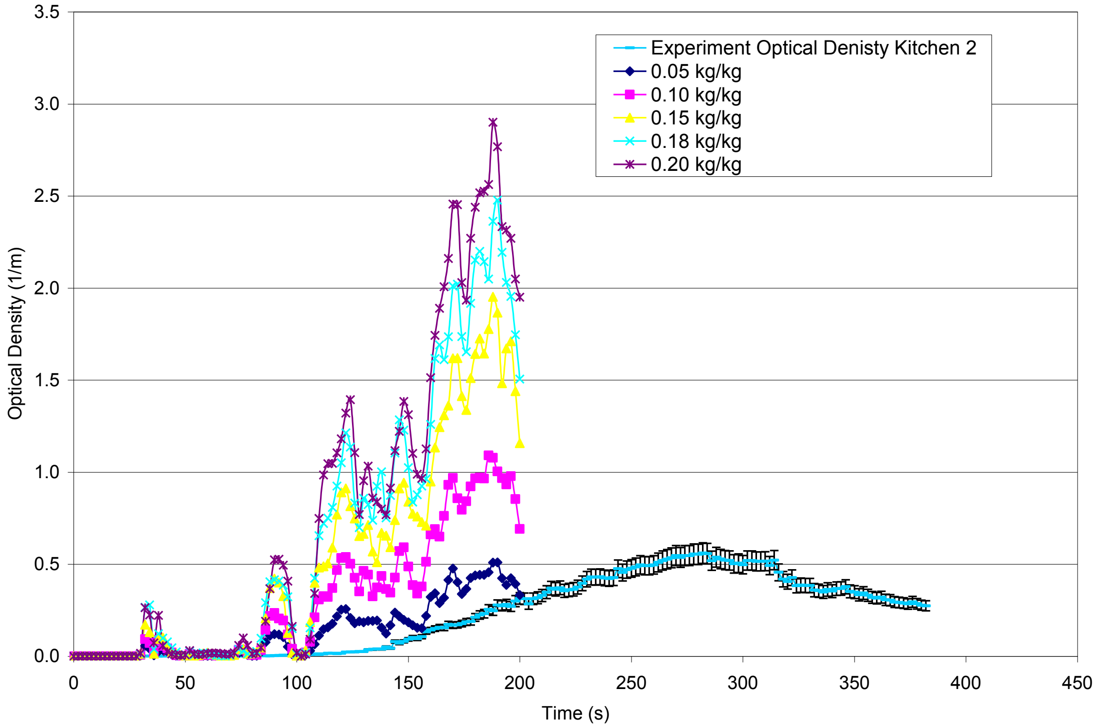


(b)

Figure 12. Experiment and model results, using FDS 100 mm grid spacing, for Living Room #1 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

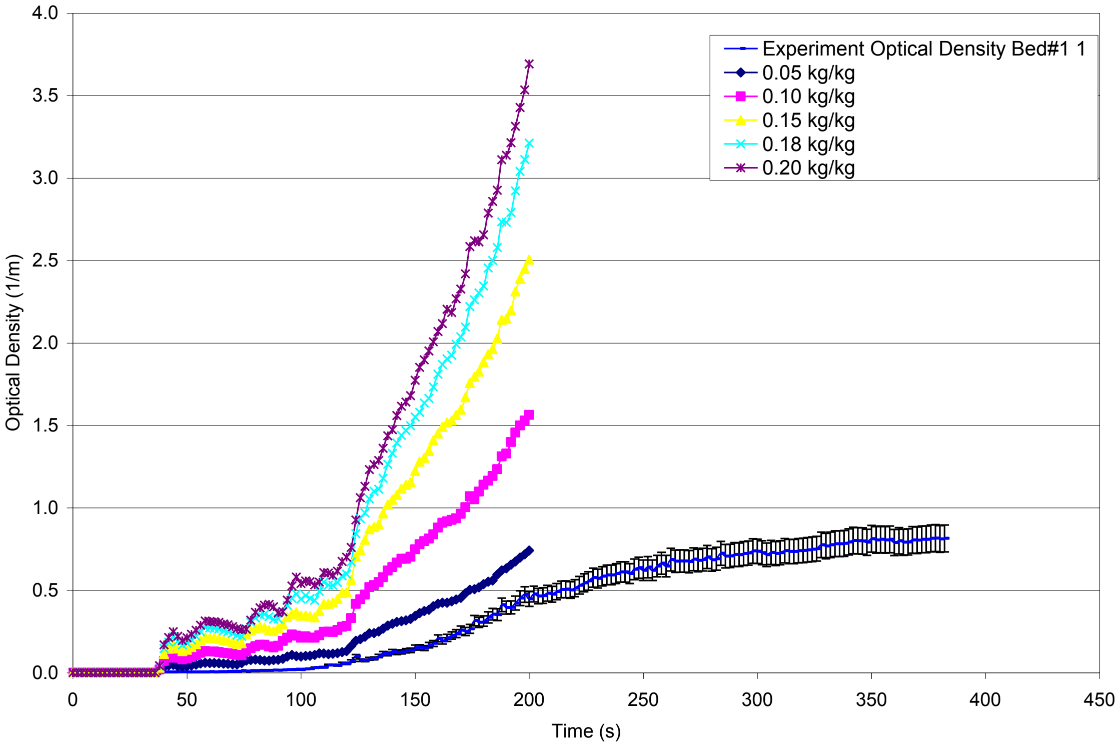


(a)

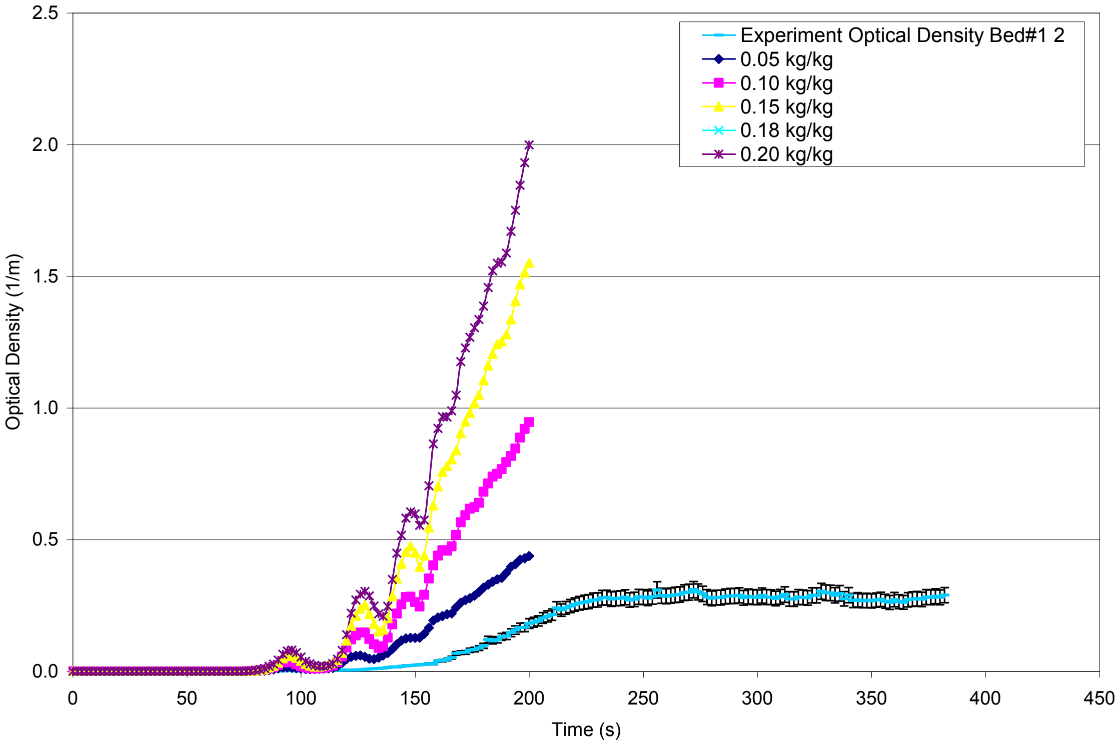


(b)

Figure 13. Experiment and model results, using FDS 100 mm grid spacing, for Kitchen optical density at locations (a) 20 mm and (b) 900 mm below the ceiling



(a)



(b)

Figure 14. Experiment and model results, using FDS 100 mm grid spacing, for Bedroom #1 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

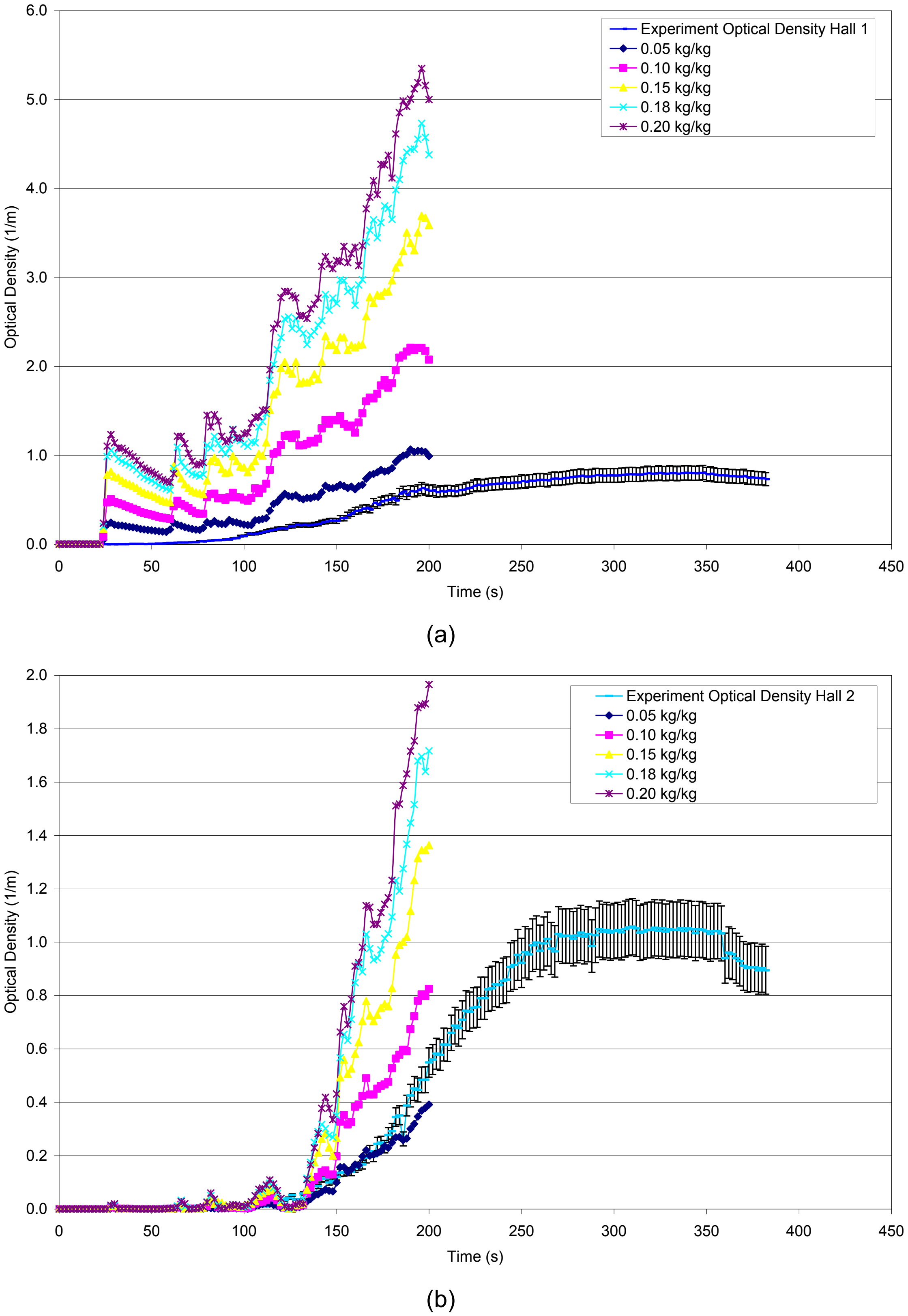
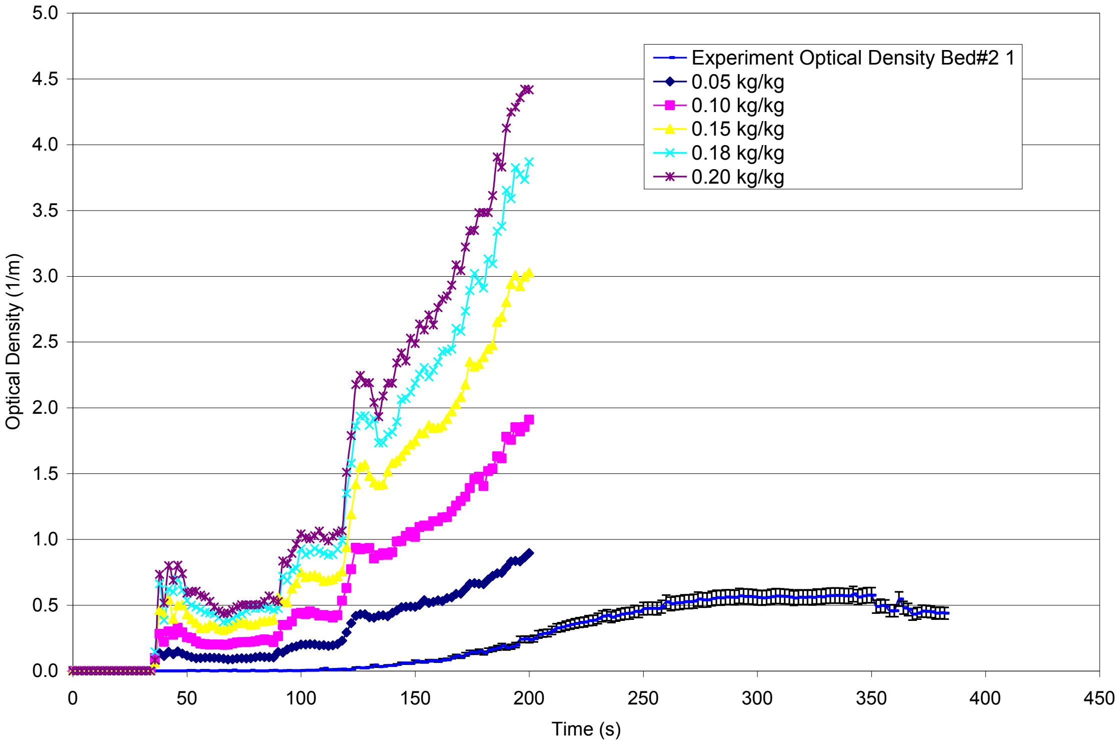
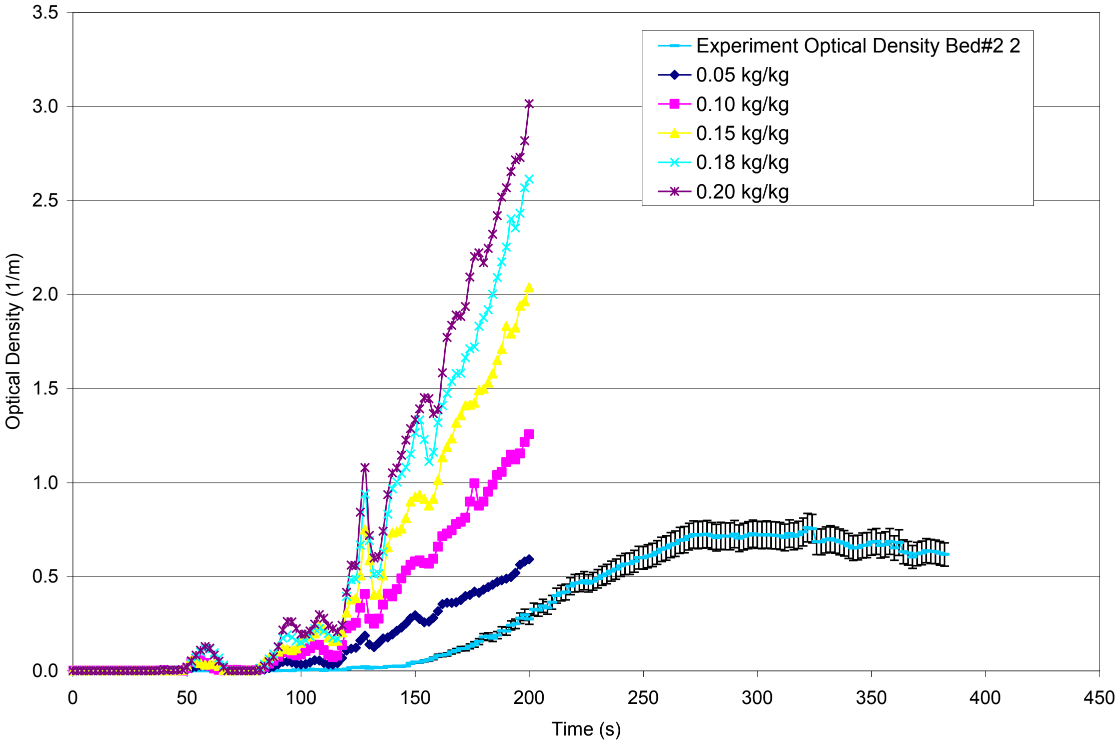


Figure 15. Experiment and model results, using FDS 100 mm grid spacing, for Hall optical density at locations (a) 20 mm and (b) 900 mm below the ceiling



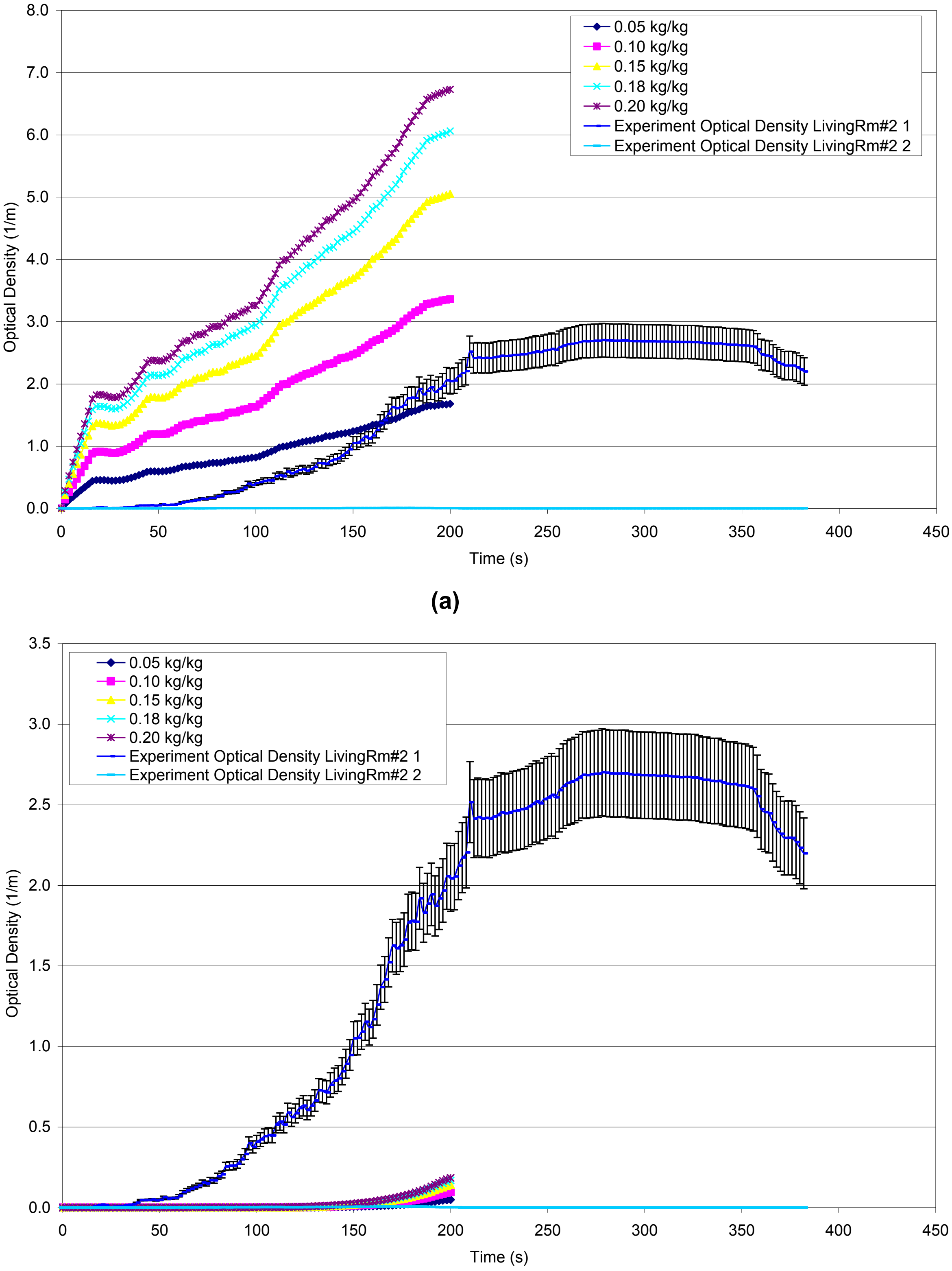
(a)



(b)

Figure 16. Experiment and model results, using FDS 100 mm grid spacing, for Bedroom #2 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

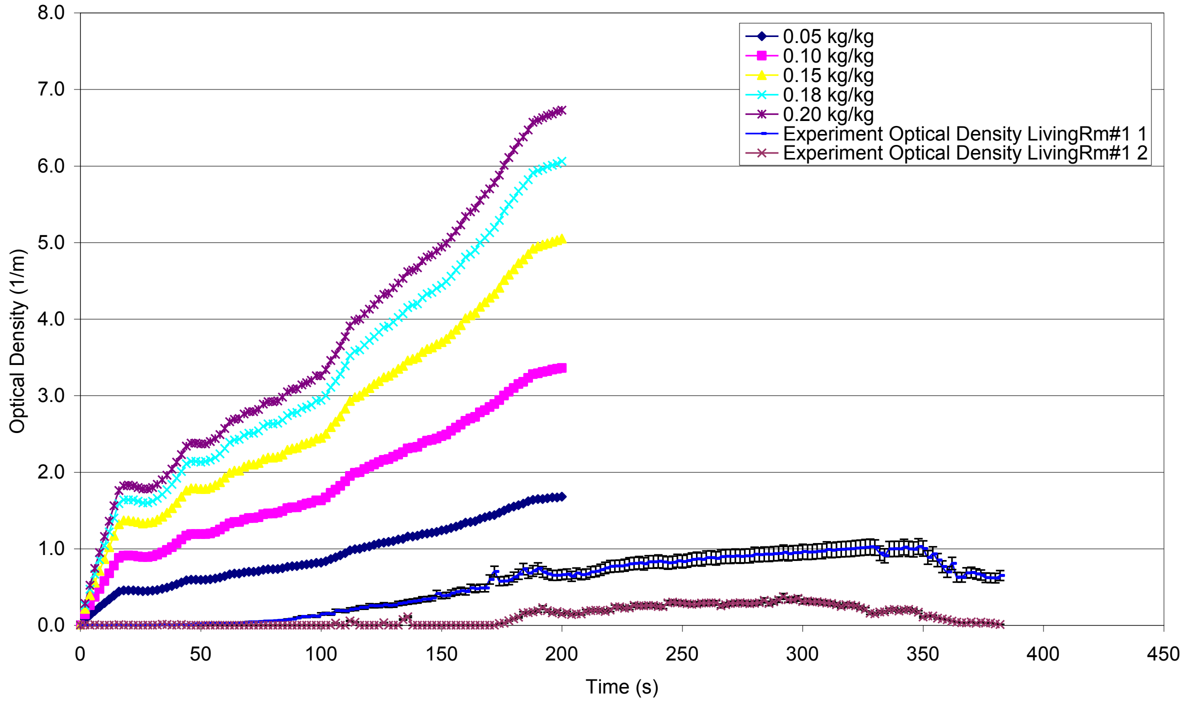
3.2.2.2 BRANZFIRE



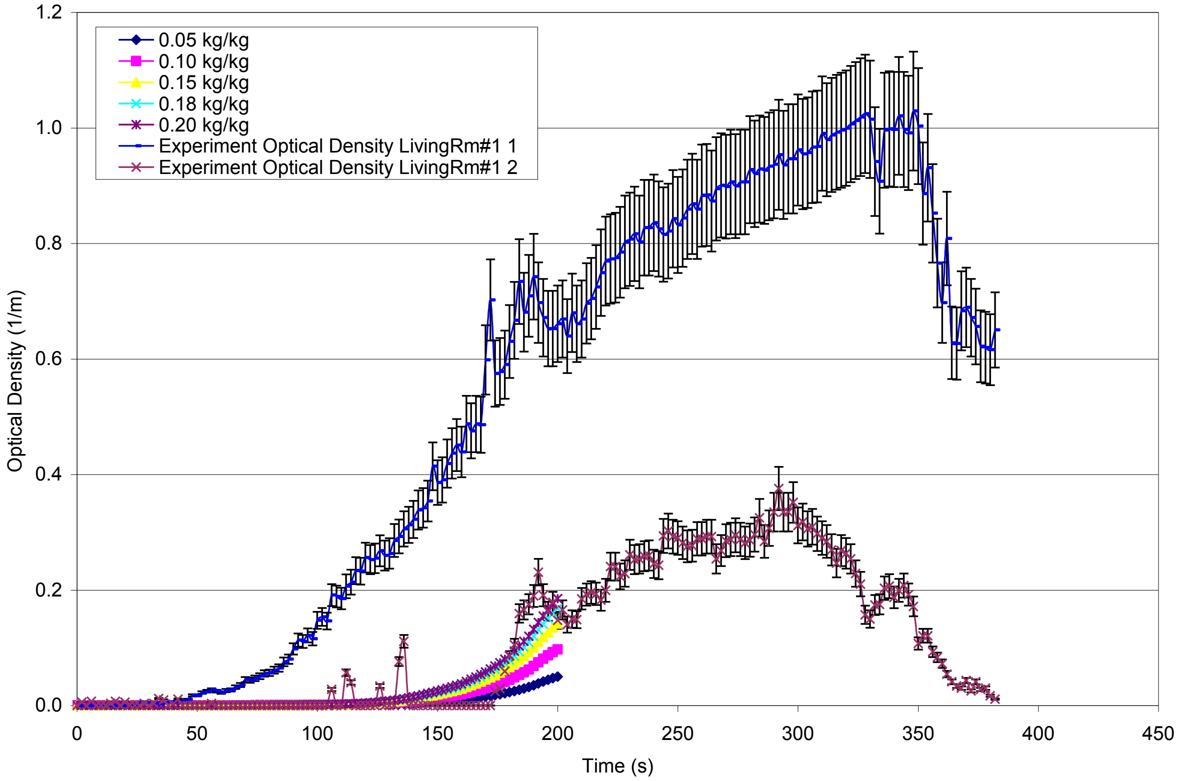
(a)

(b)

Figure 17. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Living Room #2 optical density

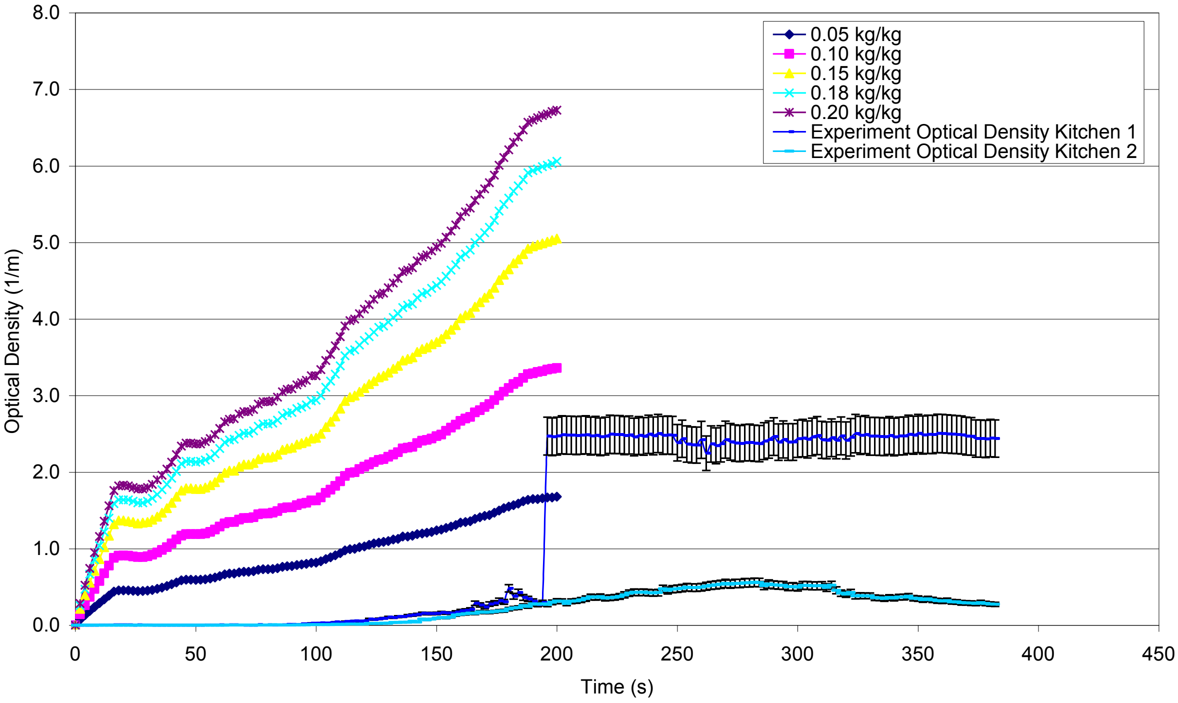


(a)

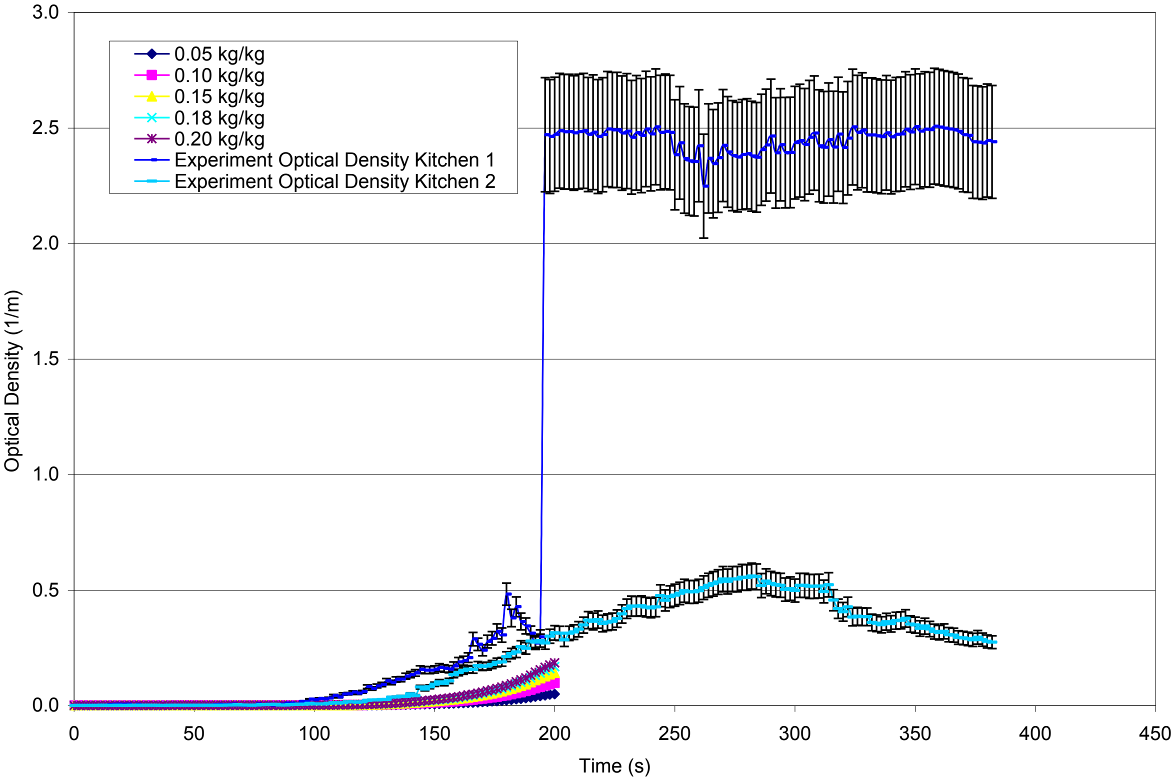


(b)

Figure 18. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Living Room #1 optical density



(a)



(b)

Figure 19. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Kitchen optical density

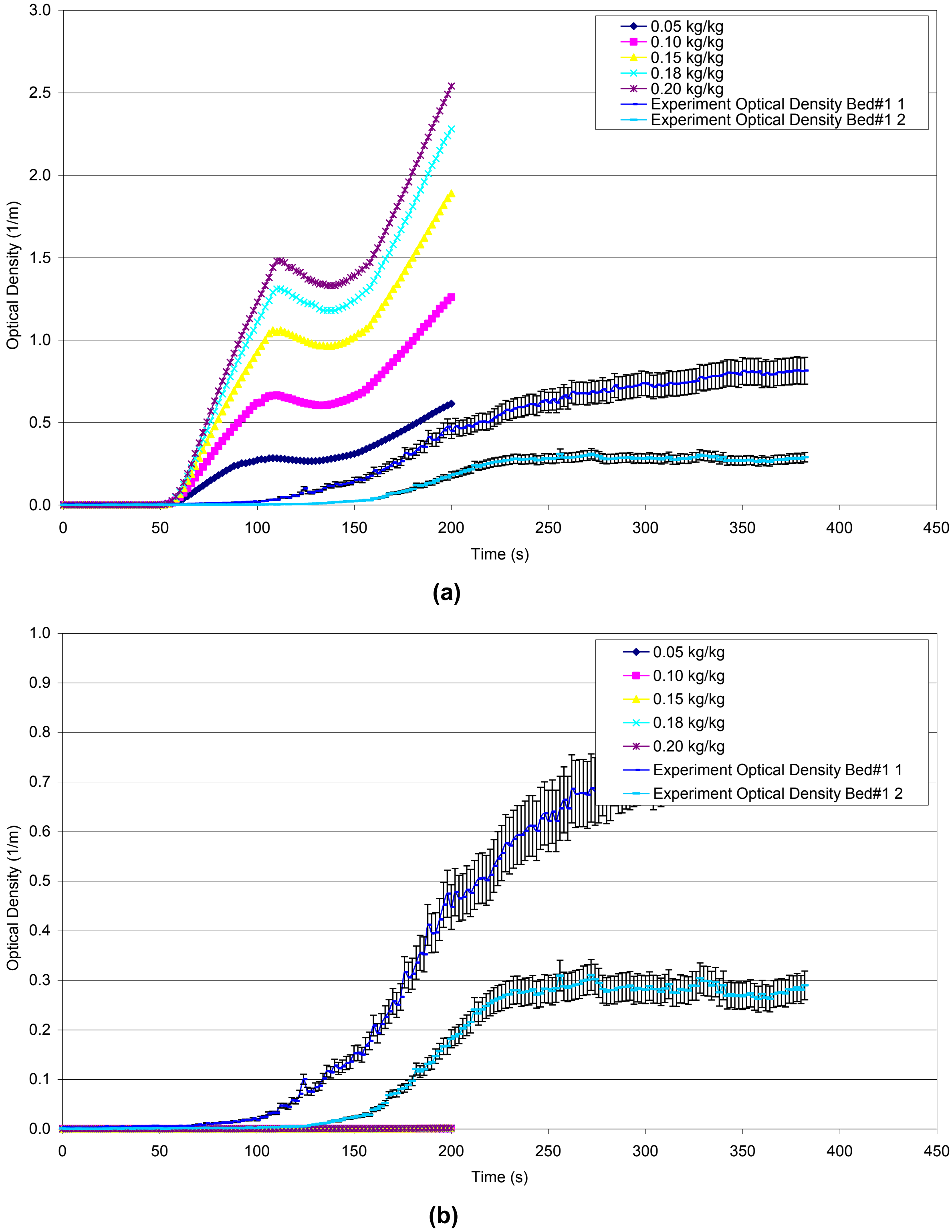
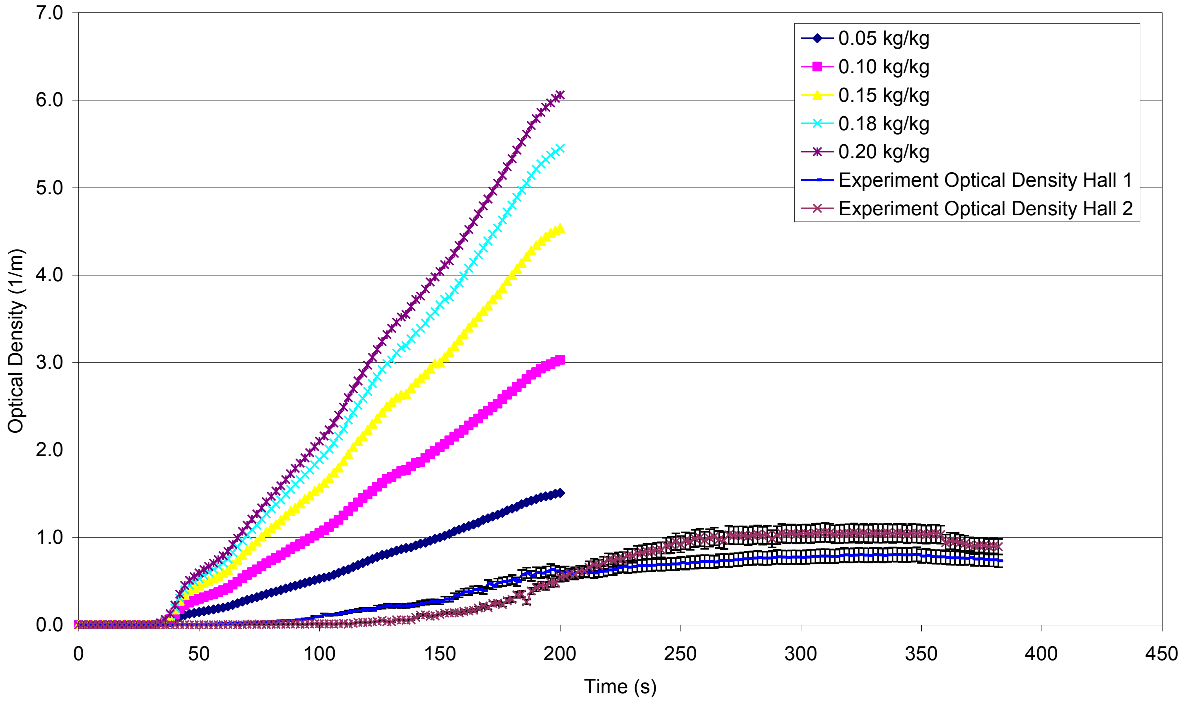
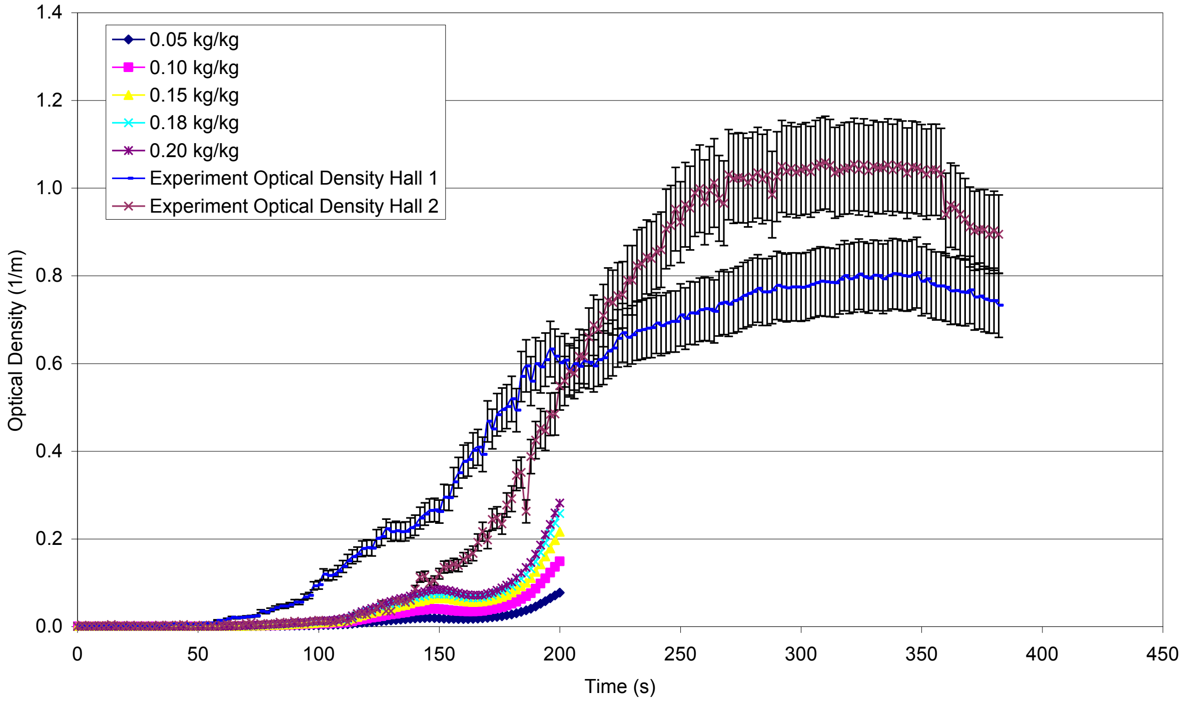


Figure 20. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Bedroom #1 optical density

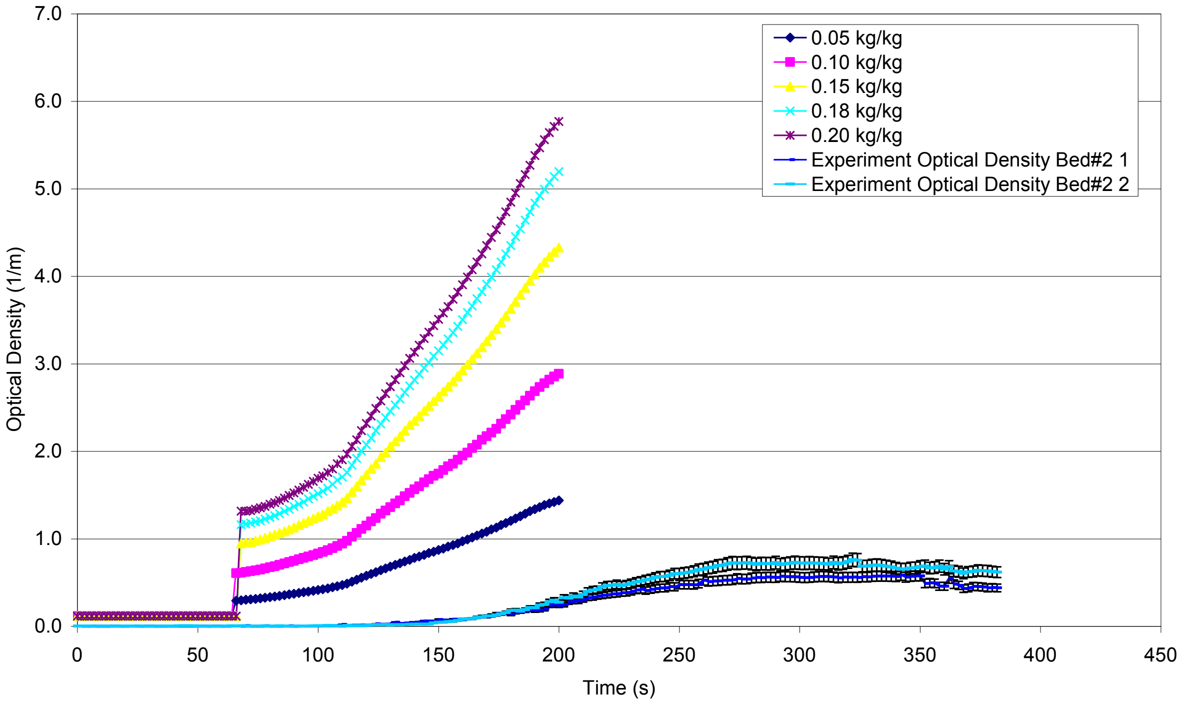


(a)

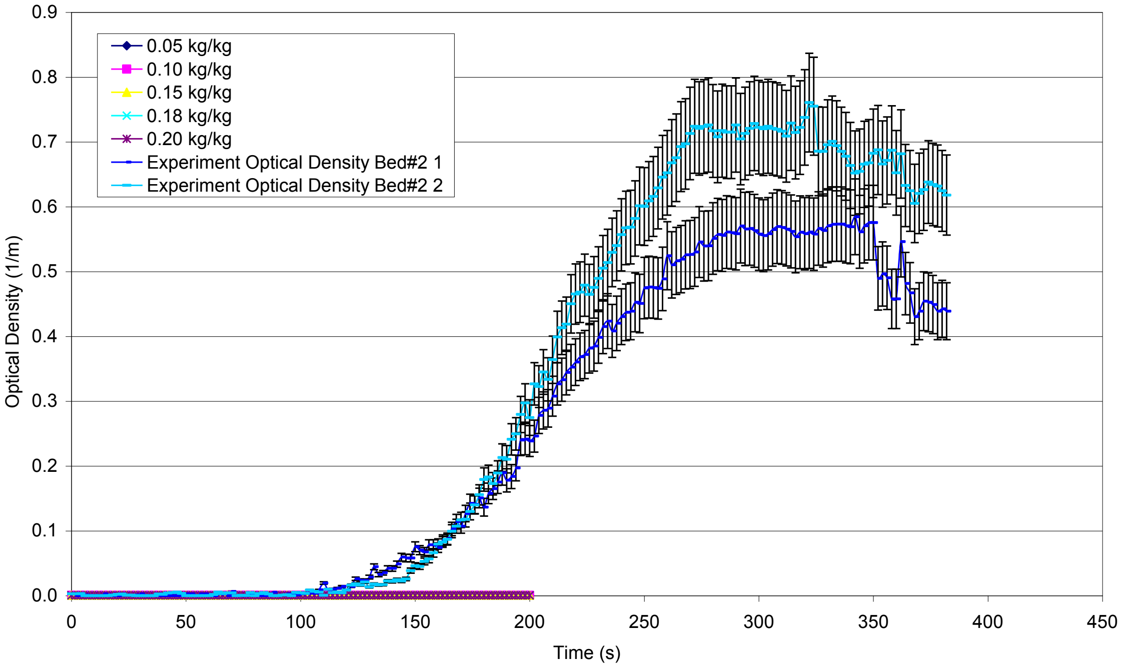


(b)

Figure 21. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Hall optical density



(a)



(b)

Figure 22. Experiment and (a) upper layer and (b) lower layer BRANZFIRE results for Bedroom #2 optical density

3.2.2.3 Analysis and Discussion

3.2.3 Grid Spacing and Temperature

The grid spacing for the FDS-based modelling approach was selected based on the results of comparing the model output for the grid spacings of 300, 150, 100 and 62.5 mm and a soot yield of 0.1 kg_{soot}/kg_{fuel} (Scenarios 1 – 4 of Table 12).

Considering the temperature results shown in Figure 9, Figure 10 and Figure 24 – Figure 29, for locations near to the seat of the fire (Living Room #2 and #1, Locations E and F respectively of Figure 2):

- model results for the 62.5 mm and 100 mm uniform grid sizes are in reasonable conservative agreement (± ~20 – 30ºC, ± ~20 – 25% of maximum temperature) with the experiment temperature results at locations 20 mm and 300 mm below the ceiling (Figure 9 and Figure 26 a and b)
- model results for the 100 mm and 150 mm uniform grid sizes are in good conservative agreement (± ~15ºC, ± ~20% of maximum temperature) with the experiment temperature results at 610 mm below the ceiling (Figure 9 and Figure 26 c)
- model results for the 62.5 mm, 100 mm and 150 mm grid sizes Living Room #2 (Location E of Figure 2) are in reasonable agreement (± ~20ºC, ± ~30% of maximum temperature) with the experiment temperature results at 900 mm below the ceiling (Figure 9 d); however model results for Living Room #1 (Location F of Figure 2) under-predicted the experiment temperatures after 150 s by up to ~40 ºC (Figure 26 d)
- model results for all the grid sizes considered are in good agreement (± ~5ºC, ± ~10% of maximum temperature) with the experiment temperature results at 1200 mm below the ceiling (Figure 9 and Figure 26 e)
- model results for the 100 mm, 150 mm and 300 mm grid sizes are in reasonable agreement (±~5ºC, ± ~15% of maximum temperature) with the experiment temperature results at 1520 mm below the ceiling (Figure 9 and Figure 26 f) although all model results consistently under-predict the temperature
- model results for all the grid sizes considered under-predict the temperature at 1820 mm below the ceiling (Figure 9 and Figure 26 g); however model results for the 300 mm grid size produced the closest prediction and are within a maximum -~15ºC at the maximum temperature.

For locations remote to the seat of the fire (Bedroom #1, Location B respectively of Figure 2):

- model results for the 62.5 mm and 100 mm grid sizes are in good conservative agreement (+ ~10ºC, + ~20% of maximum temperature) with the experiment temperature results at 20 mm below the ceiling (Figure 10 a),
- model results for all the grid sizes are in good conservative agreement (< +8ºC, +~20 – 27% of maximum temperature) with the experiment temperature results at 300, 610, 900, 1200 and 1520 mm below the ceiling (Figure 10 b, c, d, e and f),
- model results for all the grid sizes considered under-predict the temperature at 1820 mm below the ceiling (Figure 10 g); however model results for the 300 mm grid size produced the closest prediction and are within a maximum – ~15ºC at the maximum temperature.

Uncertainties associated with the measurement of experiment temperatures were stated as ±16ºC (Bukowski et al 2007). Therefore, in general, there is overall good agreement for the comparison of the FDS-model and experiment temperature results.

In general, the results from the 100 mm grid size produced the closest appropriate temperatures compared to the experiment results for locations nearest to the seat of the fire down to approximately 1200 mm below the ceiling. Below this height the larger grid sizes produced closer temperature results, although all model results under-predicted the temperatures. For locations remote from the seat of the fire the 100 mm grid size produces temperature results in reasonable conservative agreement with experiment results. As the location of the measurements and predictions is more remote from the seat of the fire, and the distance from the ceiling increases the results for the larger grid sizes increase in agreement with experiment temperatures, whereas the results using the smaller grid sizes considered do not show such agreement with the experiment results.

Overall the model results based on the 100 mm grid spacing provided the closest fit to the published experiment temperatures. Therefore the 100 mm grid spacing was used for the remainder of the Scenarios tested (5 – 8 of Table 12).

Model results using BRANZFIRE also showed good agreement with experiment temperatures, as shown in Figure 50 to Figure 55, when considered in combination with the model layer heights, as shown in Figure 60.

3.2.4 Optical Density

Considering the model results using FDS:

- Near to the fire (Living Room #2, Living Room #1 and Kitchen, as shown in Figure 11, Figure 12 and Figure 13 respectively), for the range of soot yield values considered, the optical density at 20 mm below the ceiling (part (a) of Figures) for a soot yield of 0.1 kg/kg predicts conservative optical densities in good agreement with those reported for the experiment for the location closest to the fire (Living Room #2, Figure 11). A soot yield of 0.05 kg/kg predicts conservative optical densities in good agreement with those reported for the experiment for the next locations closest to the fire (Living Room #1, Figure 12, and Kitchen Figure 13). The predicted optical density at 900 mm below the ceiling (part (b) of Figures) consistently over-predicted the experiment results for all the soot yield values considered. However, as the location is more remote from the fire the predicted soot yield values provide a closer prediction to the experiment results.
- For rooms adjacent and remote to the fire (Bedroom #2, Hall and Bedroom #1, as shown in Figure 14, Figure 15 and Figure 16 respectively), the soot yield value of 0.05 kg/kg predicts optical densities in reasonable agreement with the experiment values at 2 mm below the ceiling. The model predictions for optical densities at 900 mm below the ceiling were generally over-predicted by the model for all soot yield values, except for the Hall (Figure 15 b) where a soot yield value of 0.1 kg/kg produced results in reasonable agreement with experiment results.

The model results for the optical densities for nearer to (at 20 mm below) the ceiling for soot yields of 0.1 – 0.05 kg/kg are generally in reasonable agreement with the experiment results. For locations remote from room of fire origin, the predicted optical densities were consistently greater than the experiment results. The model results for the optical densities further from (at 900 mm below) the ceiling consistently over-predict the experiment values.

Considering the model results using BRANZFIRE:

- Near to the fire (Living Room #2, Living Room #1 and Kitchen, as shown in Figure 17, Figure 18 and Figure 19 respectively), for the range of soot yield values considered, the average optical density of the upper layer (part (a) of Figures) predicts optical densities greater than those reported for the experiment at 20 mm below the ceiling. The predicted average optical density of the lower layer (part (b) of Figures) is in good agreement with the experiment results at 900 mm below the ceiling. In addition, the maximum predicted upper layer thickness for the Living Room/Kitchen is approximately 1 m (Figure 60).
- Rooms adjacent to the fire (Bedroom #2 and Hall, as shown in Figure 20 and Figure 21 respectively), for the range of soot yield values considered, the average optical density of the upper layer (part (a) of Figures) predicts optical densities greater than those reported for the experiment at 20 mm below the ceiling. The predicted average optical density of the lower layer (part (b) of Figures) is in reasonable agreement with the experiment results at 900 mm below the ceiling. The maximum predicted upper layer thicknesses for Bedroom #2 and Hall are approximately 1.3 m and 1 m respectively (Figure 60).
- For the room more remote to the fire (Bedroom #1, as shown in Figure 22), for the range of soot yield values considered, the average optical density of the upper layer (part (a) of Figures) predicts optical densities greater than those reported for the experiment at 20 mm below the ceiling. The predicted average optical density of the lower layer (part (b) of Figures) is lower than the experiment results at 900 mm below the ceiling. The maximum predicted upper layer thickness for Bedroom #1 is approximately 1.1 m (Figure 60).

In general, the model results for the average optical densities for upper layers over-predict the experiment results at 20 and 900 mm below the ceiling and for lower layers are generally in good agreement with the experiment results for 900 mm below the ceiling.

Considering the experiment results for optical density, there is a sudden increase in the recorded values at 20 mm below the ceiling in the kitchen (as shown in Figure 13 and Figure 19) at approximately the time of the end of flaming of the specimen. However, a similar increase is not present in the results for other locations in the same room (such as Living Room #1 or Living Room #2, or at 900 mm in the room). In addition, the experiment optical density results for the Hall (Figure 15 and Figure 21) at 900 mm below the ceiling are greater than the results at 20 mm. However, similar comparative results are not observed for other rooms adjacent or remote to the room of fire origin.

Furthermore, Bukowski et al (2007) noted that heating of the meters affected the reliability of the computed smoke obscuration. Therefore care should be used when analysing these values. The uncertainty associated with the measurement of experiment optical density was stated as ±10% (Bukowski et al 2007). This level of uncertainty, included in Table 9, was used in the comparison of all optical density measurements with model outputs, although it would be expected that devices nearer to the fire would be subjected to higher heating compared to those more remote.

4. CONCLUSIONS

It is acknowledged that this study focused on a small range of scenarios, and appropriate care must be used when applying the subsequent conclusions to other situations.

For the range of smoke/soot yields considered in this study (0.05 – 0.20 kg/kg) both FDS and BRANZFIRE provided generally conservative predictions of smoke optical density for the flaming upholstered armchair located within a manufactured home as described earlier in this report. These results indicate that either the soot yield values or the method of incorporating soot into the models considered here or both are currently inappropriate.

In modelling the same experiment, a soot/smoke yield of 0.05 kg/kg generally provided the closest but conservative agreement with the experimental measurements of smoke density.

With a soot/smoke yield of 0.20 kg/kg, the models over-predicted the smoke optical density by up to a factor of 10. For the upholstered armchair used in this experiment, assuming a handbook value for soot yield based on 'flexible polyurethane foam' did not provide a good prediction of smoke optical density.

4.1 Recommendations

Our recommendation, if using the modelling methodologies consistent with those considered in this report and for scenarios similar to those considered here, is to select a design fire value for soot/smoke yields derived from optical measurements taken during flaming combustion of full-sized items of upholstered furniture (e.g. from CBUF as shown in Figure 23) where the upper 95th percentile value of the smoke yield based on 24 items of upholstered furniture (with 1 outlier removed) was 0.07 kg/kg.

4.2 Future Research

It is stressed that this report is based on a limited range of conditions and scenarios, therefore further research is recommended. Important areas for future research are:

- Consideration of post-flashover conditions and the suggested values for soot yield, such as presented in Table 1.
- Consideration of a wider range of scenarios and building layouts, including multiple storeys.
- Detailed investigation of the impact of soot modelling assumptions, since the soot yield values are only one aspect of the total problem and the scenarios for the models investigated here consistently over-estimated the optical density.

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APPENDIX A SUMMARY OF PUBLISHED SOOT YIELD VALUES

A.1 Summary and Analysis of CBUF Data

Calculation used for estimating soot yield values (Y_S in kg/kg) for flaming fires based on average smoke extinction area (SEA in m²/kg) reported for furniture calorimeter tests (CBUF 1995) is:

$$Y_S = \frac{SEA}{K_m} \tag{5.1}$$

Where the Seider and Einhorn constant for flaming combustion, K_m = 7600 m²/kg.

Table 15. Summary of estimated soot yield values calculated using CBUF data set (Table 25, CBUF 1995)

	Whole Data Set	Data Set Without Outlier
Average	0.040	0.027
Standard Deviation	0.071	0.024
95th Percentile	0.097	0.073
99th Percentile	0.30	0.096

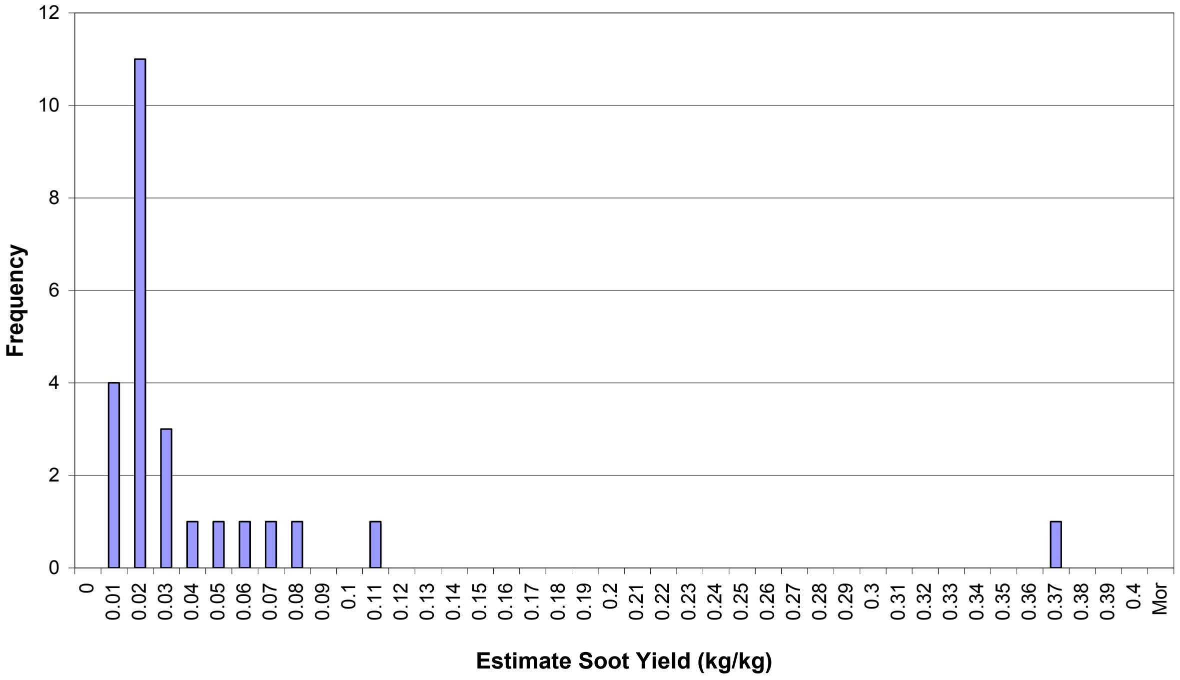

Figure 23. Histogram of the estimated soot yield values (kg_{soot}/kg_{fuel}) calculated using the CBUF data set for Furniture Calorimeter tests, Table 25 (CBUF 1995)

APPENDIX B FDS INPUT AND RESULTS

B.1 Scenario 1 – 62.5 mm grid, 0.1 kg/kg soot yield

B.1.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR', FYI='values based on POLYURETHANE', SOOT_YIELD = 0.10, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025  /

&MISC RESTART=.FALSE, DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 62.5 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=360, JBAR=108, KBAR=48 /

/… same as input for B.1.2 with geometry adaptations for changes in mesh

&TAIL /
```

B.2 Scenario 2 – 100 mm grid, 0.1 kg/kg soot yield

B.2.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR', FYI='values based on POLYURETHANE', SOOT_YIELD = 0.10, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025 /

&MISC RESTART=.FALSE, DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 100 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=225, JBAR=64, KBAR=30 /

&TIME TWFIN=200/

/open computational boundaries
&VENT CB='XBAR0', SURF_ID='OPEN' /
&VENT CB='XBAR', SURF_ID='OPEN' /
&VENT CB='YBAR0', SURF_ID='OPEN' /
&VENT CB='YBAR', SURF_ID='OPEN' /
&VENT CB='ZBAR', SURF_ID='OPEN' /

/walls of manufactured house
&OBST XB=1.0,21.2,1.0,1.1,0.0,2.1, SURF_ID='INERT'/ south
&OBST XB=1.0,21.2,5.1,5.2,0.0,2.1, SURF_ID='INERT'/ north
&OBST XB=21.1,21.2,1.0,5.2,0.0,2.4, SURF_ID='INERT'/ east
&OBST XB=1.0,1.1,1.0,5.2,0.0,2.4, SURF_ID='INERT'/ west
/pitched roof
&OBST XB=1,21.2,1,1.7,2.1,2.4, SURF_ID='INERT'/
&OBST XB=1,21.2,1.6,2.5,2.3,2.5, SURF_ID='INERT'/
 &OBST XB=1,21.2,2.4,3.2,2.4,2.6, SURF_ID='INERT'/
&OBST XB=1,21.2,5.2,4.3,2.1,2.4, SURF_ID='INERT'/
&OBST XB=1,21.2,4.4,3.7,2.2,2.5, SURF_ID='INERT'/
&OBST XB=1,21.2,3.8,3.1,2.4,2.6, SURF_ID='INERT'/

/internal warehouse walls
&OBST XB=1.0,4.5,4.3,4.4,0.0,2.4, SURF_ID='INERT'/ internal wall - closet in bedroom #1
&OBST XB=4.4,4.5,1.0,5.2,0.0,2.4, SURF_ID='INERT'/ internal wall - between bed#1 & kitchen/bath
&OBST XB=4.4,6.8,3.1,3.2,0.0,2.4, SURF_ID='INERT'/internal wall - between bath and kitchen
```

```
&OBST XB=6.7,6.8,1.0,3.2,0.0,2.4, SURF_ID='INERT'/ internal wall - between bath and dining room
&OBST XB=14.2,14.3,1.8,5.2,0.0,2.4, SURF_ID='INERT'/ internal wall - between living room and bed#3
&OBST XB=14.2,18.5,1.8,1.9,0.0,2.4, SURF_ID='INERT'/ internal wall - between bed#3 & hall
&OBST XB=16.6,16.7,1.8,5.2,0.0,2.4, SURF_ID='INERT'/ internal wall - between bed#3 & closets
&OBST XB=16.6,18.5,3.3,3.4,0.0,2.4, SURF_ID='INERT'/ internal wall - between closets of bed#3 & bed#1
&OBST XB=18.4,18.5,1.0,5.2,0.0,2.4, SURF_ID='INERT'/ internal wall - between closets & bed#1
&OBST XB=6.8,9.2,4.4,5.2,0.0,1.0, SURF_ID='INERT'/ kitchen bench
&OBST XB=9.2,10.0,3.0,5.2,0.0,1.0, SURF_ID='INERT'/ kitchen bench

/doors
&HOLE XB=2.5,3.3,4.2,4.5,0.0,2.0,/door - closet in bedroom #1
&HOLE XB=4.3,4.6,3.3,4.1,0.0,2.0,/door - between bed#1 & kitchen/bath
&OBST XB=5.0,5.8,3.0,3.3,0.0,2.0, SURF_ID='SPRUCE', COLOR='RED'/door - between bath and kitchen
&HOLE XB=5.0,5.8,3.0,3.3,0.0,0.2,/leakage under door
&OBST XB=5.8,6.6,5.0,5.3,0.0,2.0, SURF_ID='SPRUCE', COLOR='RED'/closed door - between kitchen & outside
/&HOLE XB=5.8,6.6,5.0,5.3,0.0,0.2,/leakage under door
&OBST XB=15.0,15.8,1.7,2.0,0.0,2.0, SURF_ID='SPRUCE',COLOR='RED'/closed door - between bed#3 & hall
&HOLE XB=15.0,15.8,1.7,2.0,0.0,0.2, /leakage under door
&OBST XB=12.8,13.5,0.9,1.2,0.0,2.0, SURF_ID='SPRUCE',COLOR='RED'/closed door - between dining room & outside
&HOLE XB=16.5,16.8,4.0,4.8,0.0,2.0, /door - between bed#3 & closet
&HOLE XB=18.3,18.6,2.2,3.0,0.0,2.0, /door - between closet & bed#1
&HOLE XB=18.3,18.6,1.1,1.7,0.0,2.0, /door - between hall & bed#1

/windows
&HOLE XB=2.0,3.0,1.0,1.1,1.0,2.0, T_REMOVE=0/window in bed#2
&HOLE XB=5.4,5.8,0.9,1.2,1.0,1.3, /window - in bathroom
&HOLE XB=7.0,8.0,0.9,1.2,1.0,2.0, T_REMOVE=0/window - in dining room
&HOLE XB=11.0,12.0,0.9,1.2,1.0,2.0, T_REMOVE=0/window - in living room
&HOLE XB=11.0,12.0,5.0,5.3,1.0,2.0, T_REMOVE=0/window - in living room
&HOLE XB=21.0,21.3,2.5,3.5,1.0,2.0, T_REMOVE=0/window - in bed#1
&HOLE XB=15.0,16.0,5.0,5.3,1.0,2.0, T_REMOVE=0/window - in bed#3

/&OBST XB=2.0,3.0,1.0,1.1,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window in bed#2
/&OBST XB=7.0,8.0,0.9,1.2,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window - in dining room
/&OBST XB=11.0,12.0,0.9,1.2,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window - in living room
/&OBST XB=11.0,12.0,5.0,5.3,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window - in living room
/&OBST XB=21.0,21.3,2.5,3.5,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window - in bed#1
/&OBST XB=15.0,16.0,5.0,5.3,1.0,2.0, SURF_ID='GLASS',T_CREATE=0/window - in bed#3

/armchair
&OBST XB=13.0,13.9,3.6,4.5,0.1,0.3, SURF_ID='INERT'/SURF_ID='UPHOLSTERY'/
&OBST XB=13.0,13.8,3.8,4.3,0.3,0.4, SURF_ID='INERT'/SURF_ID='UPHOLSTERY'/
&OBST XB=13.0,13.9,3.6,3.8,0.3,0.6, SURF_ID='INERT'/SURF_ID='UPHOLSTERY'/
&OBST XB=13.0,13.9,4.3,4.5,0.3,0.6, SURF_ID='INERT'/SURF_ID='UPHOLSTERY'/
&OBST XB=13.7,13.8,3.8,4.3,0.3,0.9, SURF_ID='INERT'/SURF_ID='UPHOLSTERY'/
/fire - armchair - based on mass loss rate of SDC02
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/mattress
&OBST XB=19.9, 21.0, 2.1, 4.1, 0.3, 0.5, SURF_ID='UPHOLSTERY'/
/fire - mattress
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/&RAMP ID='FIRE_RAMP_MATTRESS', T=120,F=1/
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/OUTPUTS:

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/thermocouples
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&THCP XYZ=14.0,3.1,1.8,QUANTITY='TEMPERATURE',LABEL='LIVING#2_TEMPERATURE_03'/
&THCP XYZ=14.0,3.1,1.5,QUANTITY='TEMPERATURE',LABEL='LIVING#2_TEMPERATURE_04'/
&THCP XYZ=14.0,3.1,1.2,QUANTITY='TEMPERATURE',LABEL='LIVING#2_TEMPERATURE_05'/
&THCP XYZ=14.0,3.1,0.9,QUANTITY='TEMPERATURE',LABEL='LIVING#2_TEMPERATURE_06'/
&THCP XYZ=14.0,3.1,0.6,QUANTITY='TEMPERATURE',LABEL='LIVING#2_TEMPERATURE_07'/
&SLCF PBX=14.0,QUANTITY='TEMPERATURE'/,LABEL='LIVING#2_TEMPERATURE'/
&THCP XYZ=6.2,4.8,2.1,QUANTITY='TEMPERATURE',IOR=-3,LABEL='KITCH_TEMPERATURE_01'/
&THCP XYZ=6.2,4.8,1.8,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_02'/
&THCP XYZ=6.2,4.8,1.5,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_03'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_04'/
&THCP XYZ=6.2,4.8,0.9,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_05'/
&THCP XYZ=6.2,4.8,0.6,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_06'/
&THCP XYZ=6.2,4.8,0.3,QUANTITY='TEMPERATURE',LABEL='KITCH_TEMPERATURE_07'/
&SLCF PBX=6.2,QUANTITY='TEMPERATURE'/,LABEL='KITCH_TEMPERATURE'/
&THCP XYZ=2.1,3.1,2.4,QUANTITY='TEMPERATURE',IOR=-3,LABEL='BED#2_TEMPERATURE_01'/
&THCP XYZ=2.1,3.1,2.1,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_02'/
&THCP XYZ=2.1,3.1,1.8,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_03'/
&THCP XYZ=2.1,3.1,1.5,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_04'/
&THCP XYZ=2.1,3.1,1.2,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_05'/
&THCP XYZ=2.1,3.1,0.9,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_06'/
&THCP XYZ=2.1,3.1,0.6,QUANTITY='TEMPERATURE',LABEL='BED#2_TEMPERATURE_07'/
&SLCF PBX=2.1,QUANTITY='TEMPERATURE'/,LABEL='BED#2_TEMPERATURE'/

/smoke detectors
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.93,LABEL='BED#1_SMOKE_DECT_01a' /
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.33,LABEL='BED#1_SMOKE_DECT_01b' /
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.53,LABEL='BED#1_SMOKE_DECT_02a' /
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.93,LABEL='BED#1_SMOKE_DECT_02b' /
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='BED#1_SMOKE_DECT_03a' /
&SMOD XYZ=18.9,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=11.06,LABEL='BED#1_SMOKE_DECT_03b' /
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=2.93,LABEL='HALL#1_SMOKE_DECT_01a'/
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=5.33,LABEL='HALL#1_SMOKE_DECT_01b'/
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=2.53,LABEL='HALL#1_SMOKE_DECT_02a'/
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='HALL#1_SMOKE_DECT_02b'/
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='HALL#1_SMOKE_DECT_03a'/
&SMOD XYZ=18.0,1.5,2.0,LENGTH=1.8,ACTIVATION_OBSCURATION=11.06,LABEL='HALL#1_SMOKE_DECT_03b'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.93,LABEL='LIVING#2_SMOKE_DECT_01a'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.33,LABEL='LIVING#2_SMOKE_DECT_01b'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.53,LABEL='LIVING#2_SMOKE_DECT_02a'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.93,LABEL='LIVING#2_SMOKE_DECT_02b'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='LIVING#2_SMOKE_DECT_03a'/
&SMOD XYZ=13.8,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=11.06,LABEL='LIVING#2_SMOKE_DECT_03b'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.93,LABEL='KITCH_SMOKE_DECT_01a'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.33,LABEL='KITCH_SMOKE_DECT_01b'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.53,LABEL='KITCH_SMOKE_DECT_02a'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.93,LABEL='KITCH_SMOKE_DECT_02b'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='KITCH_SMOKE_DECT_03a'/
&SMOD XYZ=4.9,3.6,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=11.06,LABEL='KITCH_SMOKE_DECT_03b'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.93,LABEL='BED#2_SMOKE_DECT_01a'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.33,LABEL='BED#2_SMOKE_DECT_01b'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.53,LABEL='BED#2_SMOKE_DECT_02a'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=5.93,LABEL='BED#2_SMOKE_DECT_02b'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=2.46,LABEL='BED#2_SMOKE_DECT_03a'/
&SMOD XYZ=1.5,2.7,2.2,LENGTH=1.8,ACTIVATION_OBSCURATION=11.06,LABEL='BED#2_SMOKE_DECT_03b'/

/volume fraction O2, CO, CO2
&THCP XYZ=19.7,3.2,1.4,QUANTITY='oxygen',LABEL='BED#1_OXYGEN_VOL_FRAC_04', DTSAM=2.0/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='oxygen',LABEL='LIVING#1_OXYGEN_VOL_FRAC_04'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='oxygen',LABEL='KITCH_OXYGEN_VOL_FRAC_04'/
```

```
&THCP XYZ=2.8,3.0,1.5,QUANTITY='oxygen',LABEL='BED#2_OXYGEN_VOL_FRAC_04'/
&THCP XYZ=19.7,3.2,1.4,QUANTITY='carbon dioxide',LABEL='BED#1_CO2_VOL_FRAC_04'/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='carbon dioxide',LABEL='LIVING#1_CO2_VOL_FRAC_04'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='carbon dioxide',LABEL='KITCH_CO2_VOL_FRAC_04'/
&THCP XYZ=2.8,3.0,1.5,QUANTITY='carbon dioxide',LABEL='BED#2_CO2_VOL_FRAC_04'/
&THCP XYZ=19.7,3.2,1.4,QUANTITY='carbon monoxide',LABEL='BED#1_CO_VOL_FRAC_04'/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='carbon monoxide',LABEL='LIVING#1_CO_VOL_FRAC_04'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='carbon monoxide',LABEL='KITCH_CO_VOL_FRAC_04'/
&THCP XYZ=2.8,3.0,1.5,QUANTITY='carbon monoxide',LABEL='BED#2_CO_VOL_FRAC_04'/

/extinction coefficient
&THCP XYZ=19.7,3.1,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='BED#1_EXTINCTION COEFFICIENT_01',
DTSAM=2.0/
&THCP XYZ=19.7,3.1,1.5,QUANTITY='extinction coefficient',LABEL='BED#1_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=19.7, QUANTITY='extinction coefficient'/, LABEL='BED#1_EXTINCTION COEFFICIENT', DTSAM=2.0/
&THCP XYZ=18.0,1.2,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='HALL#1_EXTINCTION COEFFICIENT_01'/
&THCP XYZ=18.0,1.2,1.2,QUANTITY='extinction coefficient',LABEL='HALL#1_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=18.0,QUANTITY='extinction coefficient'/,LABEL='HALL#1_EXTINCTION COEFFICIENT'/
&THCP XYZ=13.2,1.5,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='LIVING#1_EXTINCTION COEFFICIENT_01'/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='extinction coefficient',LABEL='LIVING#1_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=13.2,QUANTITY='extinction coefficient'/,LABEL='LIVING#1_EXTINCTION COEFFICIENT'/
&THCP XYZ=14.0,3.1,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='LIVING#2_EXTINCTION COEFFICIENT_01'/
&THCP XYZ=14.0,3.1,1.5,QUANTITY='extinction coefficient',LABEL='LIVING#2_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=14.0,QUANTITY='extinction coefficient'/,LABEL='LIVING#2_EXTINCTION COEFFICIENT'/
&THCP XYZ=6.2,4.8,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='KITCH_EXTINCTION COEFFICIENT_01'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='extinction coefficient',LABEL='KITCH_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=6.2,QUANTITY='extinction coefficient'/,LABEL='KITCH_EXTINCTION COEFFICIENT'/
&THCP XYZ=2.1,3.1,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='BED#2_EXTINCTION COEFFICIENT_01'/
&THCP XYZ=2.1,3.1,1.5,QUANTITY='extinction coefficient',LABEL='BED#2_EXTINCTION COEFFICIENT_04'/
&SLCF PBX=2.1,QUANTITY='extinction coefficient'/,LABEL='BED#2_EXTINCTION COEFFICIENT'/

/soot density
&THCP XYZ=19.7,3.1,2.4,QUANTITY='soot density',IOR=-3,LABEL='BED#1_SOOT DENSITY_01', DTSAM=2.0/
&THCP XYZ=19.7,3.1,1.5,QUANTITY='soot density',LABEL='BED#1_SOOT DENSITY_04'/
&SLCF PBX=19.7, QUANTITY='soot density'/, LABEL='BED#1_SOOT DENSITY', DTSAM=2.0/
&THCP XYZ=18.0,1.2,2.1,QUANTITY='soot density',IOR=-3,LABEL='HALL#1_SOOT DENSITY_01'/
&THCP XYZ=18.0,1.2,1.2,QUANTITY='soot density',LABEL='HALL#1_SOOT DENSITY_04'/
&SLCF PBX=18.0,QUANTITY='soot density'/,LABEL='HALL#1_SOOT DENSITY'/
&THCP XYZ=13.2,1.5,2.1,QUANTITY='soot density',IOR=-3,LABEL='LIVING#1_SOOT DENSITY_01'/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='soot density',LABEL='LIVING#1_SOOT DENSITY_04'/
&SLCF PBX=13.2,QUANTITY='soot density'/,LABEL='LIVING#1_SOOT DENSITY'/
&THCP XYZ=14.0,3.1,2.4,QUANTITY='soot density',IOR=-3,LABEL='LIVING#2_SOOT DENSITY_01'/
&THCP XYZ=14.0,3.1,1.5,QUANTITY='soot density',LABEL='LIVING#2_SOOT DENSITY_04'/
&SLCF PBX=14.0,QUANTITY='soot density'/,LABEL='LIVING#2_SOOT DENSITY'/
&THCP XYZ=6.2,4.8,2.1,QUANTITY='soot density',IOR=-3,LABEL='KITCH_SOOT DENSITY_01'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='soot density',LABEL='KITCH_SOOT DENSITY_04'/
&SLCF PBX=6.2,QUANTITY='soot density'/,LABEL='KITCH_SOOT DENSITY'/
&THCP XYZ=2.1,3.1,2.4,QUANTITY='soot density',IOR=-3,LABEL='BED#2_SOOT DENSITY_01'/
&THCP XYZ=2.1,3.1,1.5,QUANTITY='soot density',LABEL='BED#2_SOOT DENSITY_04'/
&SLCF PBX=2.1,QUANTITY='soot density'/,LABEL='BED#2_SOOT DENSITY'/

/soot volume fraction
&THCP XYZ=19.7,3.1,2.4,QUANTITY='soot volume fraction',IOR=-3,LABEL='BED#1_SOOT VOLUME FRACTION_01',
DTSAM=2.0/
&THCP XYZ=19.7,3.1,1.5,QUANTITY='soot volume fraction',LABEL='BED#1_SOOT VOLUME FRACTION_04', DTSAM=2.0/
&SLCF PBX=19.7, QUANTITY='soot volume fraction'/, LABEL='BED#1_SOOT VOLUME FRACTION', DTSAM=2.0/
&THCP XYZ=18.0,1.2,2.1,QUANTITY='soot volume fraction',IOR=-3,LABEL='HALL#1_SOOT VOLUME FRACTION_01'/
&THCP XYZ=18.0,1.2,1.2,QUANTITY='soot volume fraction',LABEL='HALL#1_SOOT VOLUME FRACTION_04'/
&SLCF PBX=18.0,QUANTITY='soot volume fraction'/,LABEL='HALL#1_SOOT VOLUME FRACTION'/
&THCP XYZ=13.2,1.5,2.1,QUANTITY='soot volume fraction',IOR=-3,LABEL='LIVING#1_SOOT VOLUME FRACTION_01'/
&THCP XYZ=13.2,1.5,1.2,QUANTITY='soot volume fraction',LABEL='LIVING#1_SOOT VOLUME FRACTION_04'/
&SLCF PBX=13.2,QUANTITY='soot volume fraction'/,LABEL='LIVING#1_SOOT VOLUME FRACTION'/
&THCP XYZ=14.0,3.1,2.4,QUANTITY='soot volume fraction',IOR=-3,LABEL='LIVING#2_SOOT VOLUME FRACTION_01'/
&THCP XYZ=14.0,3.1,1.5,QUANTITY='soot volume fraction',LABEL='LIVING#2_SOOT VOLUME FRACTION_04'/
&SLCF PBX=14.0,QUANTITY='soot volume fraction'/,LABEL='LIVING#2_SOOT VOLUME FRACTION'/
&THCP XYZ=6.2,4.8,2.1,QUANTITY='soot volume fraction',IOR=-3,LABEL='KITCH_SOOT VOLUME FRACTION_01'/
&THCP XYZ=6.2,4.8,1.2,QUANTITY='soot volume fraction',LABEL='KITCH_SOOT VOLUME FRACTION_04'/
&SLCF PBX=6.2,QUANTITY='soot volume fraction'/,LABEL='KITCH_SOOT VOLUME FRACTION'/
&THCP XYZ=2.1,3.1,2.4,QUANTITY='soot volume fraction',IOR=-3,LABEL='BED#2_SOOT VOLUME FRACTION_01'/
&THCP XYZ=2.1,3.1,1.5,QUANTITY='soot volume fraction',LABEL='BED#2_SOOT VOLUME FRACTION_04'/
&SLCF PBX=2.1,QUANTITY='soot volume fraction'/,LABEL='BED#2_SOOT VOLUME FRACTION'/

/extinction coefficient - larger sample volume
&THCP XB=19.5,19.7,2.9,3.1,2.2,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='BED#1_EXTINCTION
COEFFICIENT_01'/
&THCP XB=19.5,19.7,2.9,3.1,1.3,1.5,QUANTITY='extinction coefficient',LABEL='BED#1_EXTINCTION COEFFICIENT_04'/
```

```
&THCP XB=17.8,18.0,1.0,1.2,1.9,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='HALL#1_EXTINCTION
COEFFICIENT_01'/
&THCP XB=17.8,18.0,1.0,1.2,1.0,1.2,QUANTITY='extinction coefficient',LABEL='HALL#1_EXTINCTION COEFFICIENT_04'/
&THCP XB=13.0,13.2,1.3,1.5,1.9,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='LIVING#1_EXTINCTION
COEFFICIENT_01'/
&THCP XB=13.0,13.2,1.3,1.5,1.0,1.2,QUANTITY='extinction coefficient',LABEL='LIVING#1_EXTINCTION COEFFICIENT_04'/
&THCP XB=13.8,14.0,2.9,3.1,2.2,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='LIVING#2_EXTINCTION
COEFFICIENT_01'/
&THCP XB=13.8,14.0,2.9,3.1,1.3,1.5,QUANTITY='extinction coefficient',LABEL='LIVING#2_EXTINCTION COEFFICIENT_04'/
&THCP XB=6.0,6.2,4.6,4.8,2.0,2.1,QUANTITY='extinction coefficient',IOR=-3,LABEL='KITCH_EXTINCTION
COEFFICIENT_01'/
&THCP XB=6.0,6.2,4.6,4.8,1.0,1.2,QUANTITY='extinction coefficient',LABEL='KITCH_EXTINCTION COEFFICIENT_04'/
&THCP XB=1.9,2.1,2.9,3.1,2.2,2.4,QUANTITY='extinction coefficient',IOR=-3,LABEL='BED#2_EXTINCTION
COEFFICIENT_01'/
&THCP XB=1.9,2.1,2.9,3.1,1.3,1.5,QUANTITY='extinction coefficient',LABEL='BED#2_EXTINCTION COEFFICIENT_04'/

&TAIL /
```

B.3 Scenario 3 – 150 mm grid, 0.1 kg/kg soot yield

B.3.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.10, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025 /

&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 150 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.75, ZBAR=3 /
&GRID IBAR=150, JBAR=45, KBAR=20 /

/… same as input for B.1.2 with geometry adaptations for changes in mesh

&TAIL /
```

B.4 Scenario 4 – 300 mm grid, 0.1 kg/kg soot yield

B.4.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.10, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025 /

&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 300 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=7.2, ZBAR=3 /
&GRID IBAR=75, JBAR=24, KBAR=10 /

/… same as input for B.1.2 with geometry adaptations for changes in mesh

&TAIL /
```

B.5 Scenario 5 – 100 mm grid, 0.05 kg/kg soot yield

B.5.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /
```

```
&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.05, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025  /

&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 100 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=225, JBAR=64, KBAR=30 /

&TIME TWFIN=200/

/… same as input for B.1.2

&TAIL /
```

B.6 Scenario 6 – 100 mm grid, 0.15 kg/kg soot yield

B.6.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.15, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025  /

&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 100 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=225, JBAR=64, KBAR=30 /

/… same as input for B.1.2

&TAIL /
```

B.7 Scenario 7 – 100 mm grid, 0.18 kg/kg soot yield

B.7.1 Input

```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.18, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025  /

&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 100 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=225, JBAR=64, KBAR=30 /

/… same as input for B.1.2

&TAIL /
```

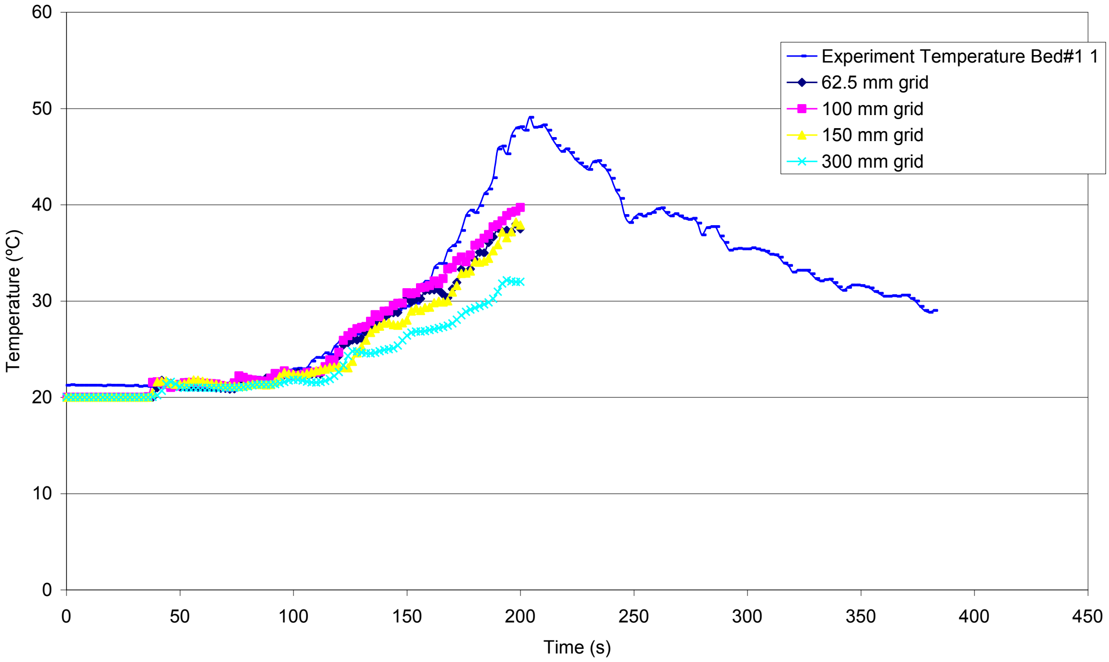
B.8 Scenario 8 – 100 mm grid, 0.2 kg/kg soot yield

B.8.1 Input

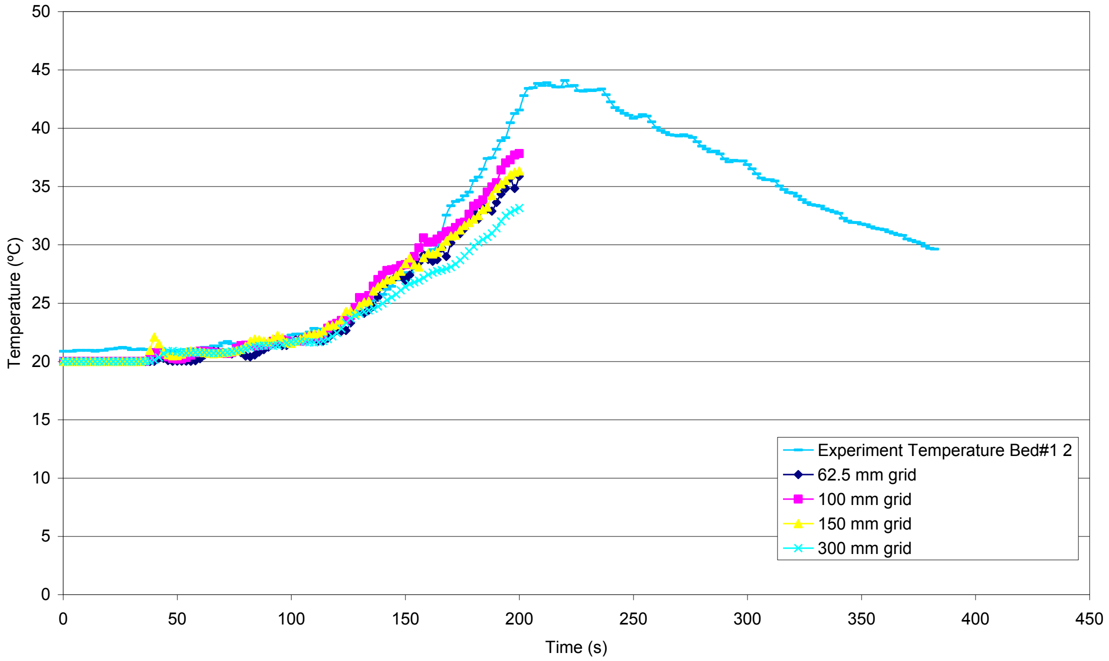
```
&HEAD CHID='manufactured_house_01', TITLE='NIST TN 1455 Manufactured House' /

&REAC ID='ARMCHAIR',FYI='values based on POLYURETHANE', SOOT_YIELD = 0.20, CO_YIELD = 0.04, MW_FUEL=
130.3, FUEL_N2 = 0.5, NU_CO2 = 6.3, NU_H2O = 3.55, NU_O2 = 7.025  /
```

```
&MISC RESTART=.FALSE., DTCORE=100, DATABASE_DIRECTORY='C:\nist\fds\database4\' /sets path for location of
database
&MISC SURF_DEFAULT='INERT', REACTION='ARMCHAIR'/

/MESH at 100 mm cubed
&PDIM XBAR0=0, YBAR0=0, ZBAR=0, XBAR=22.5, YBAR=6.4, ZBAR=3 /
&GRID IBAR=225, JBAR=64, KBAR=30 /

/… same as input for B.1.2

&TAIL /
```

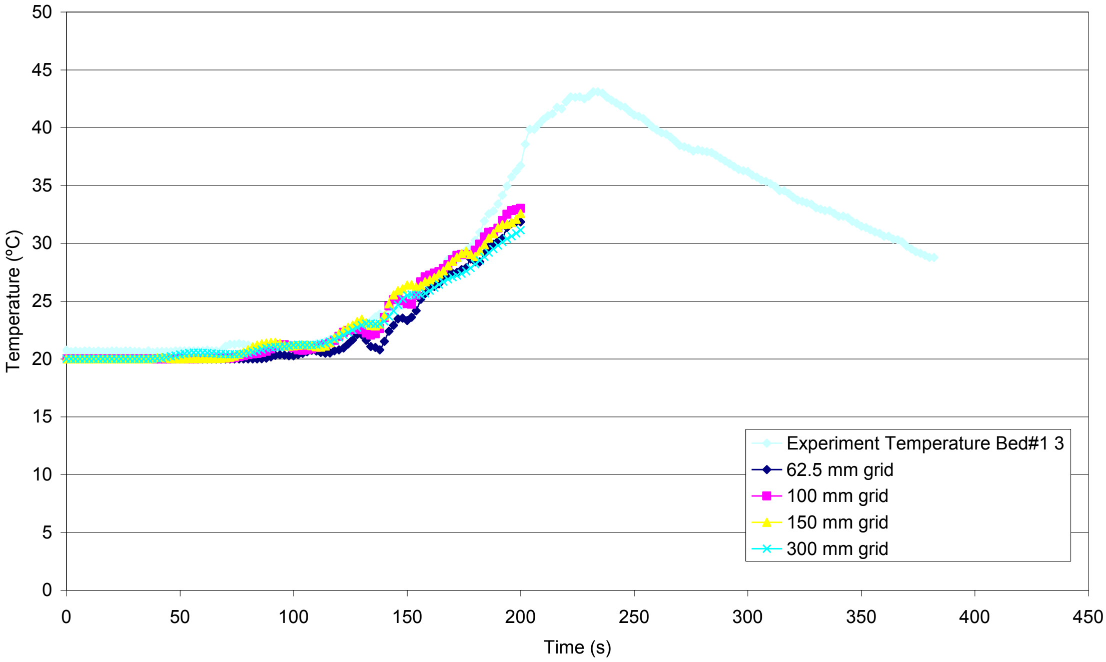
B.9 Additional Results – 0.10 kg/kg Soot Yield – Scenarios 1 to 4



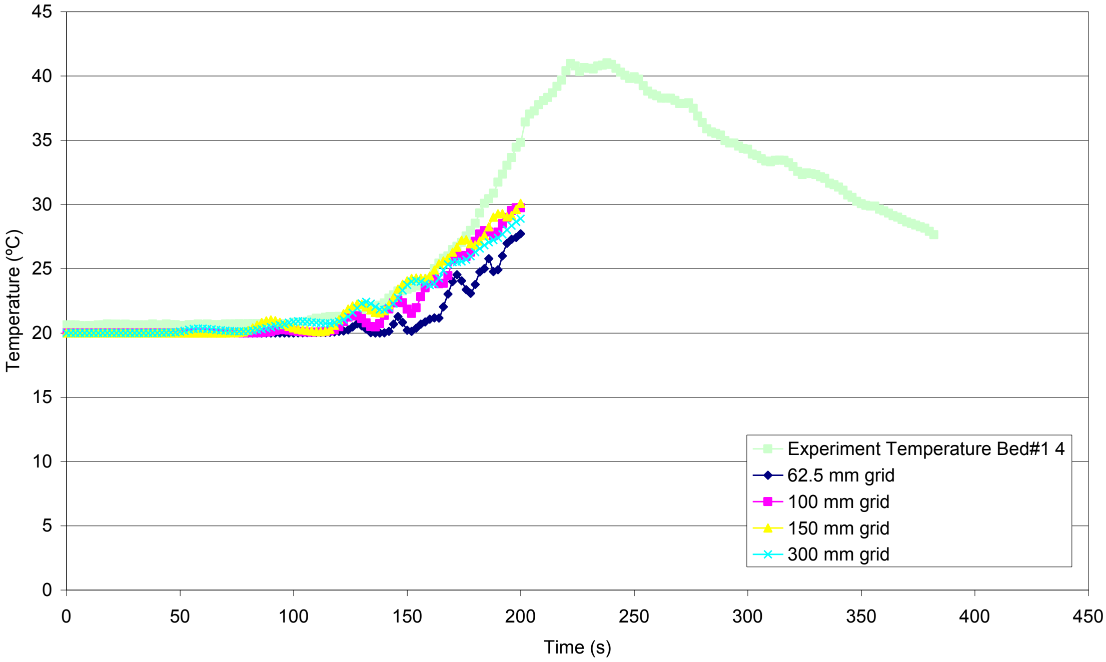
(a)



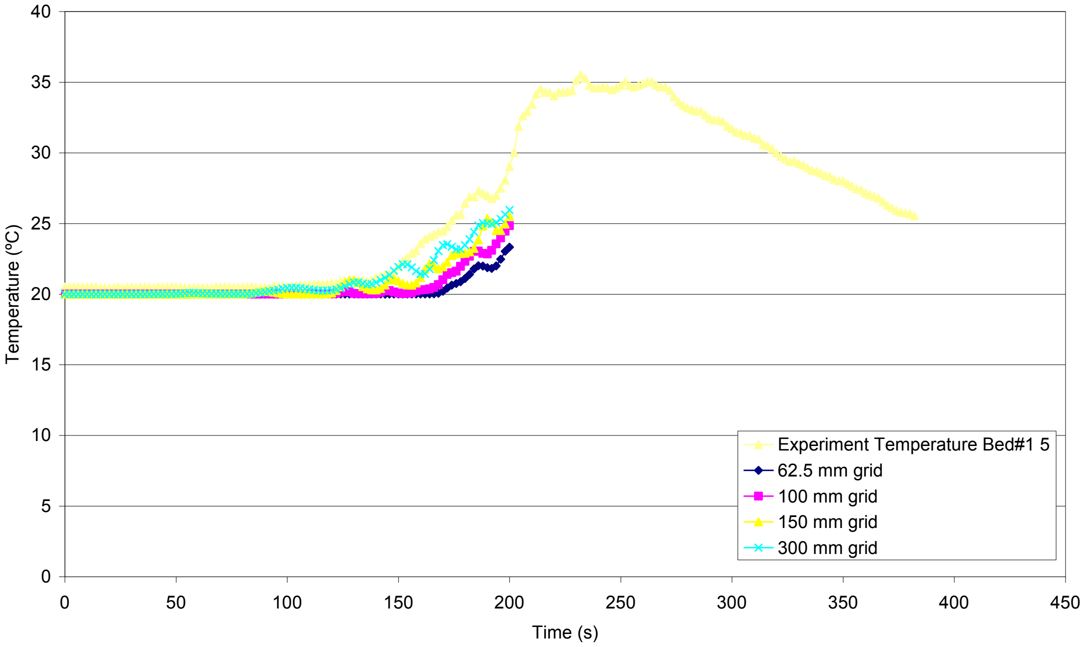
(b)


50
45
40
35
30
25
20
15
10
5
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(c)

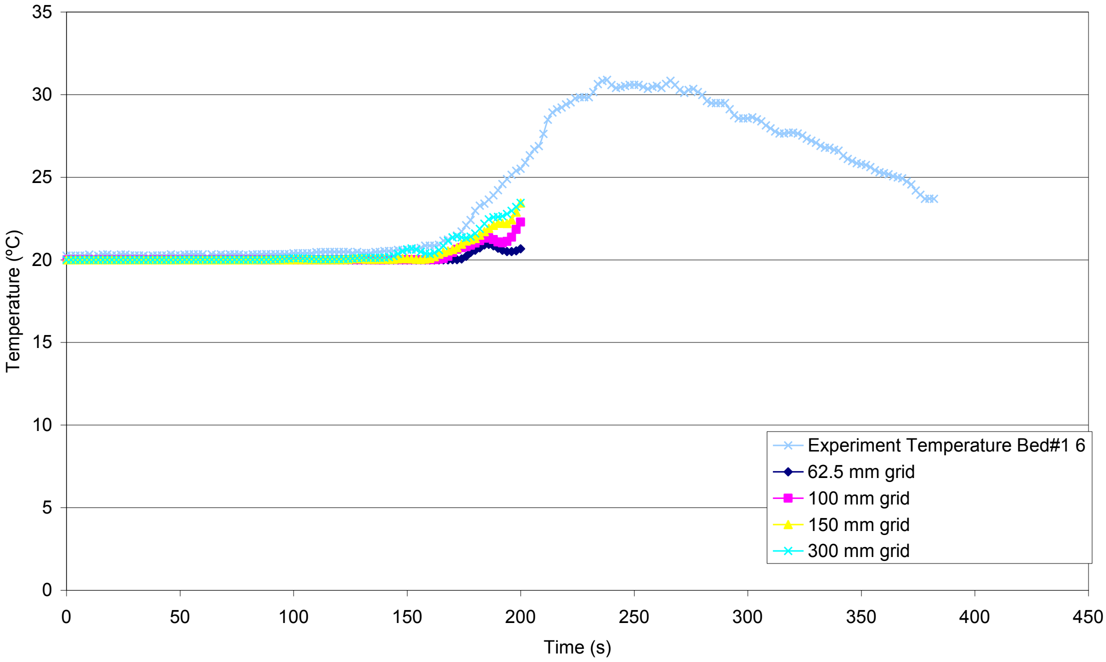

45
40
35
30
25
20
15
10
5
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(d)



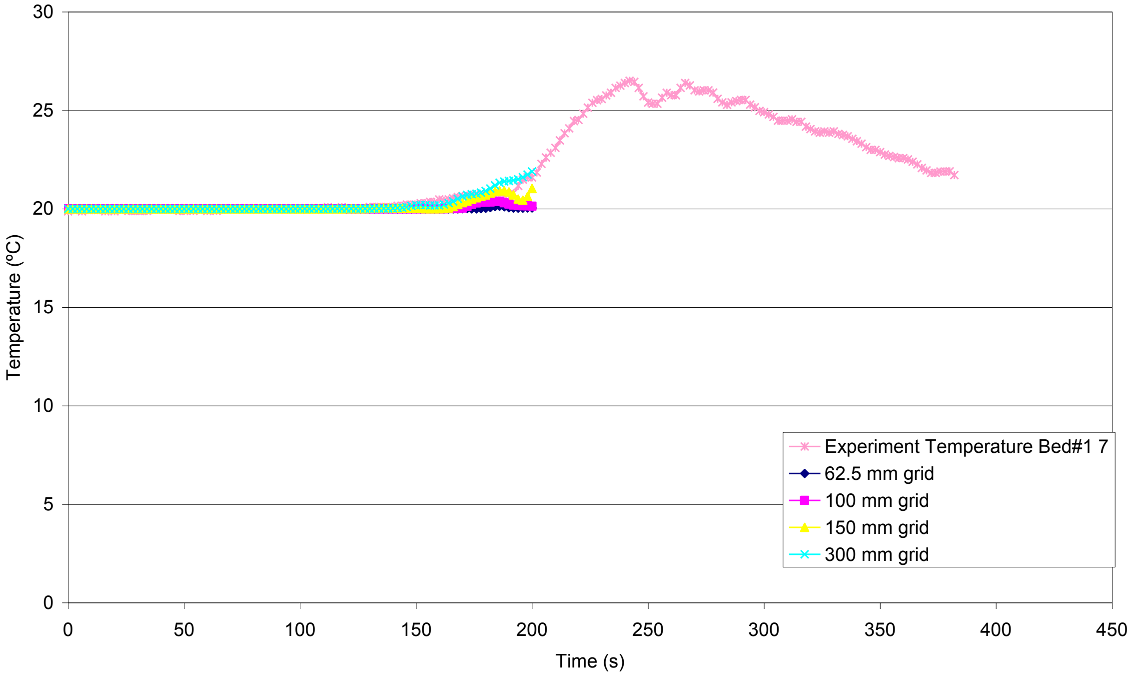
Temperature (ºC)
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)



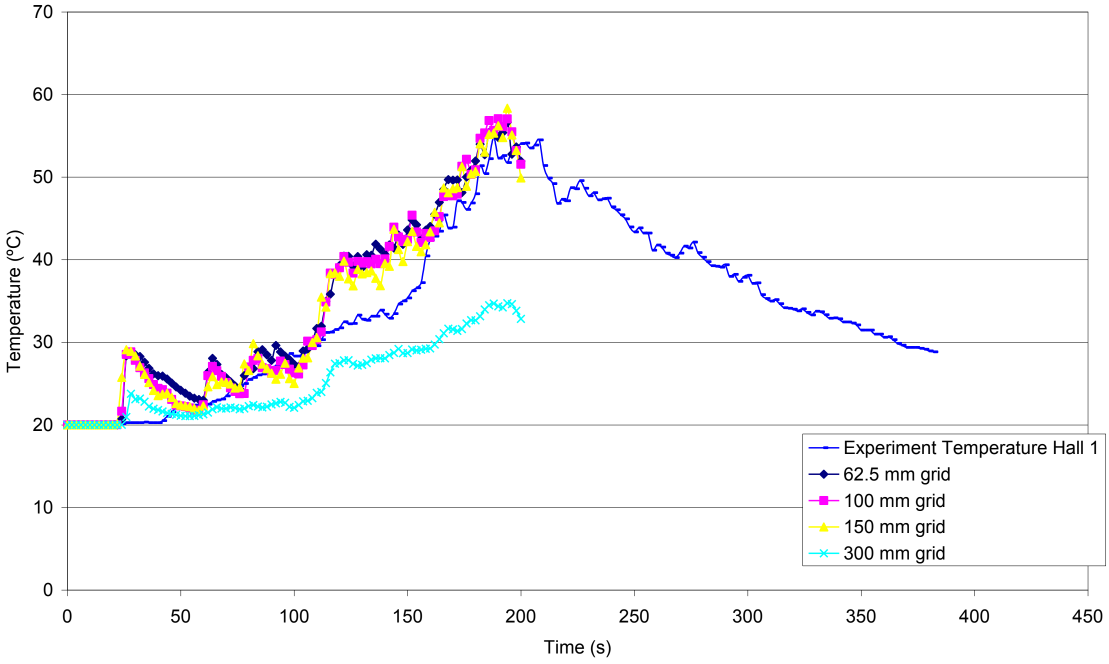
Temperature (ºC)
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 6
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(f)

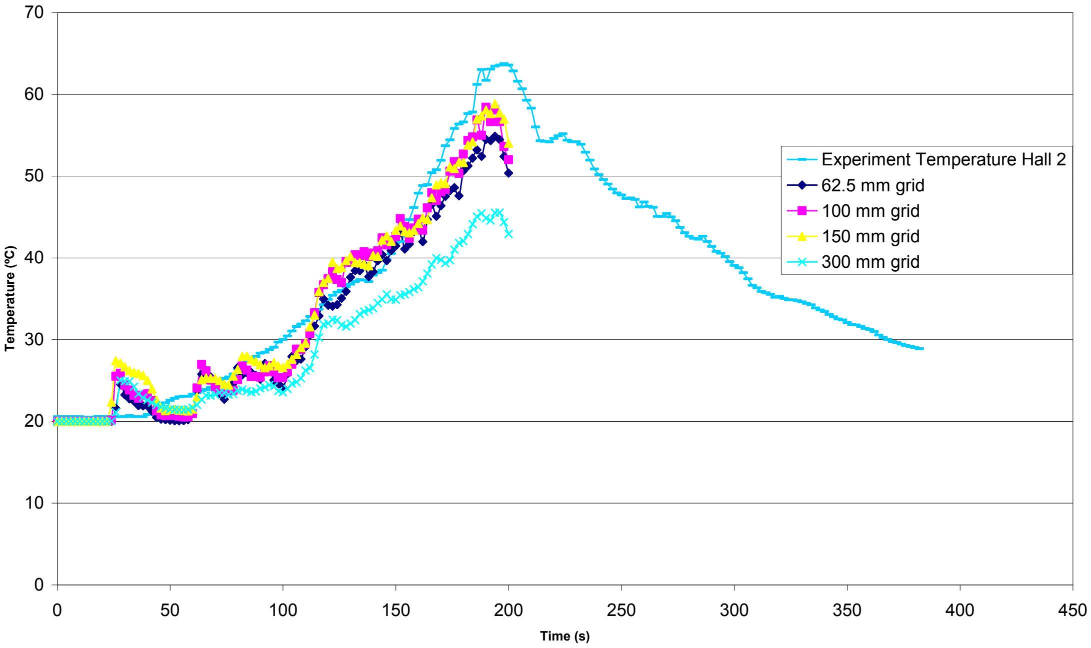


(g)

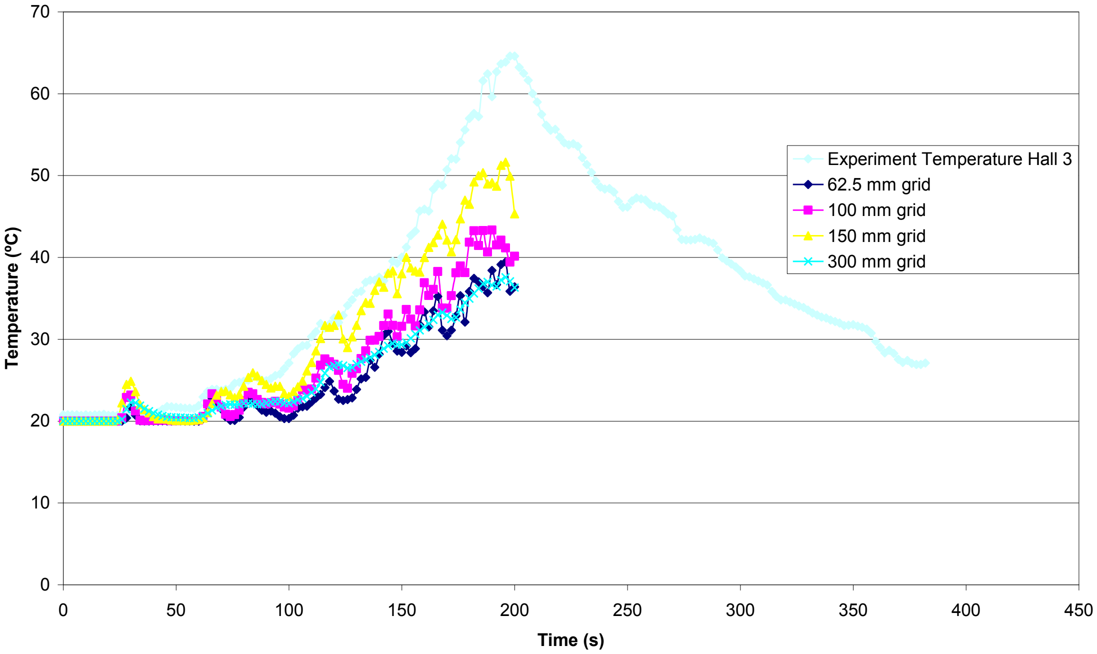
Figure 24. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #1 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



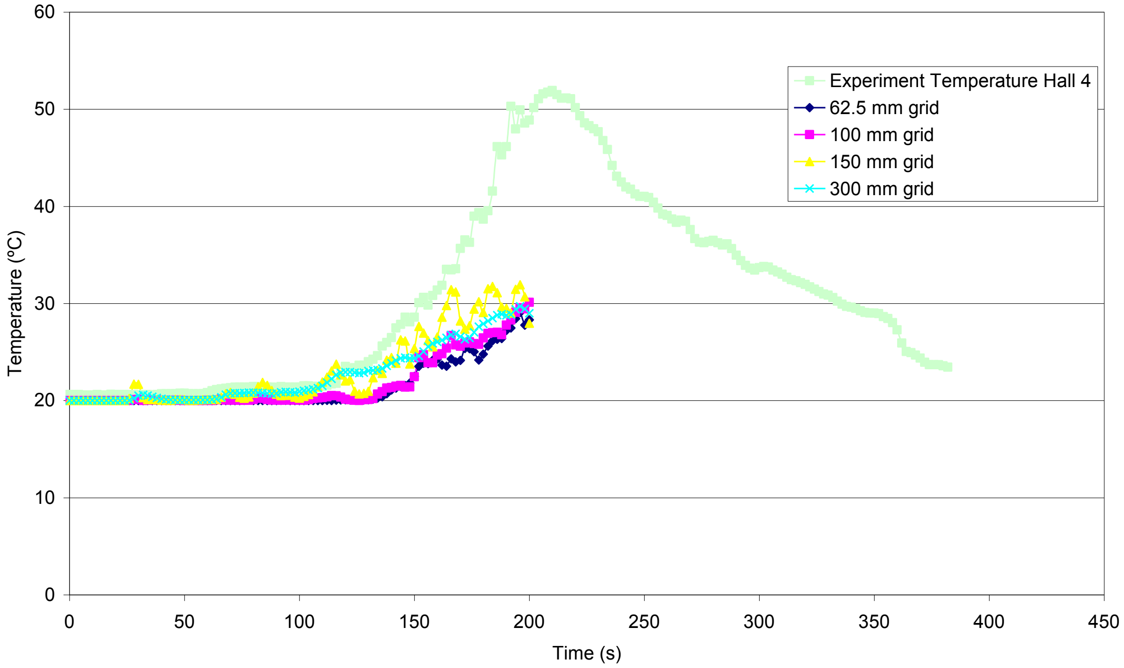
(a)


70
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(b)

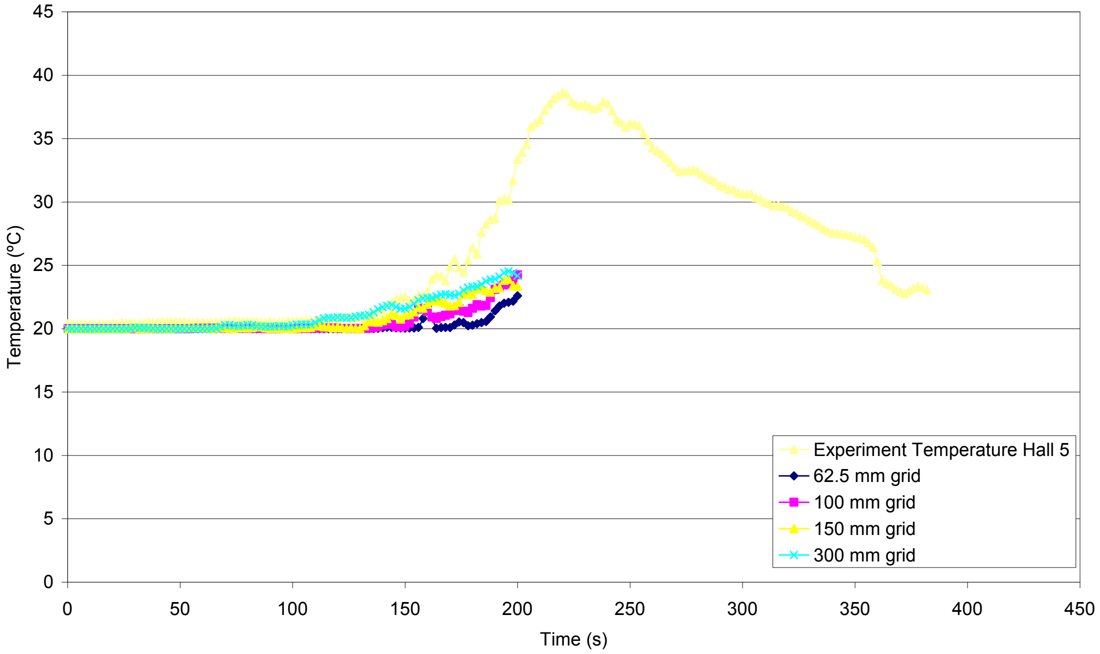

70
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(c)



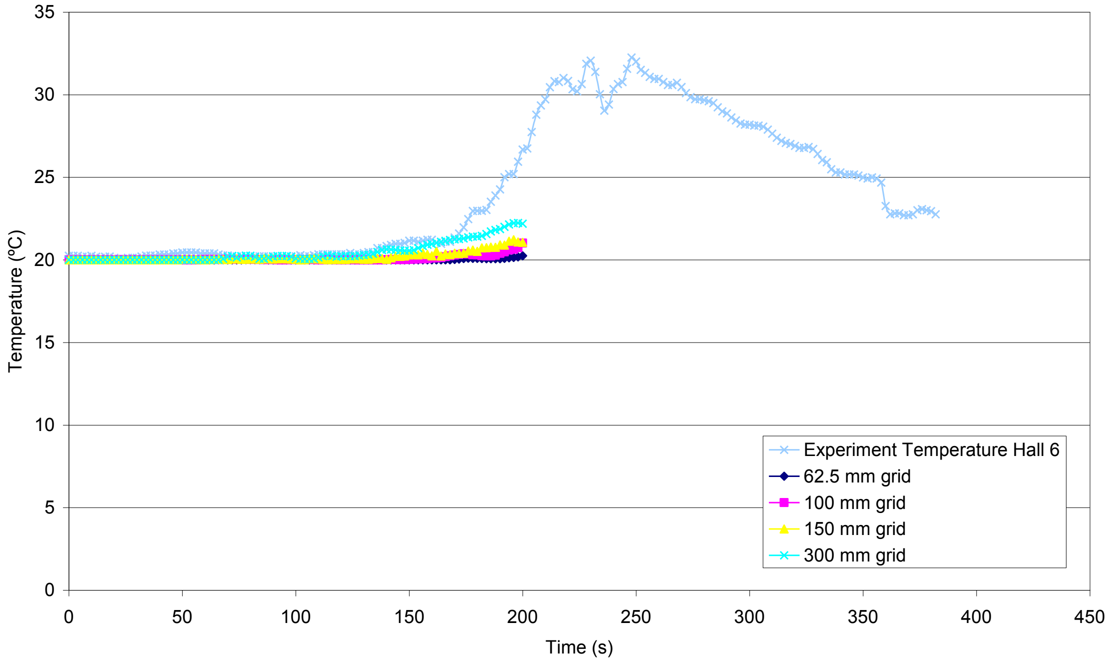
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(d)

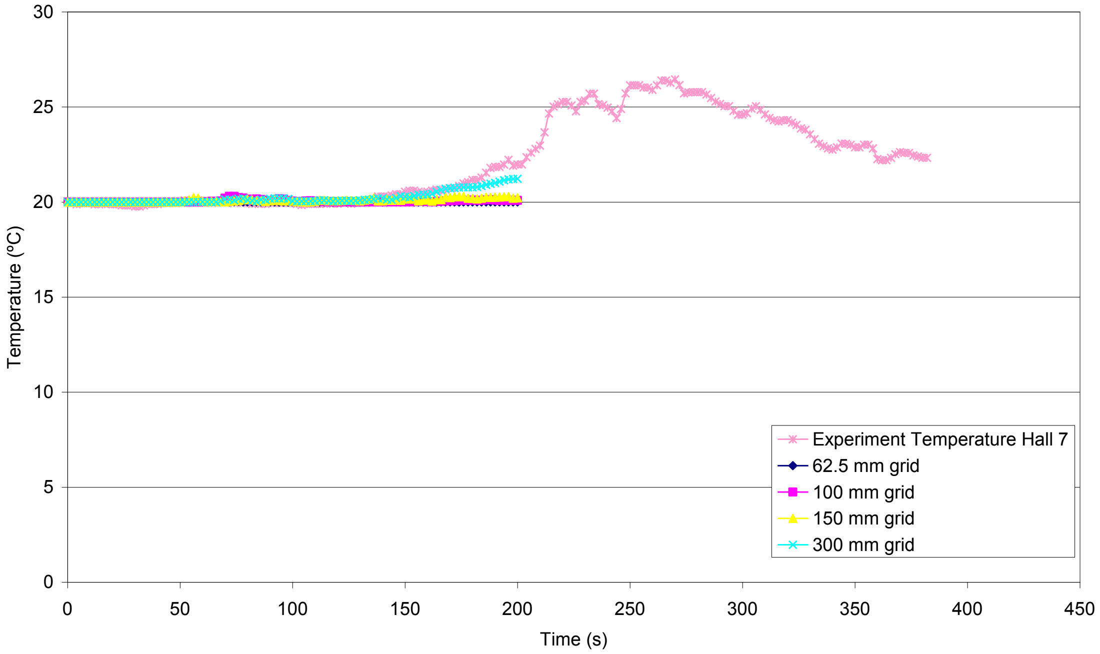


45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

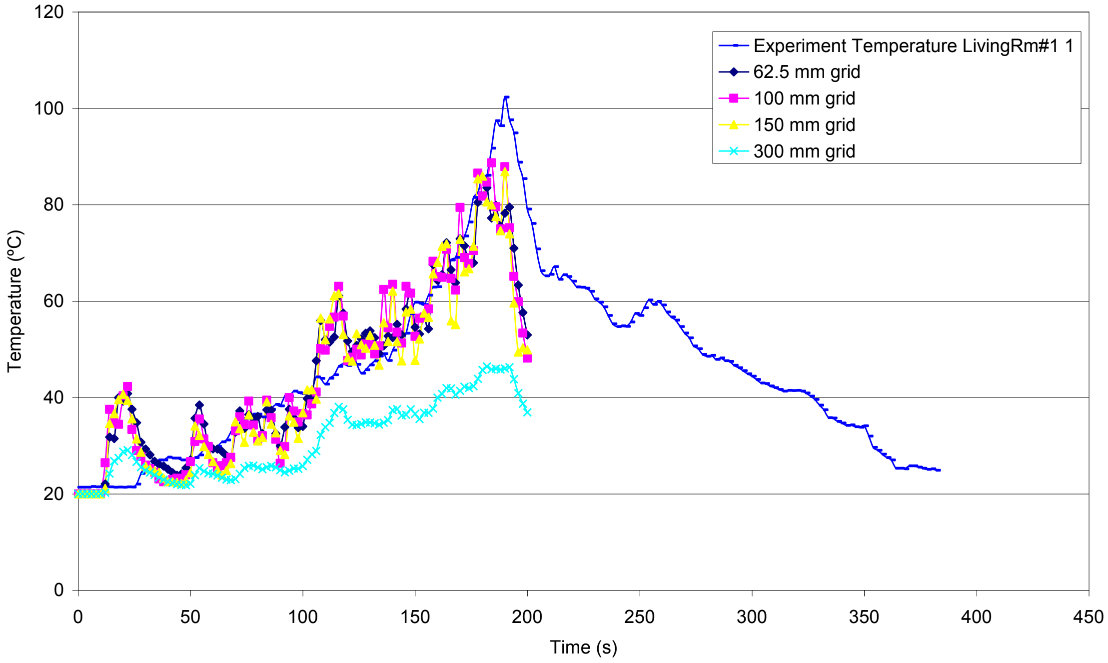


(f)

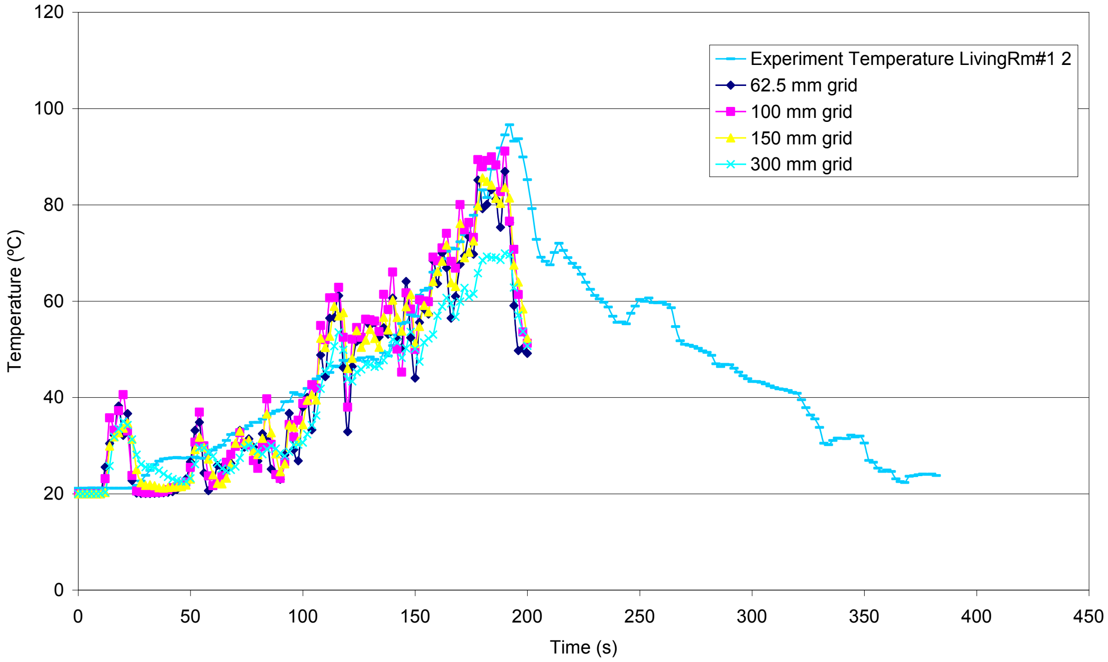


(g)

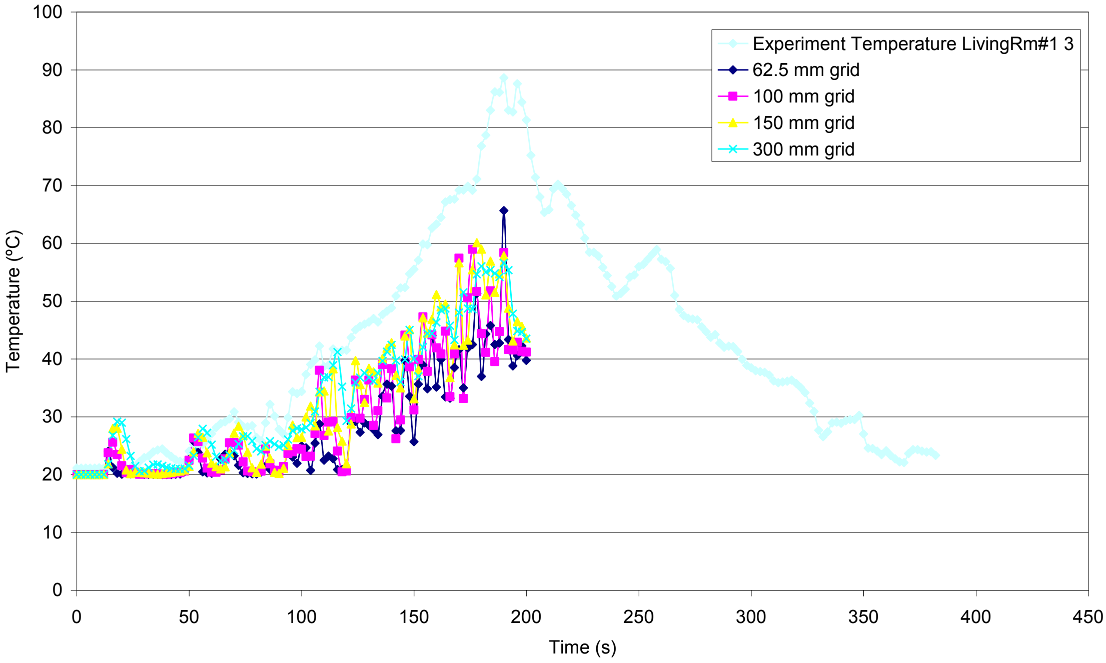
Figure 25. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Hall temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


Experiment Temperature LivingRm#1 1
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid
Temperature (°C)
Time (s)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400
450

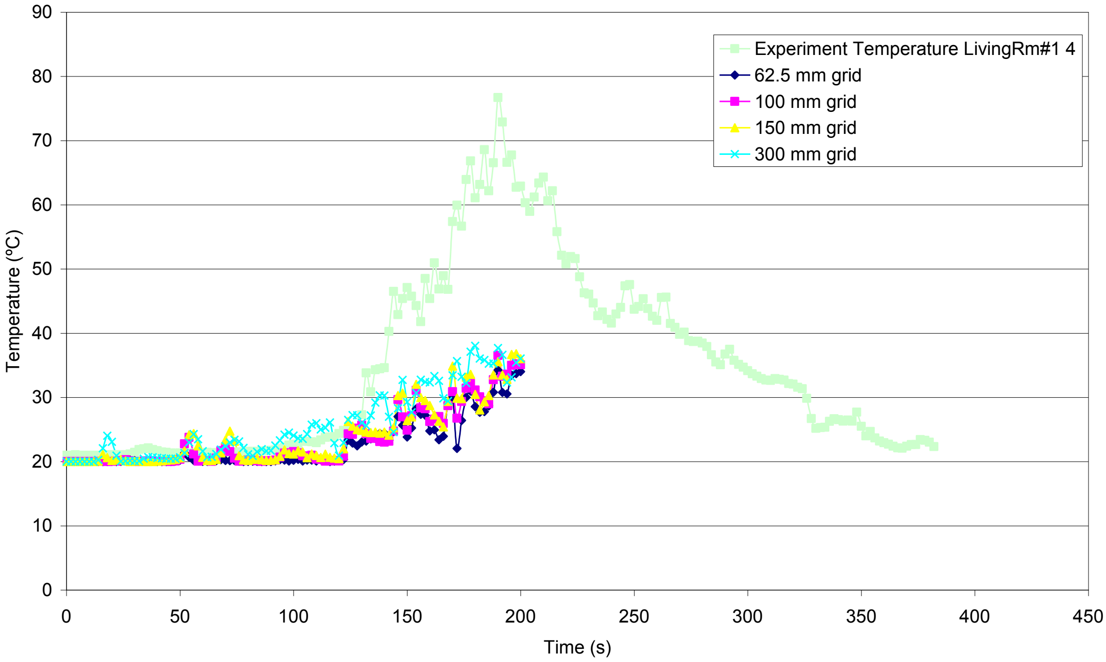
(a)


Experiment Temperature LivingRm#1 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid
Temperature (°C)
Time (s)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400
450

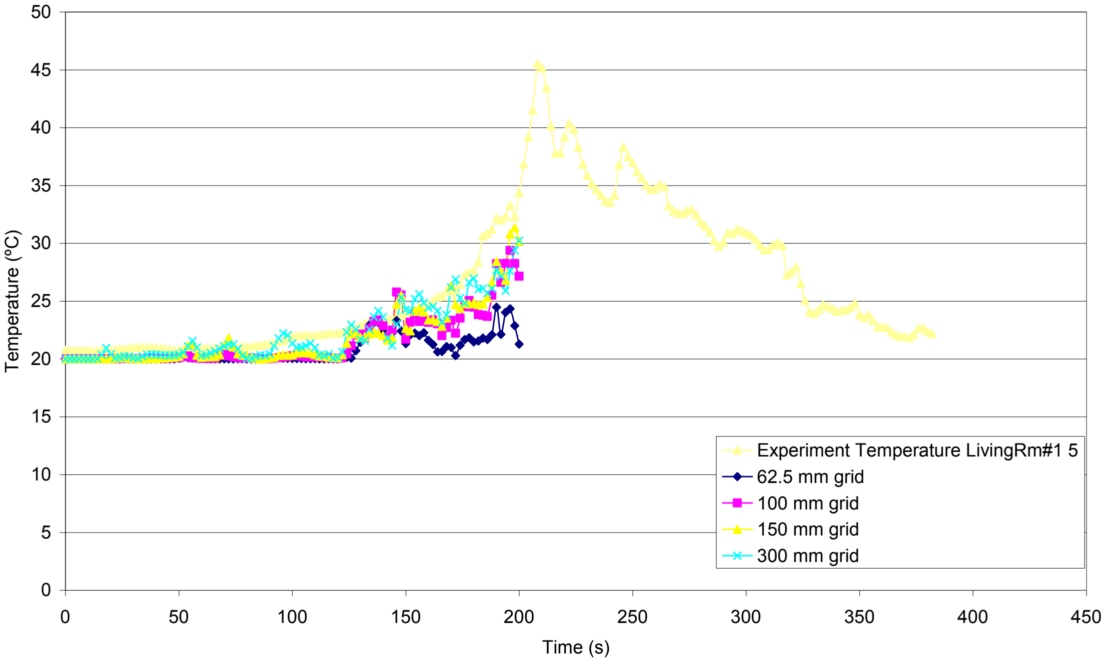
(b)


Temperature (°C)
Time (s)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#1 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

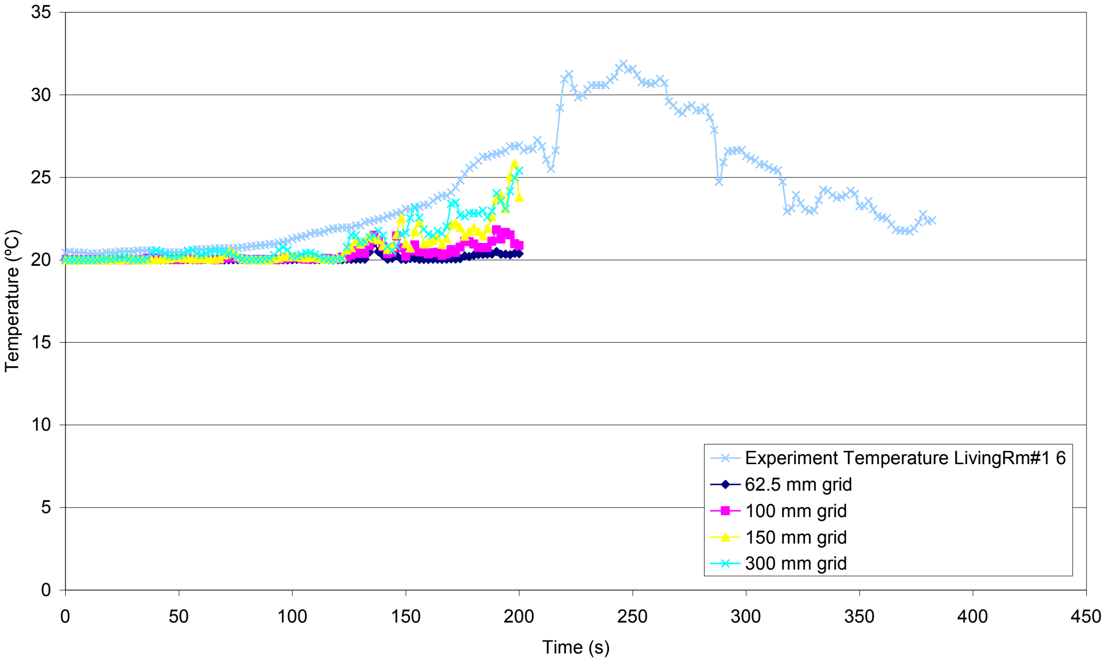
(c)


Temperature (°C)
Time (s)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#1 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

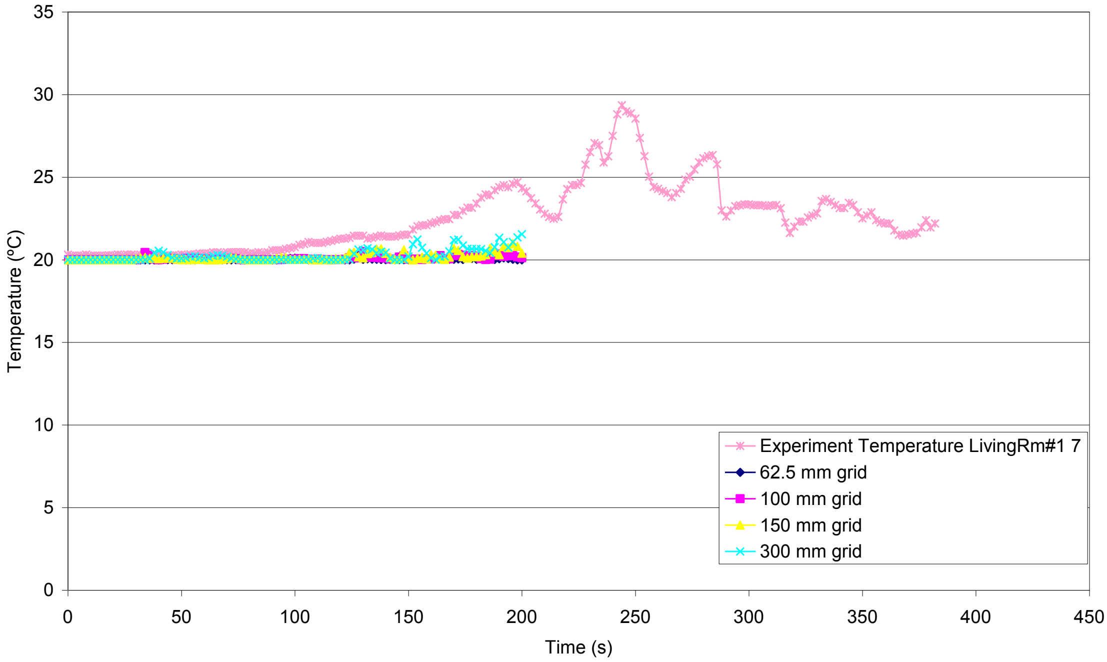
(d)


Temperature (°C)
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#1 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

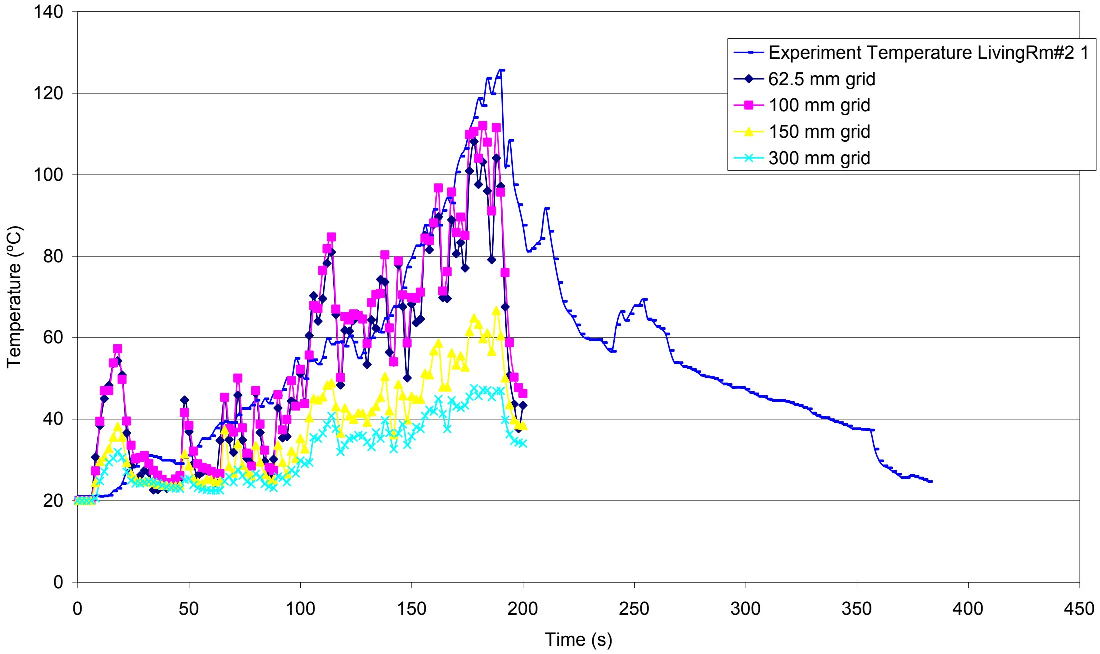

Temperature (°C)
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#1 6
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(f)

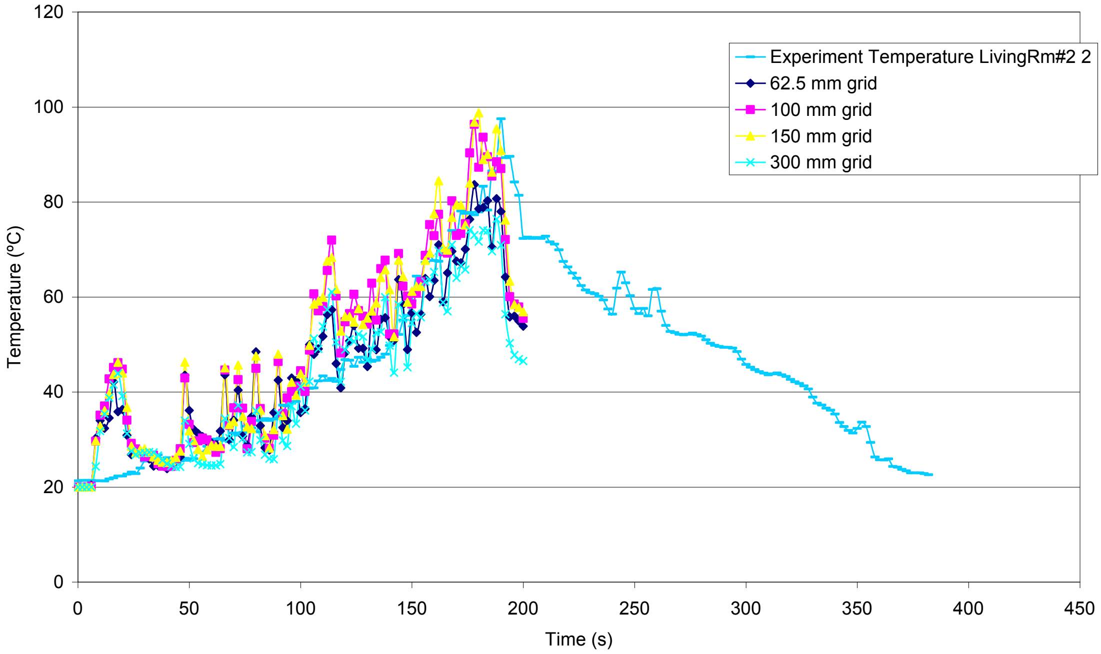


(g)

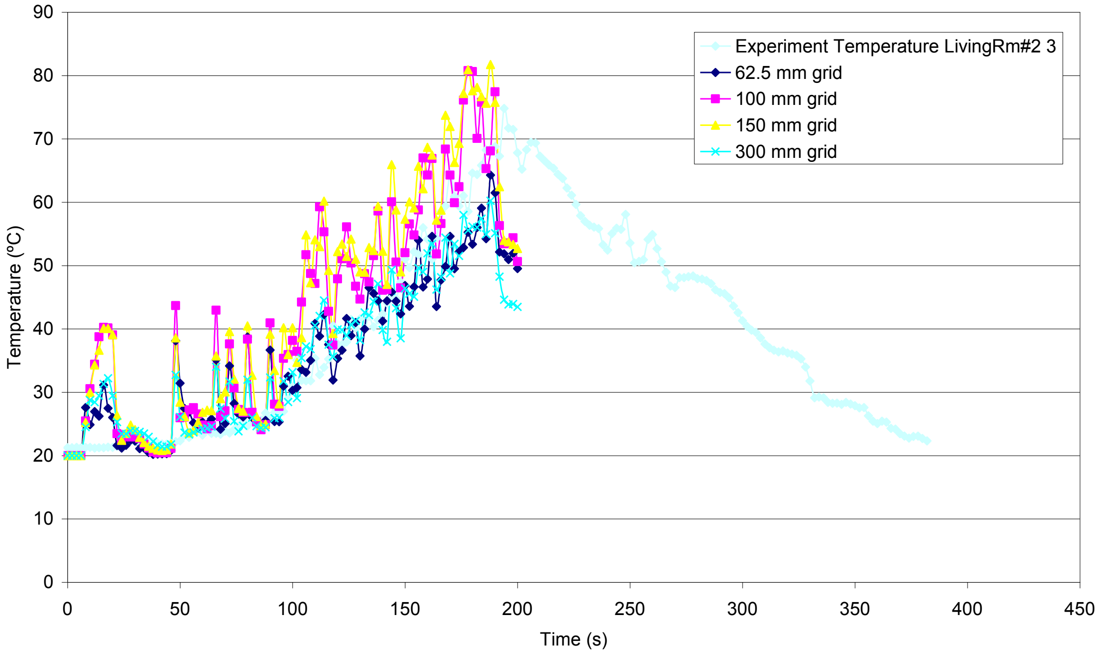
Figure 26. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #1 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



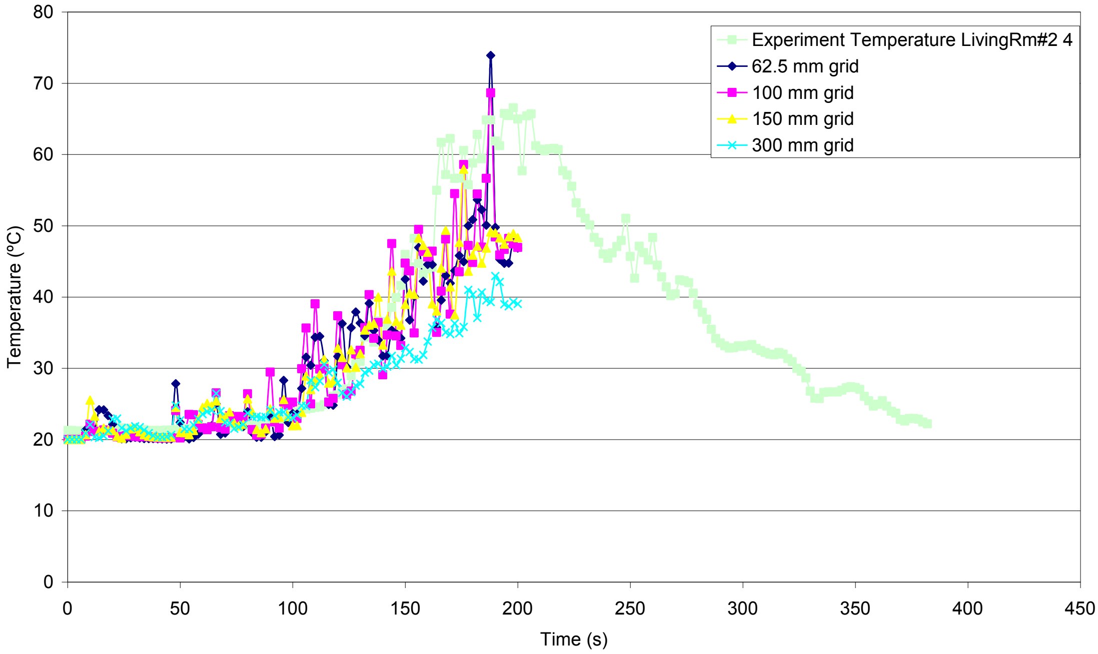
(a)


Temperature (ºC)
Time (s)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(b)


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

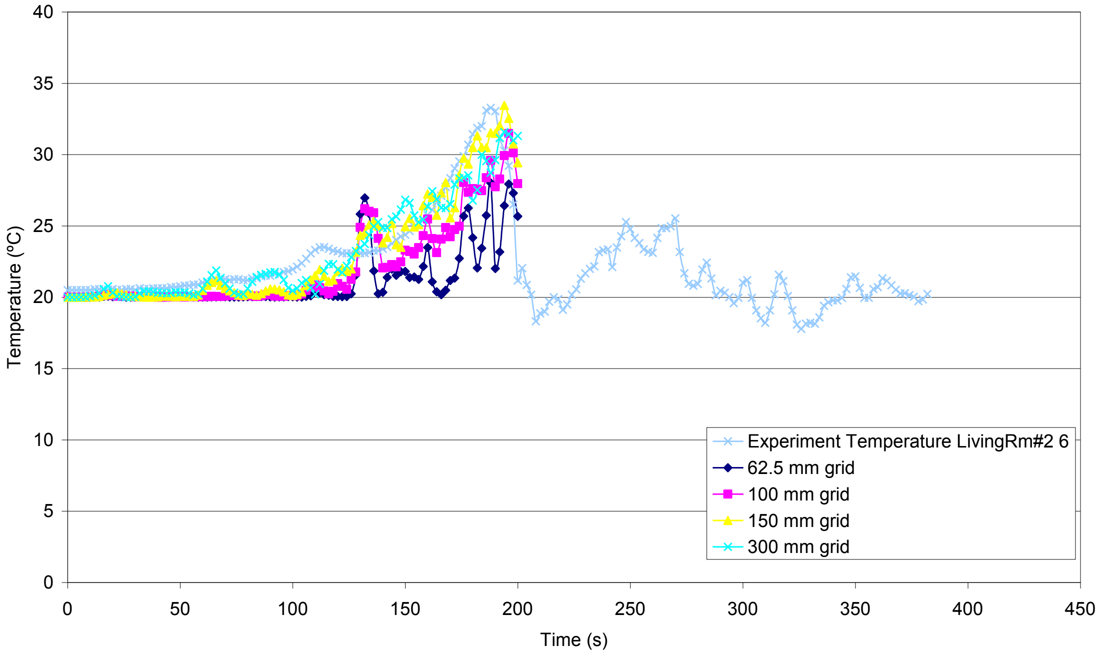
(c)


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

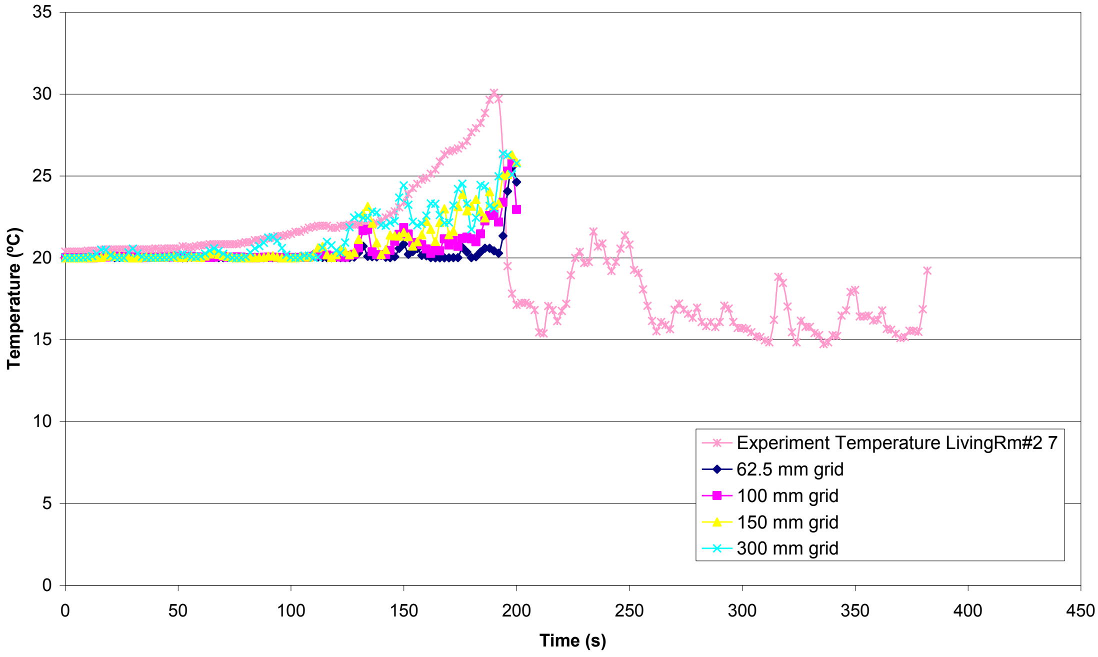
(d)


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

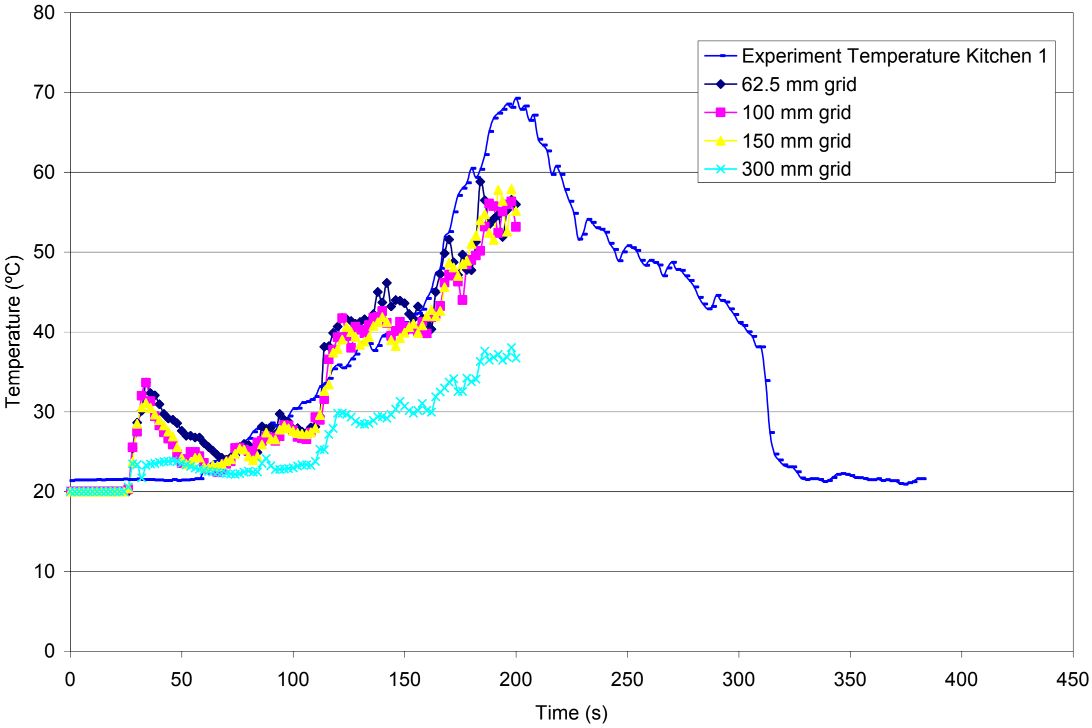


(f)

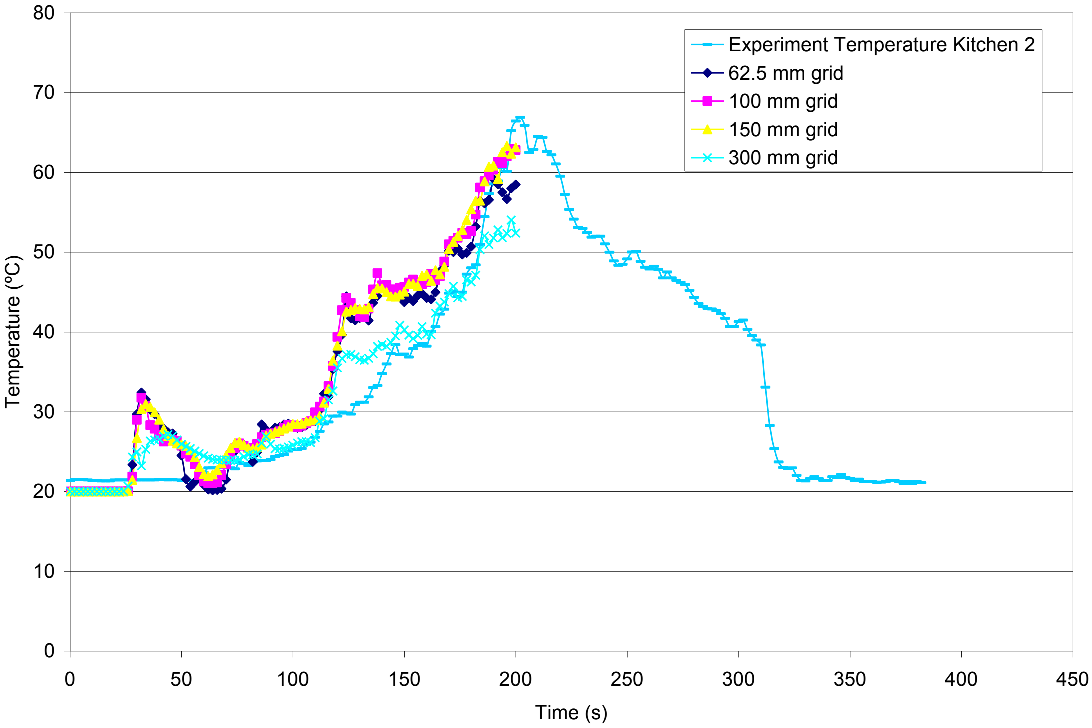


(g)

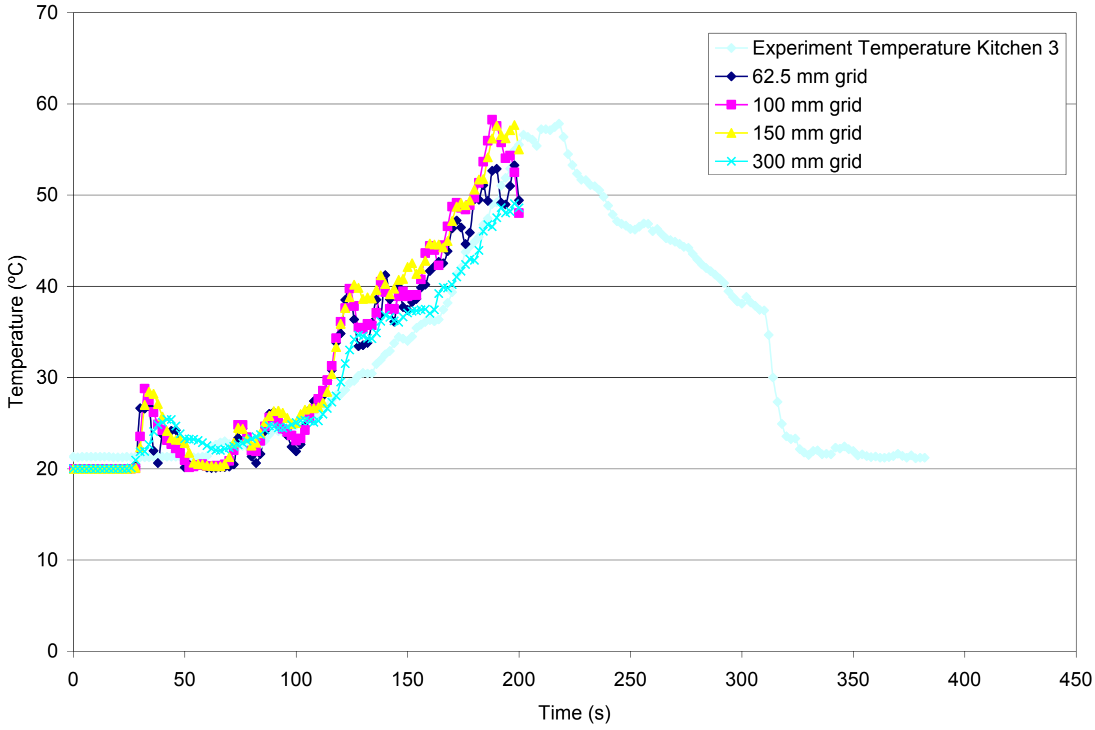
Figure 27. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #2 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


Experiment Temperature Kitchen 1
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid
Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450

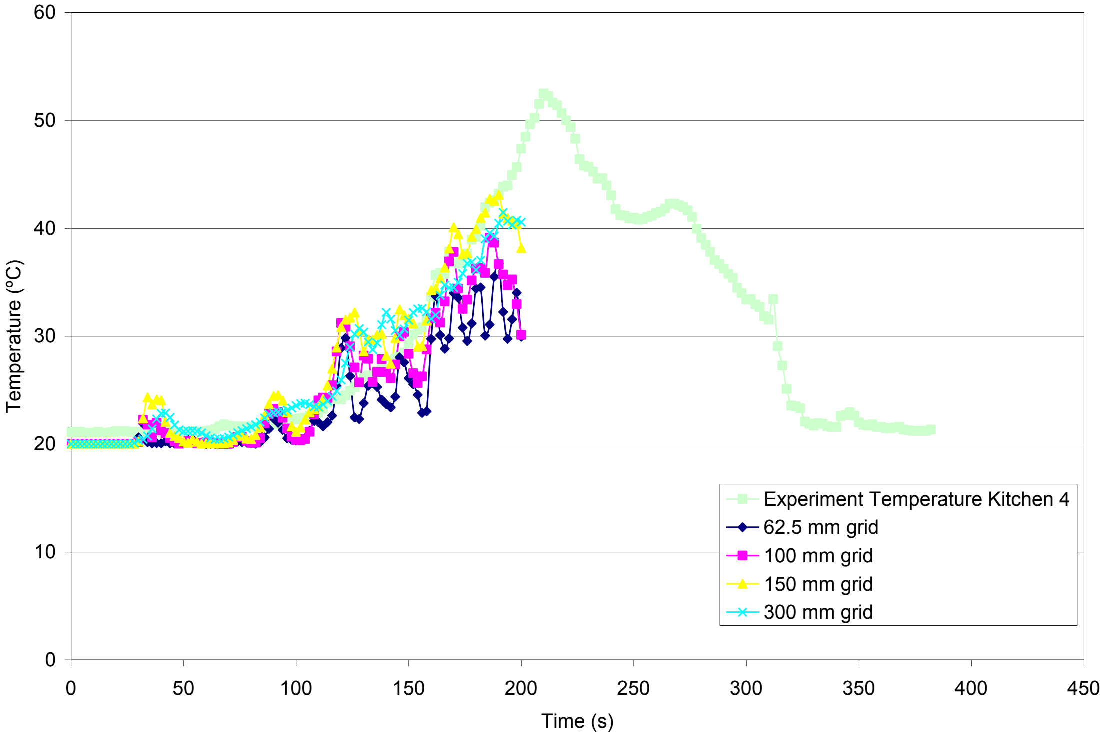
(a)


Experiment Temperature Kitchen 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid
Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450

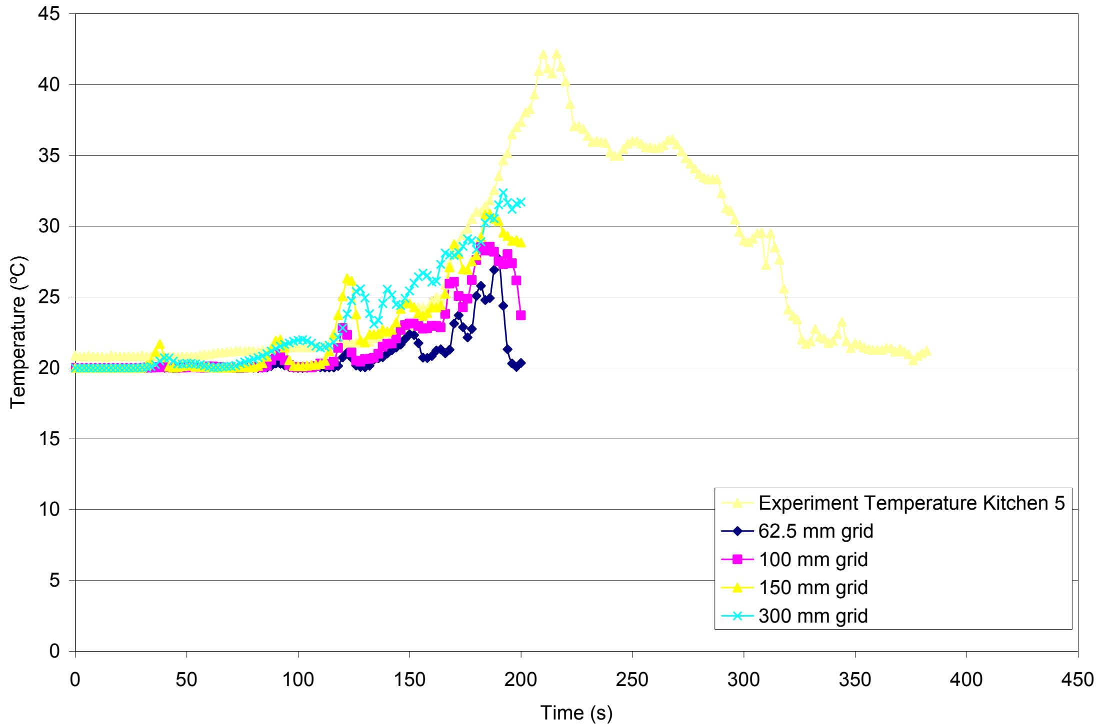
(b)


70
60
50
40
30
20
10
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

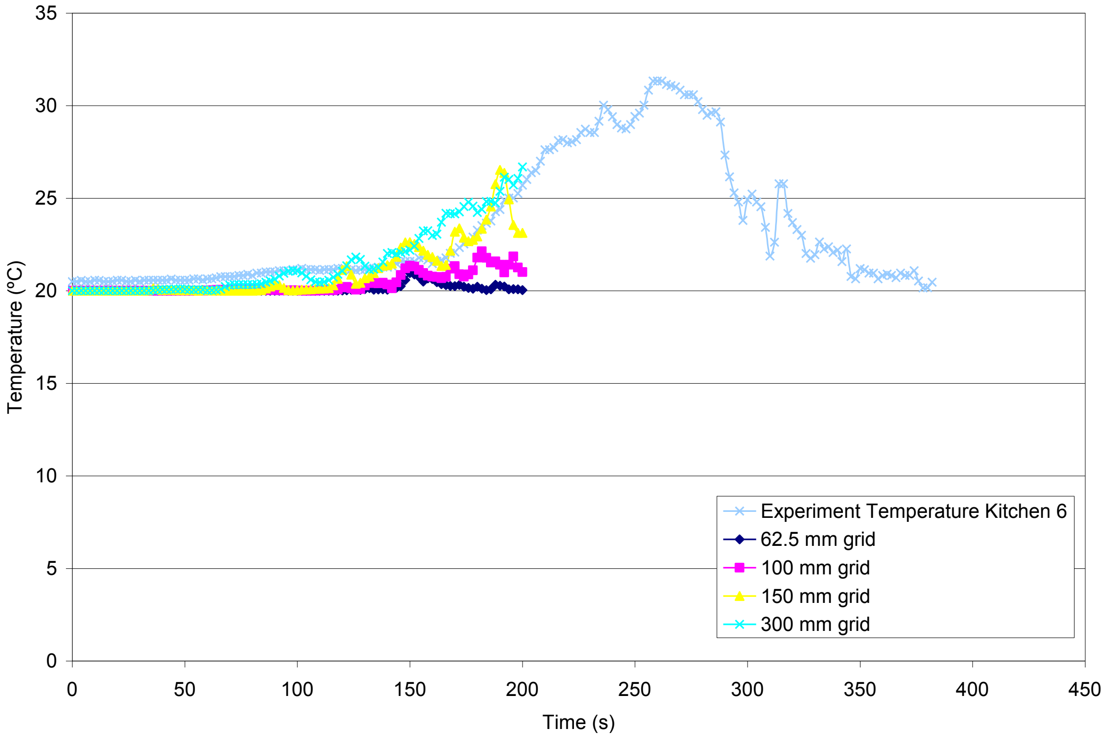
(c)


60
50
40
30
20
10
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

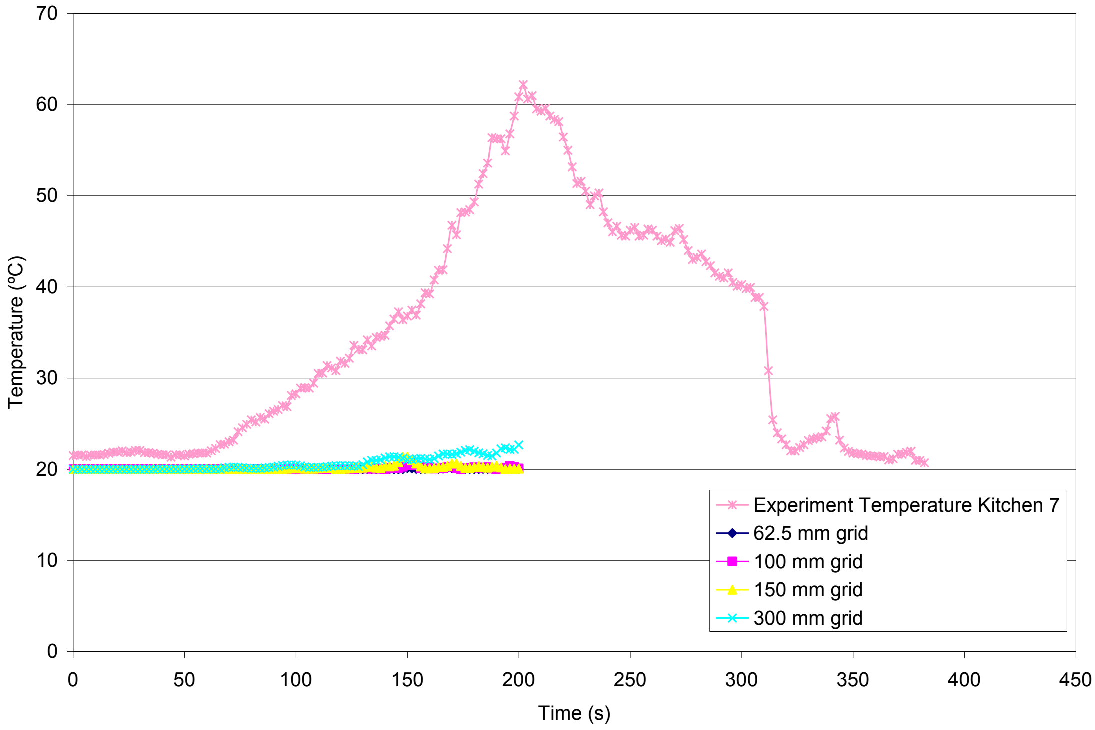
(d)


45
40
35
30
25
20
15
10
5
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

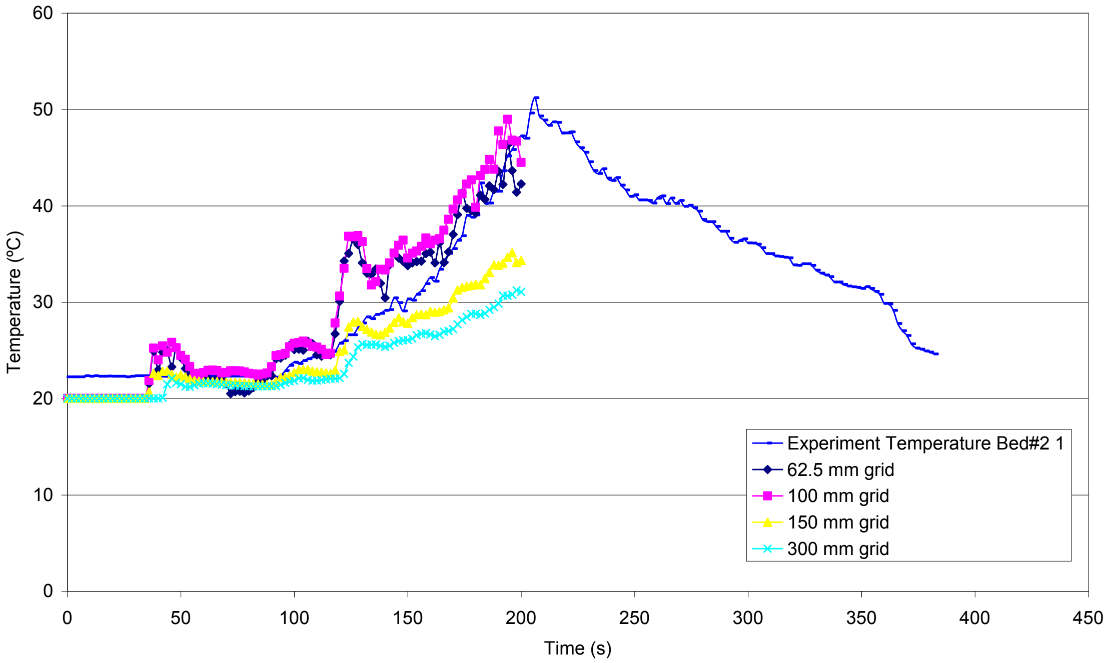

35
30
25
20
15
10
5
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 6
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(f)

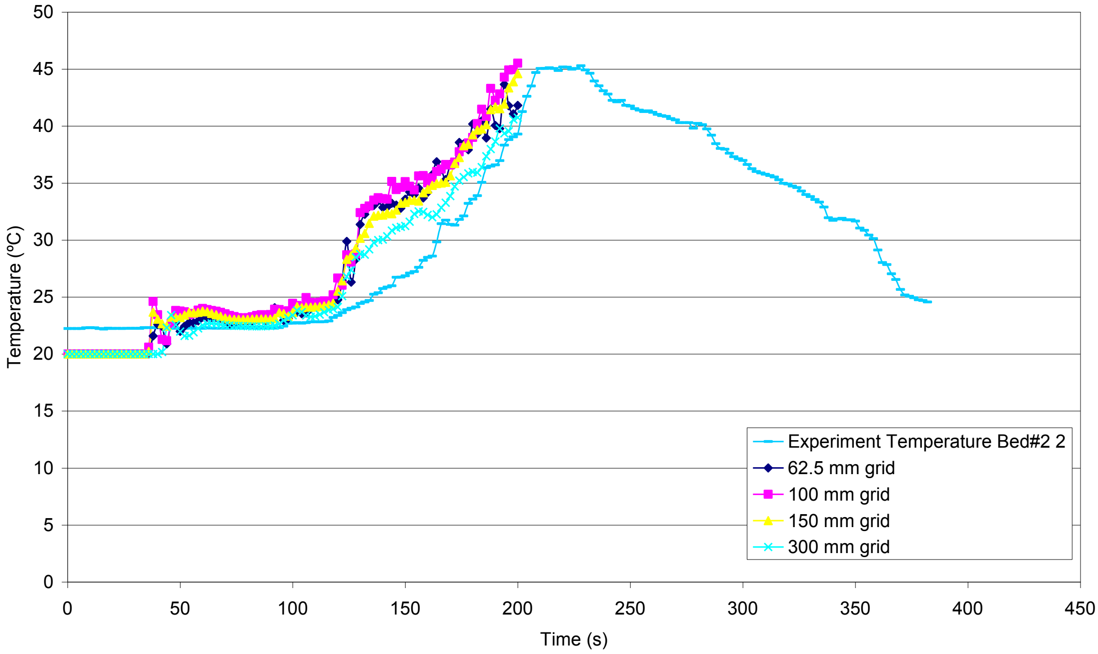


(g)

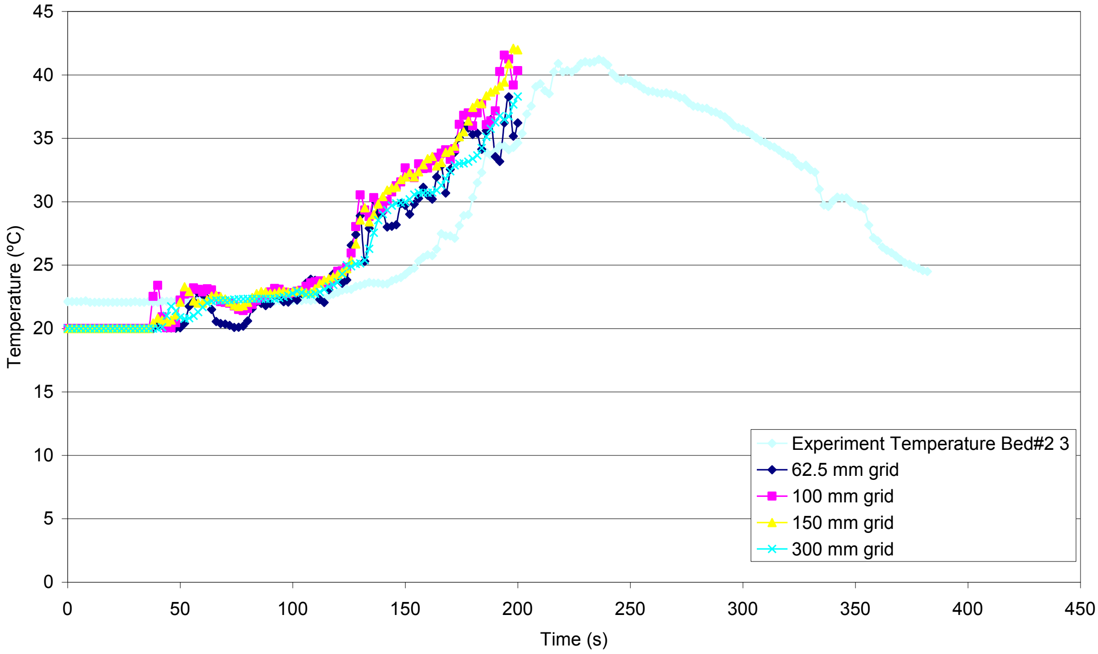
Figure 28. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Kitchen temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



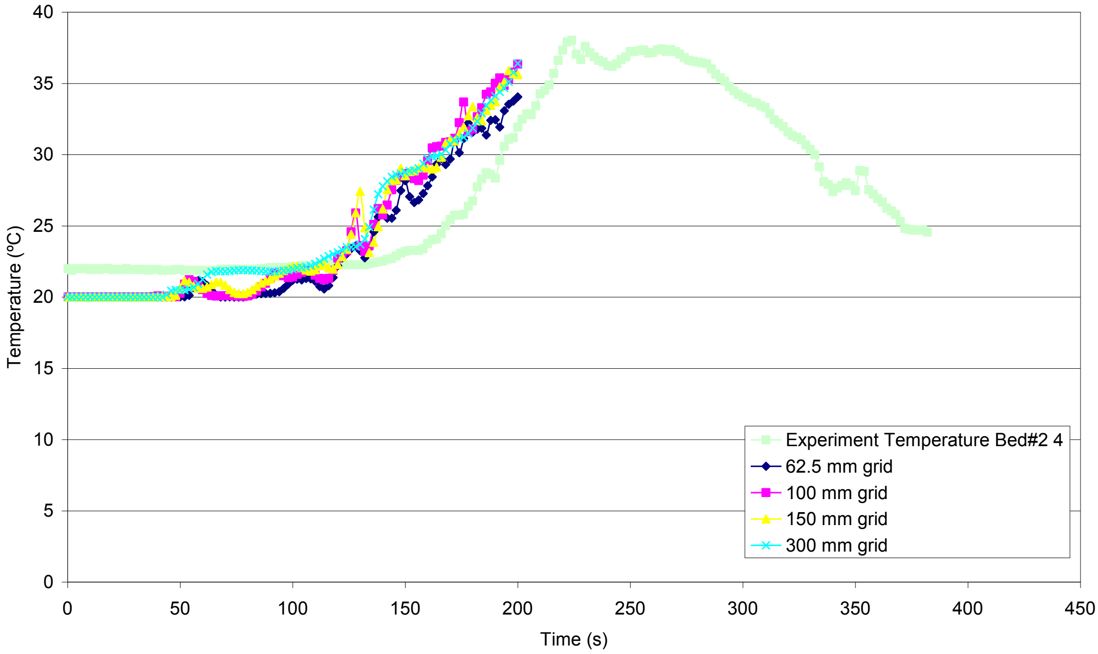
(a)


50
45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

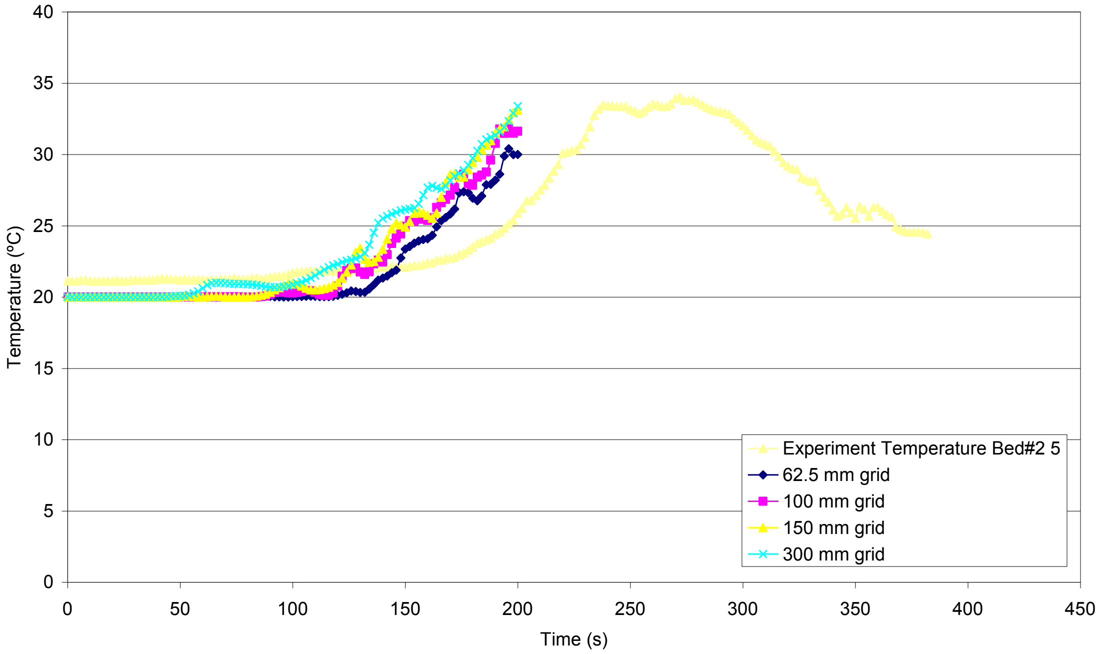
(b)


45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 3
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

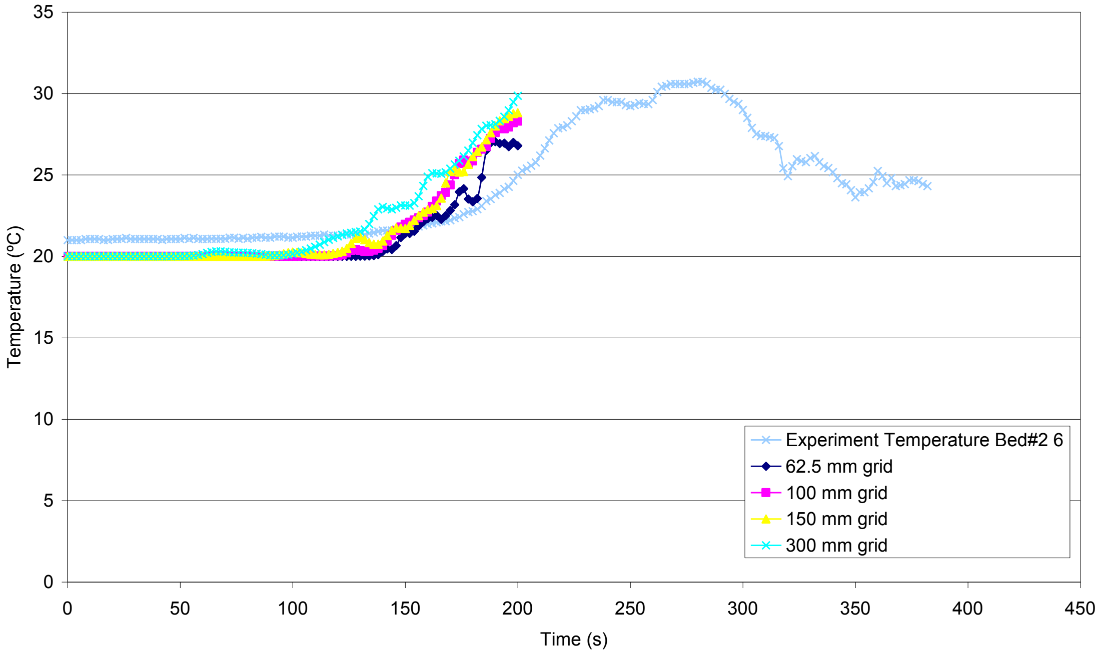
(c)


40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 4
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

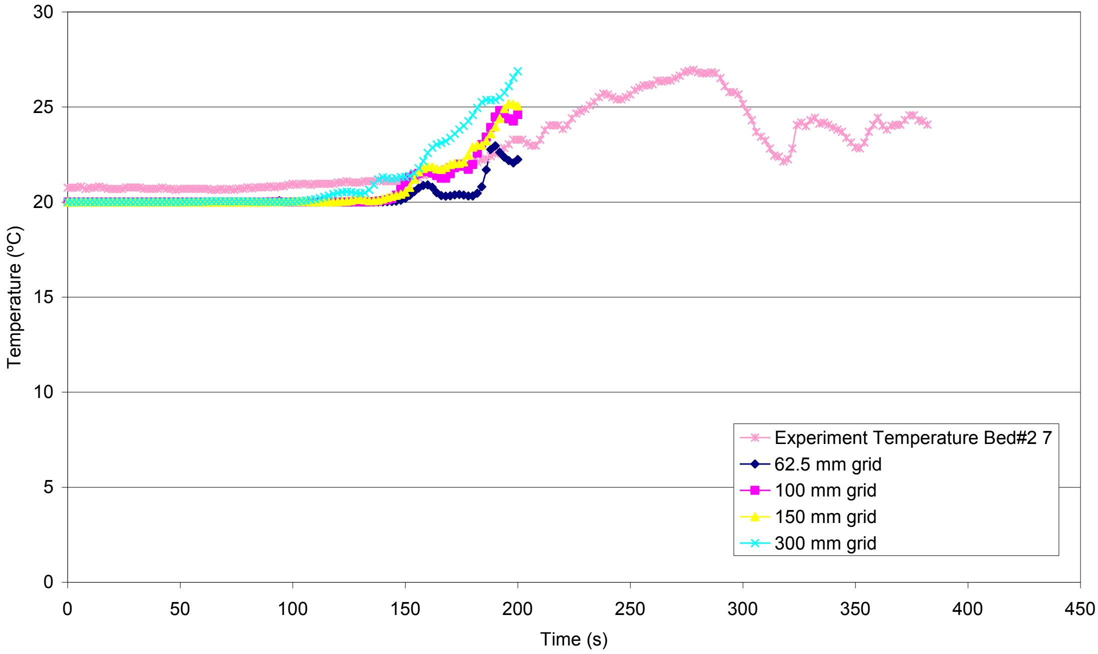
(d)


40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 5
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(e)

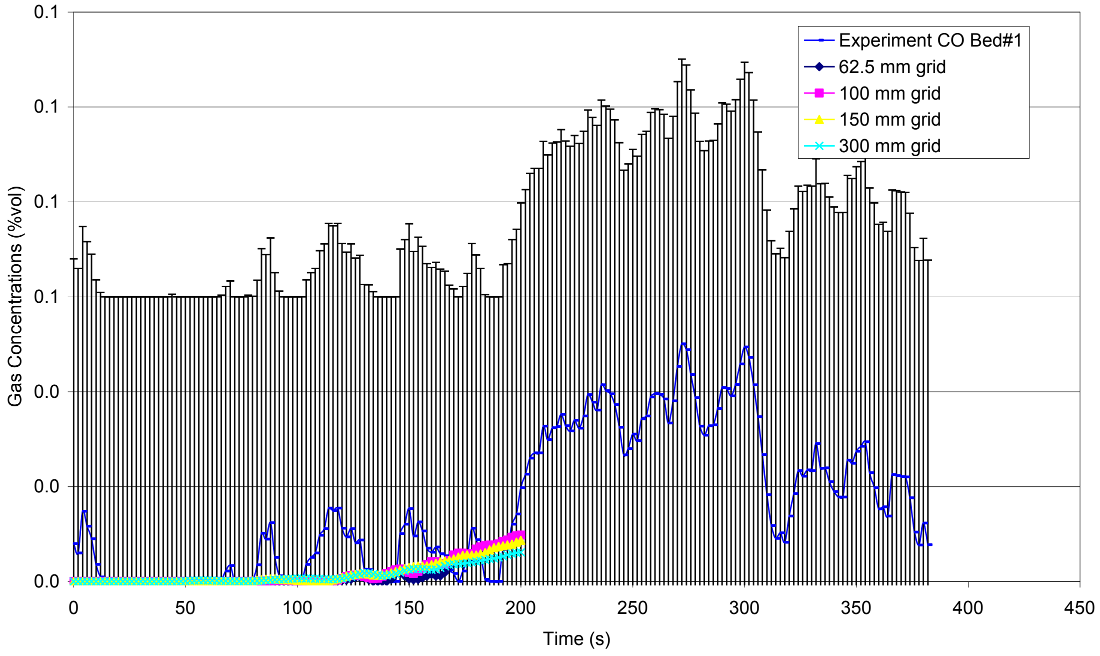


(f)



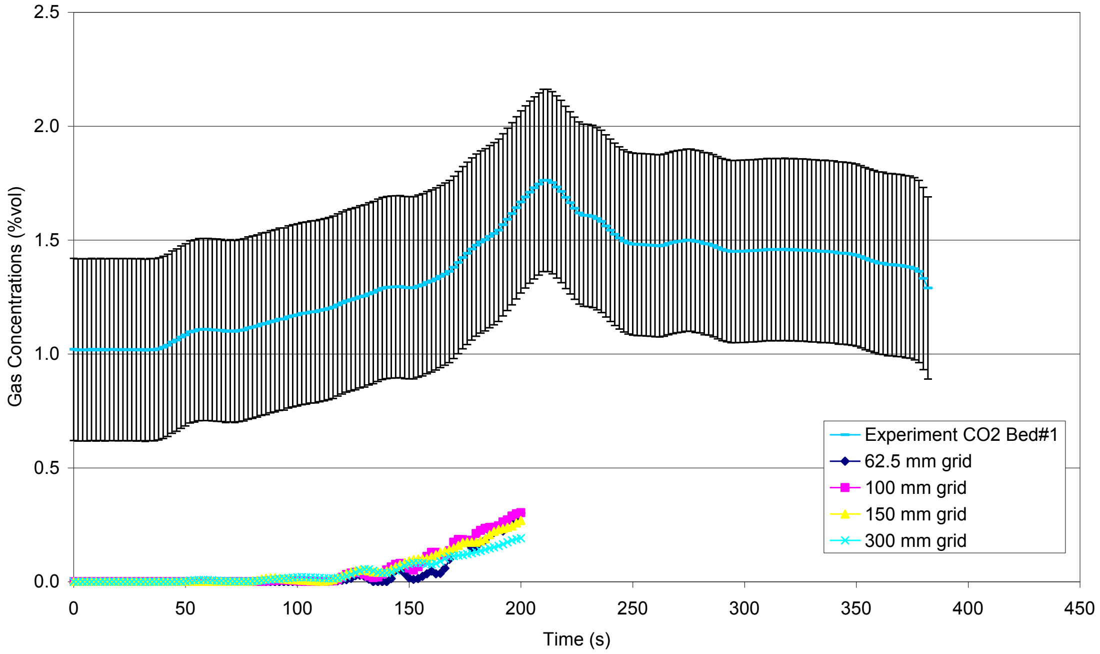
(g)

Figure 29. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #2 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



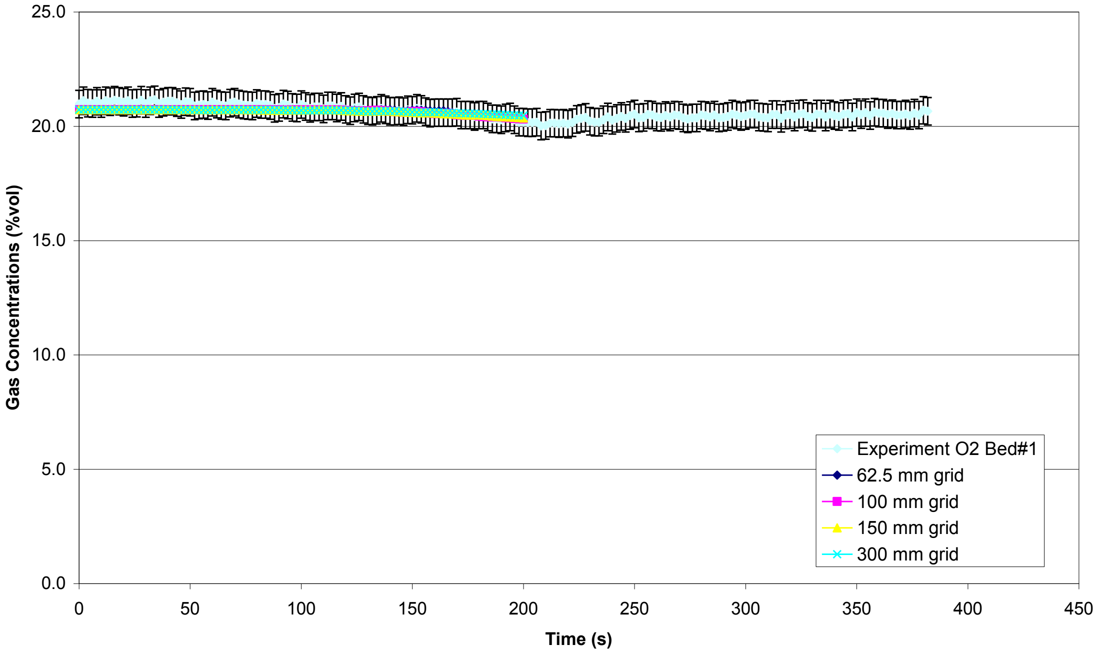
0.1
0.1
0.1
0.1
0.0
0.0
0.0
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Bed#1
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(a)



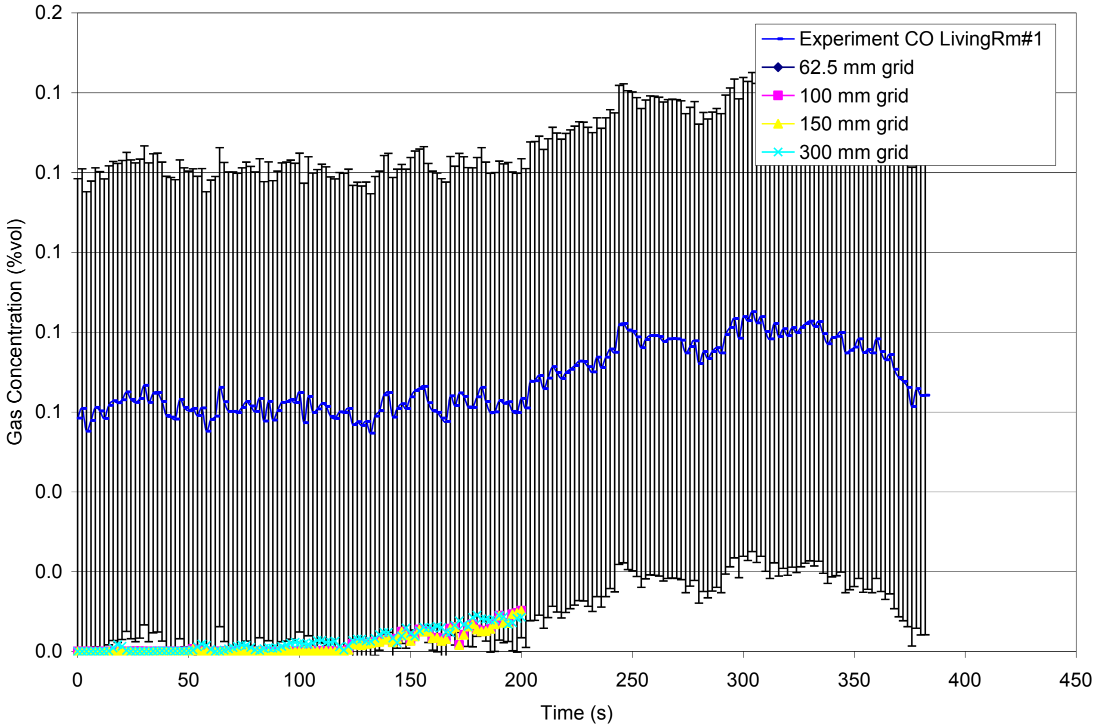
2.5
2.0
1.5
1.0
0.5
0.0
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Bed#1
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(b)

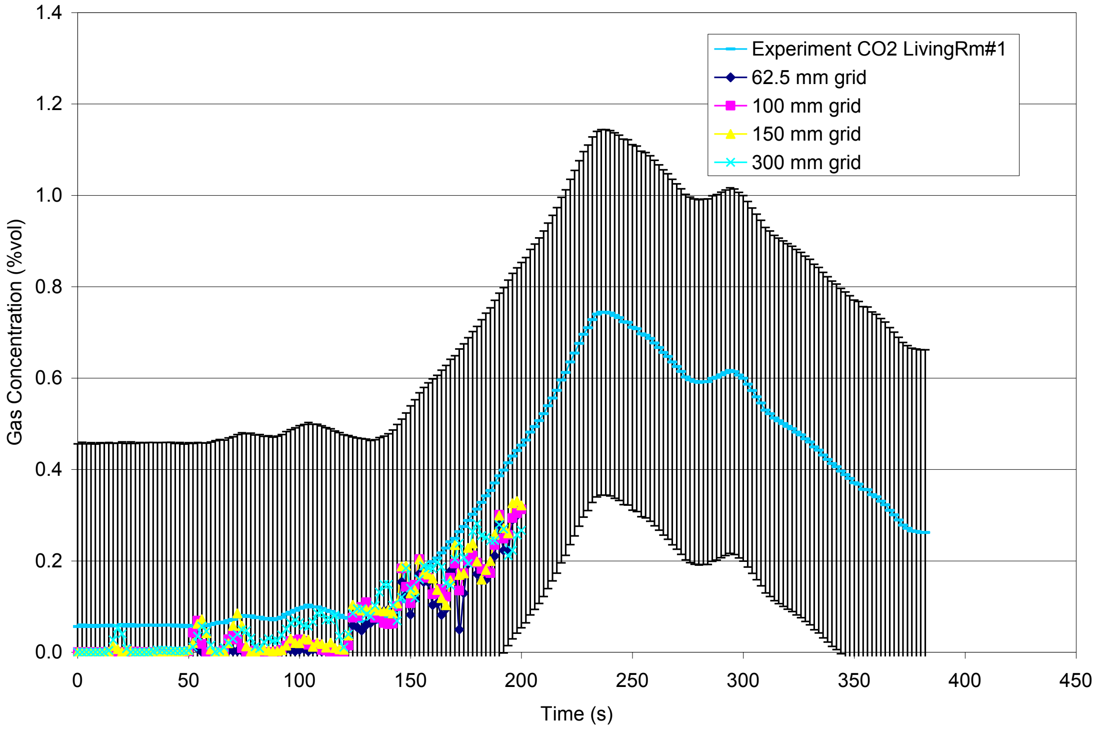


(c)

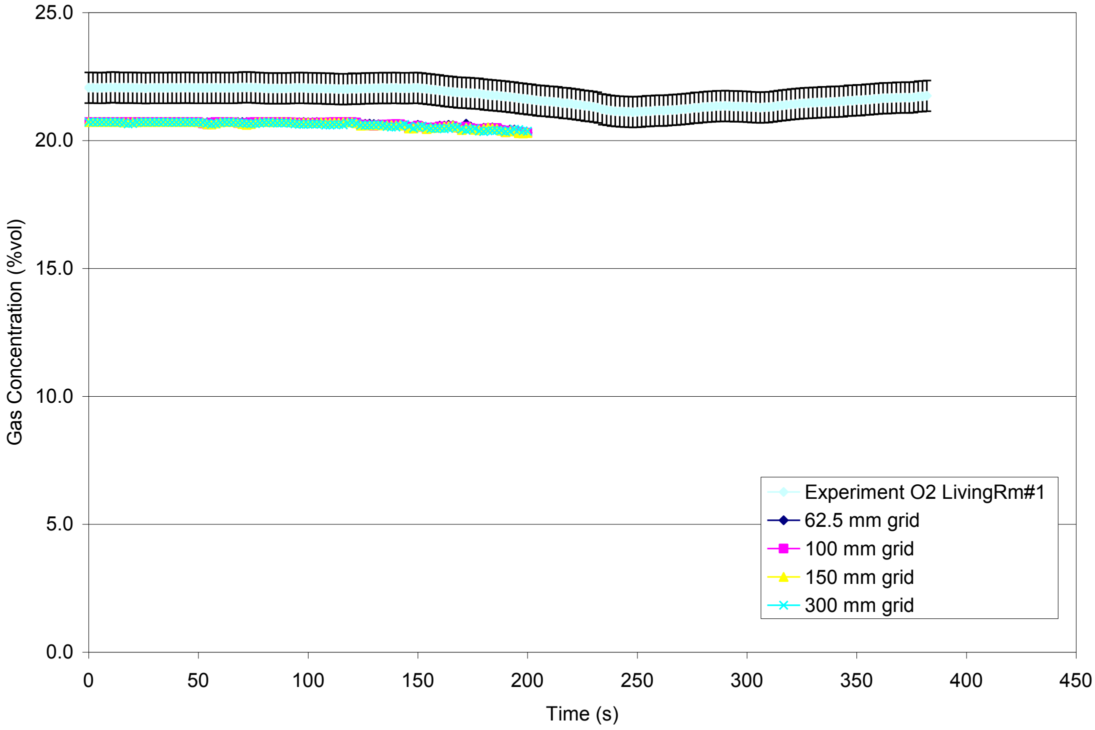
Figure 30. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #1 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



(a)

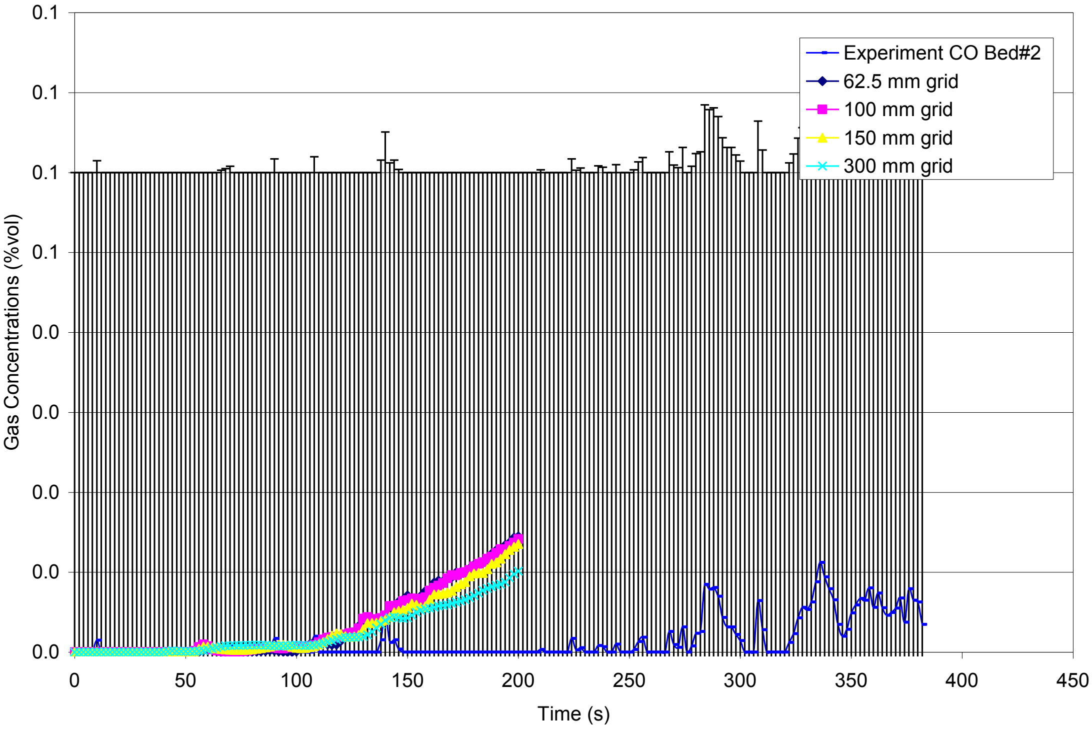


(b)

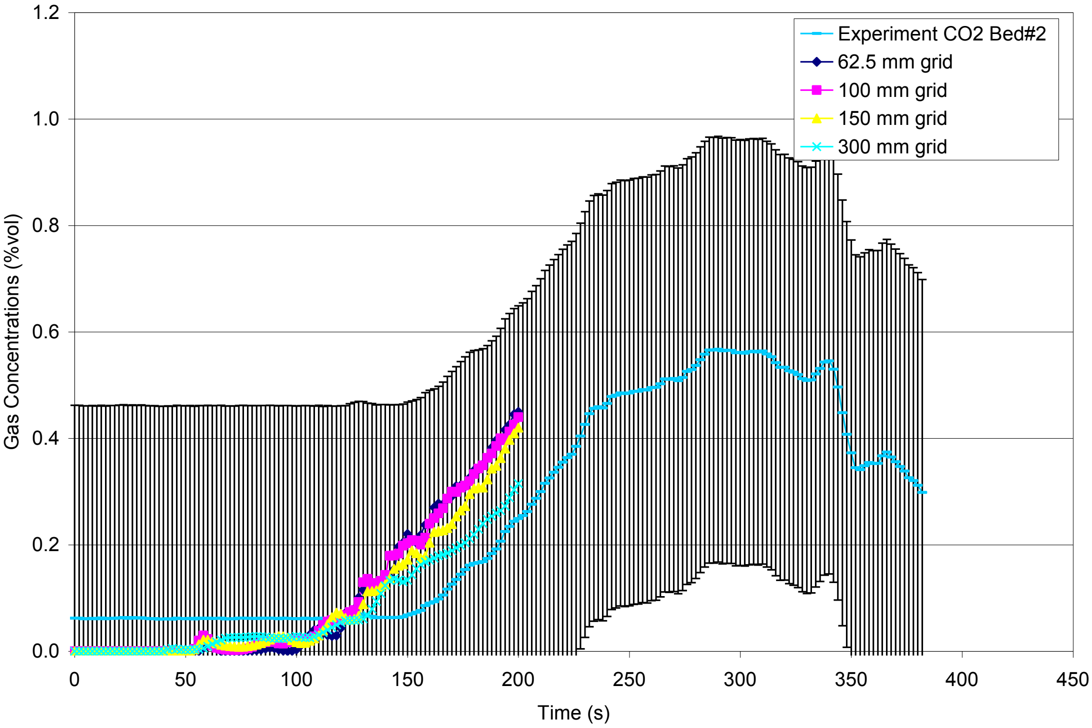


(c)

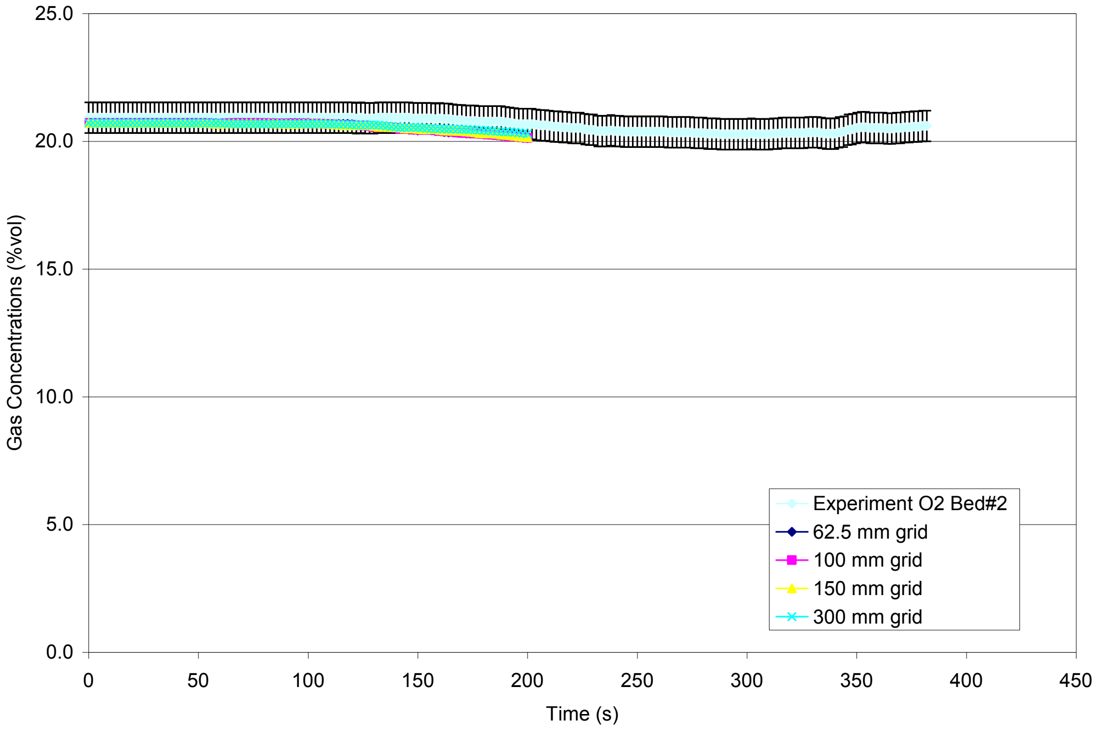
Figure 31. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages


0.1
0.1
0.1
0.1
0.0
0.0
0.0
0.0
0.0
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Bed#2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(a)

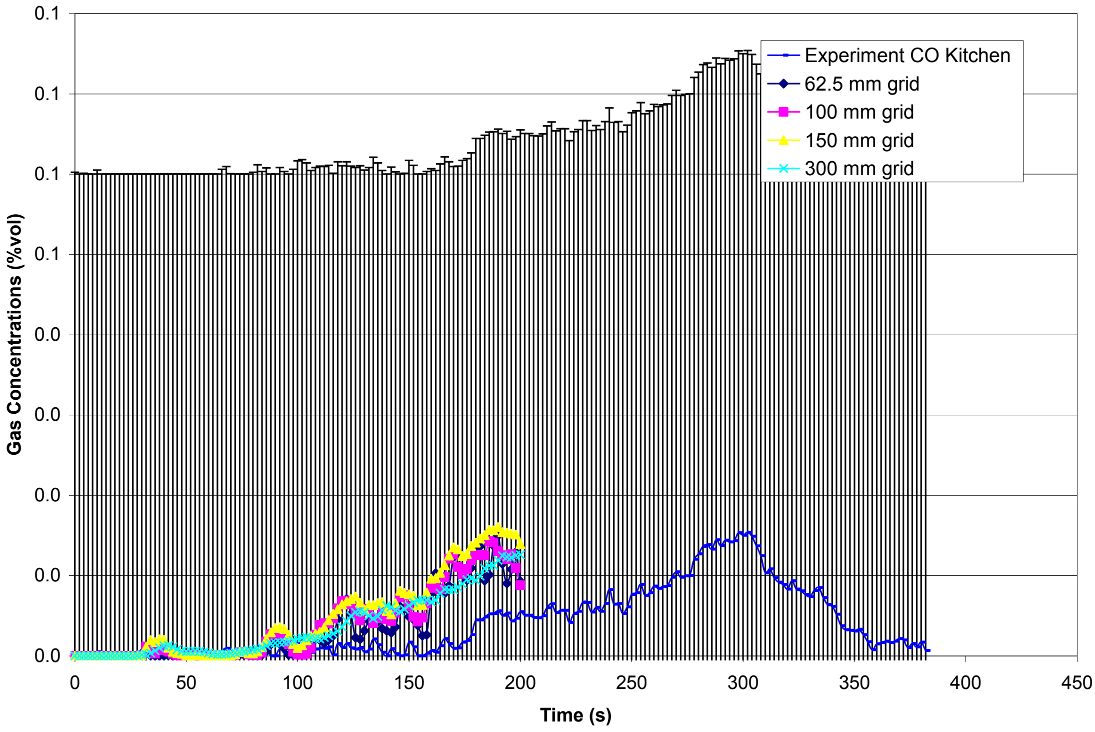

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Bed#2
62.5 mm grid
100 mm grid
150 mm grid
300 mm grid

(b)

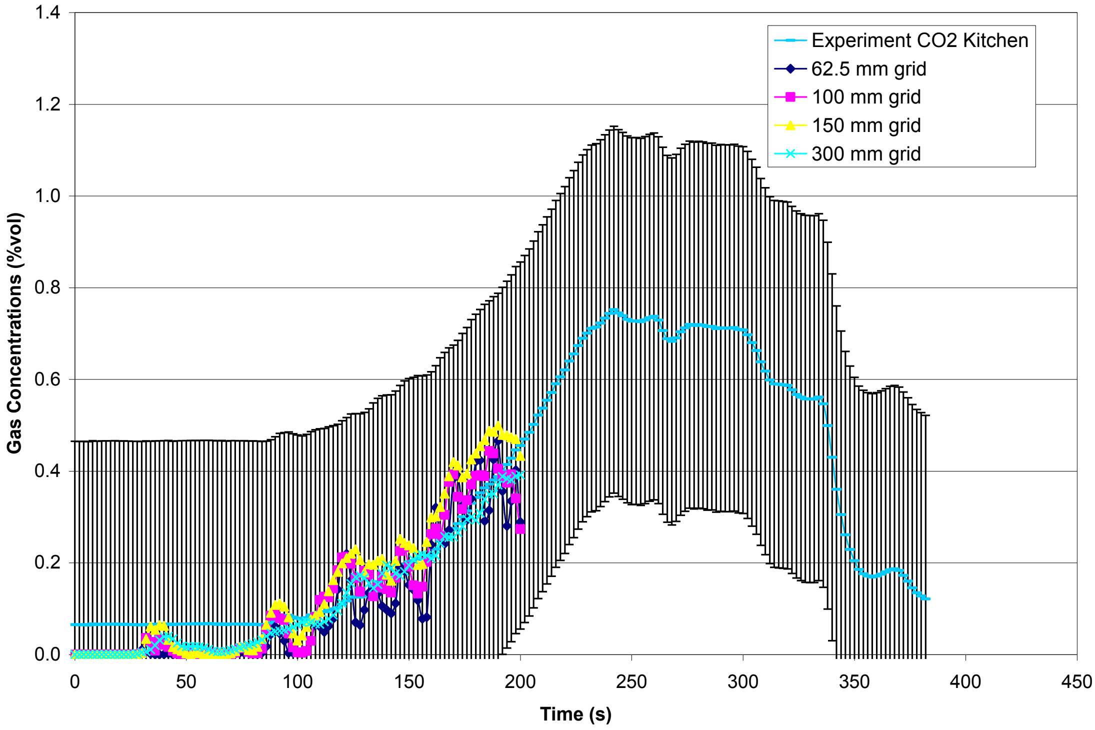


(c)

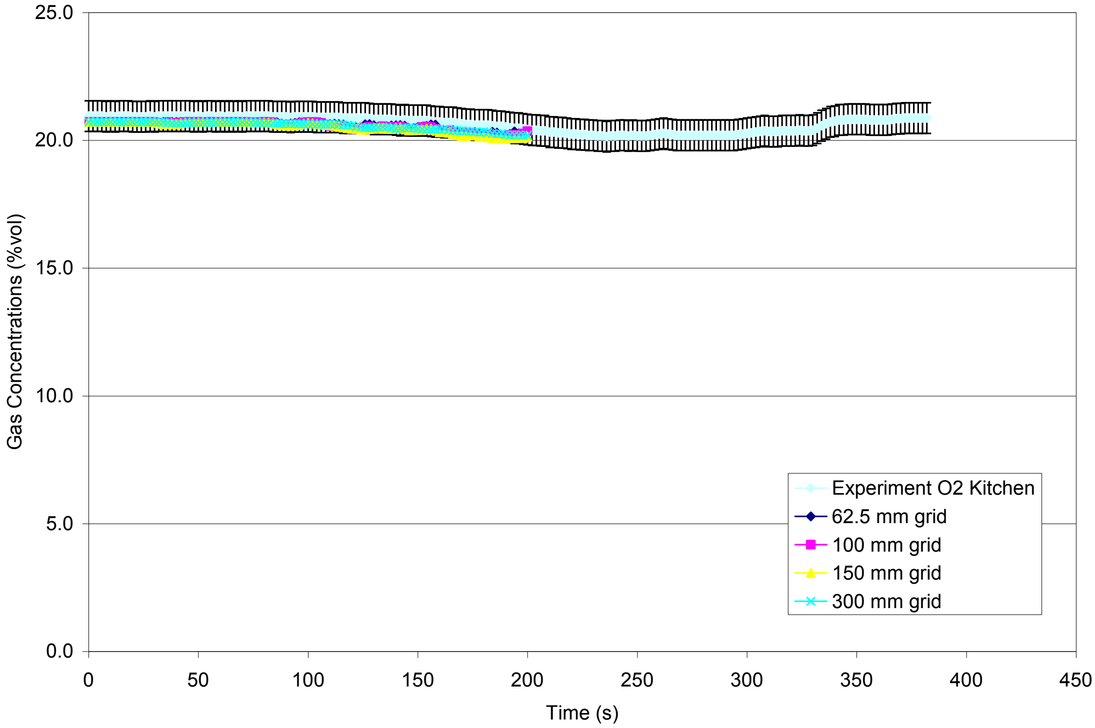
Figure 32. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



(a)

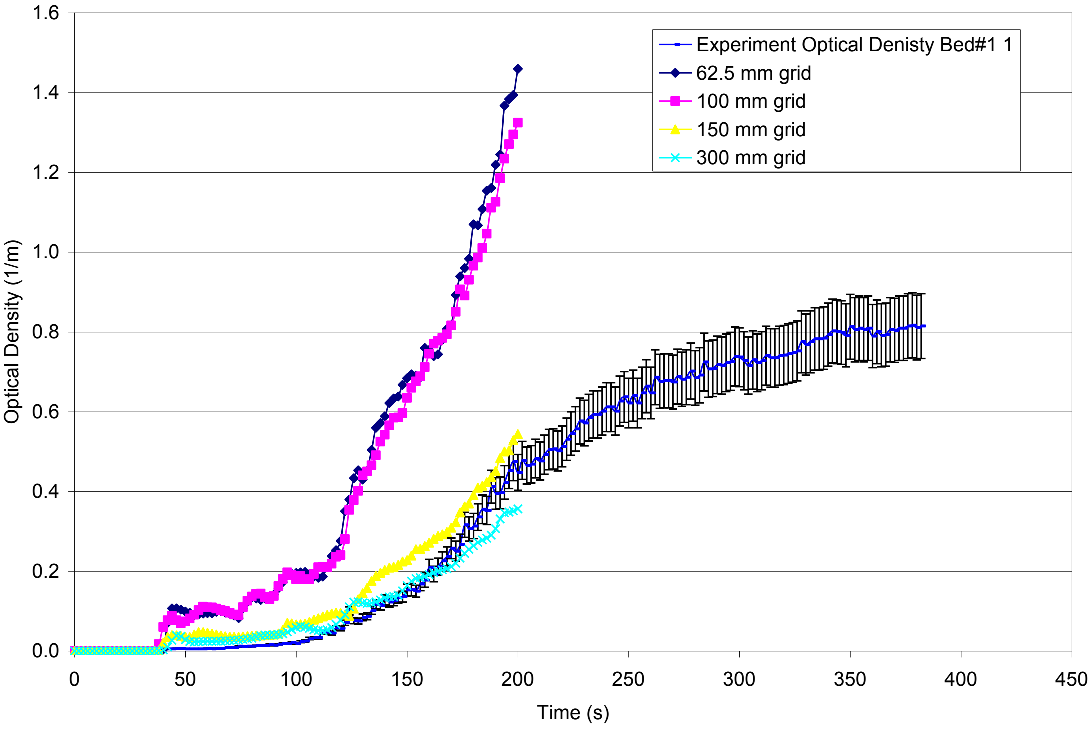


(b)

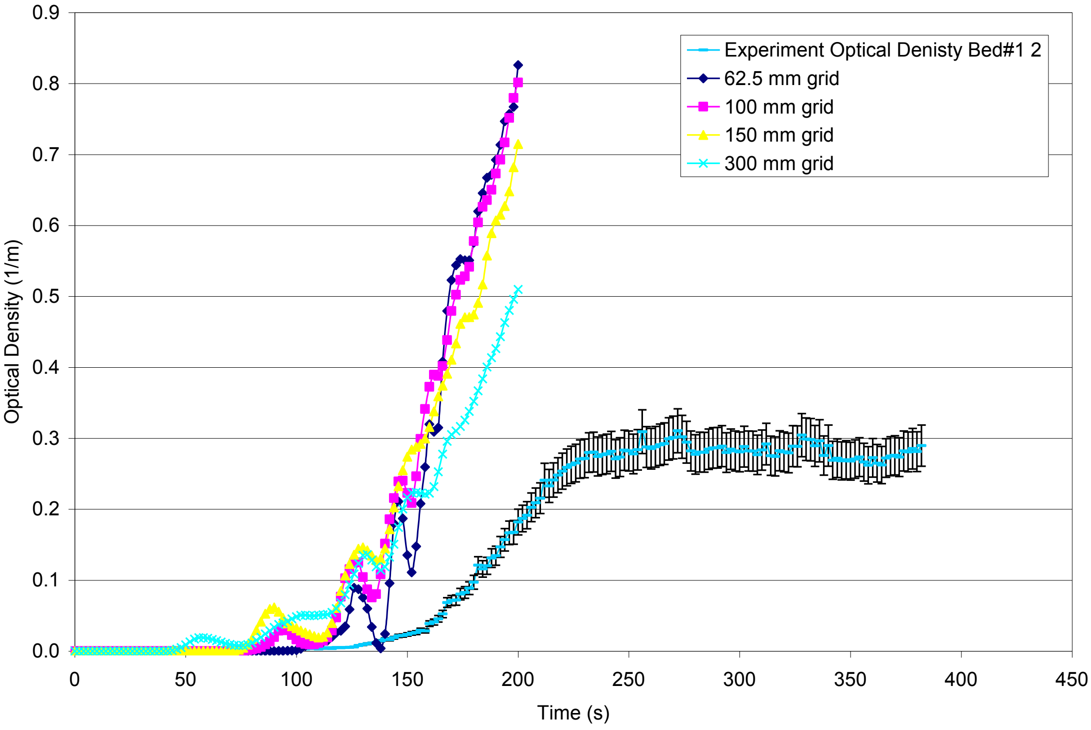


(c)

Figure 33. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Kitchen (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages

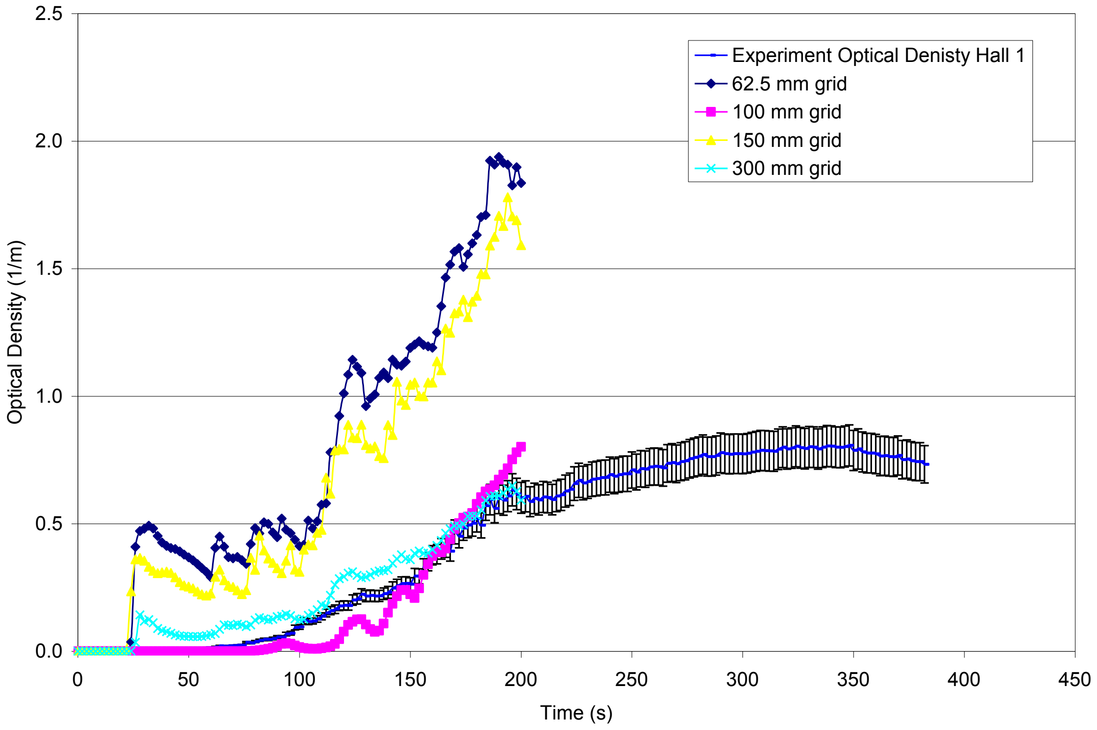


(a)

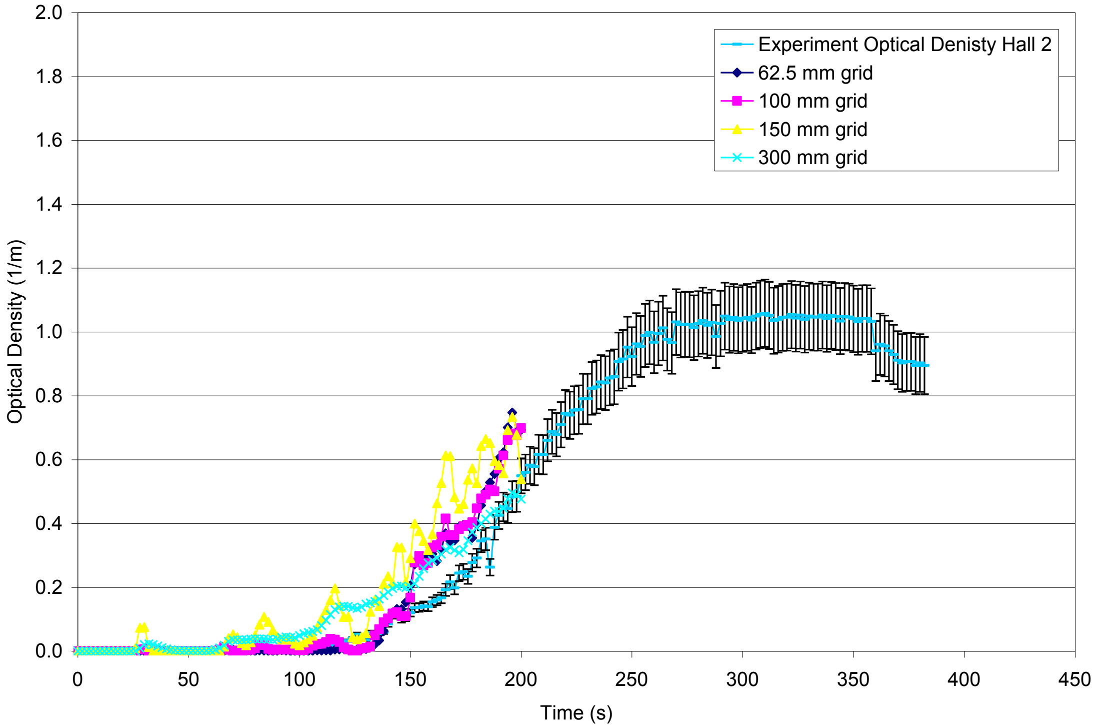


(b)

Figure 34. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #1 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

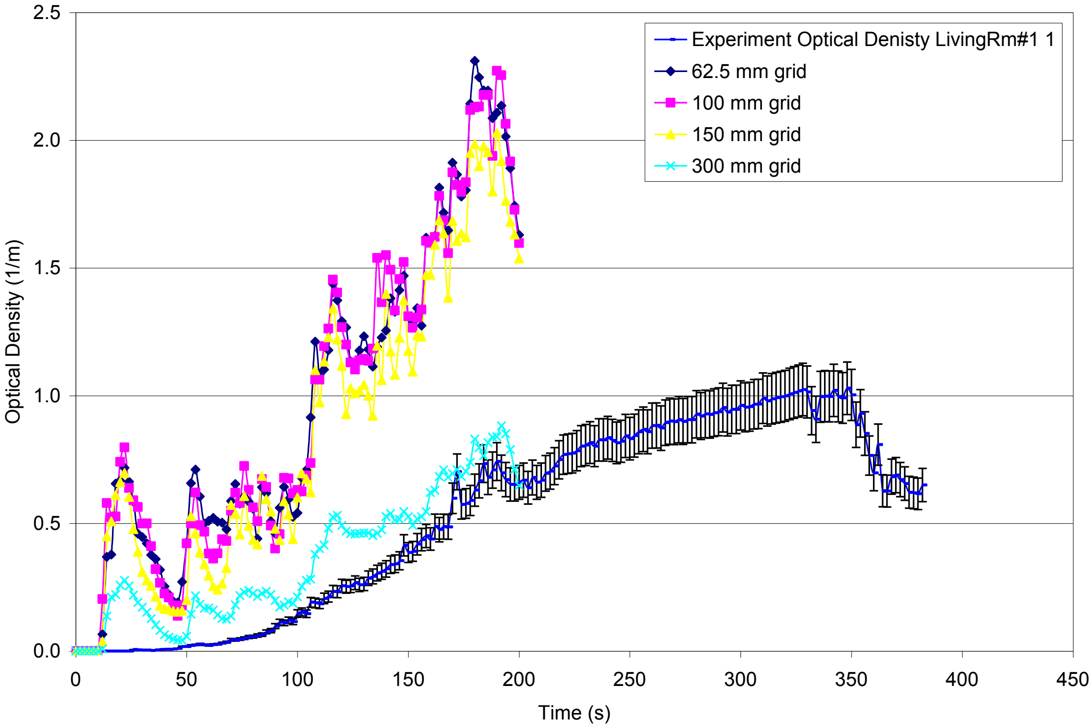


(a)

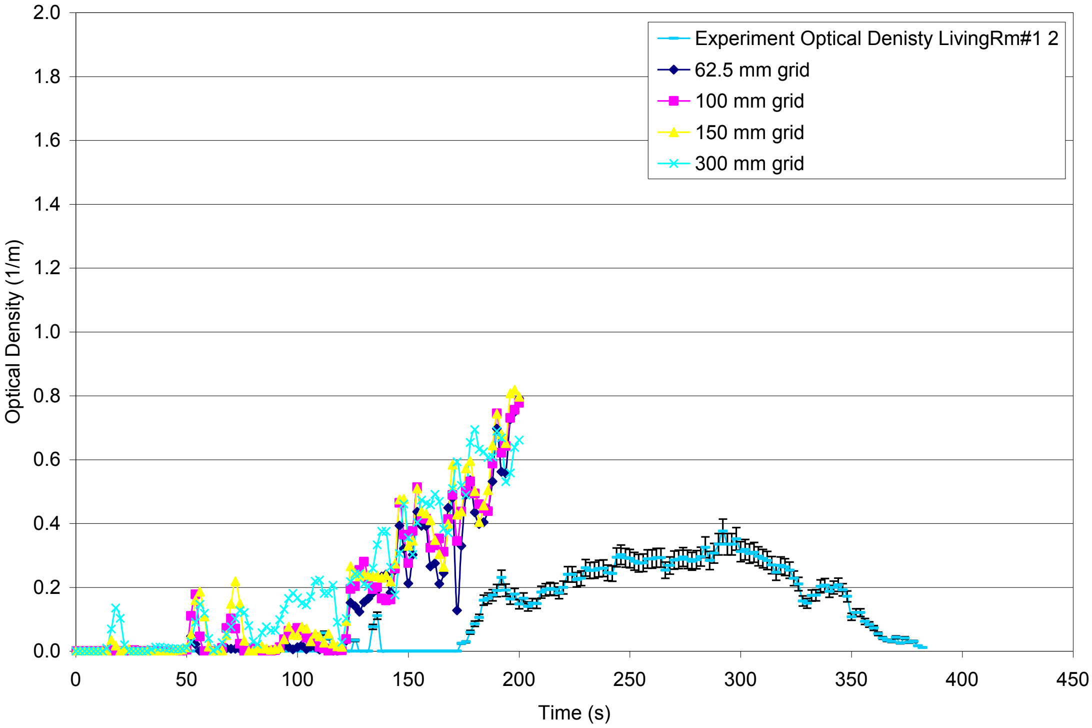


(b)

Figure 35. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Hall optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

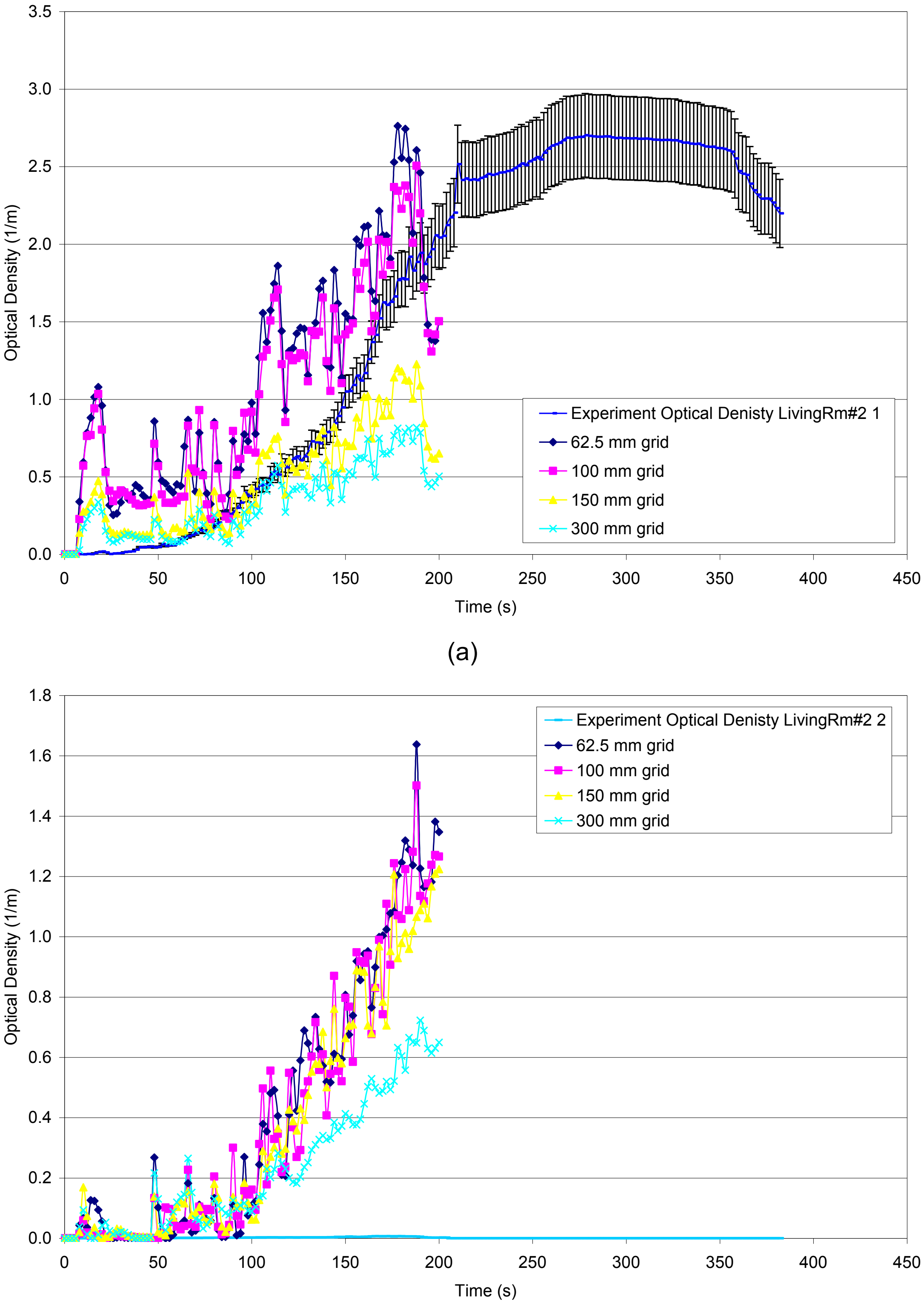


(a)



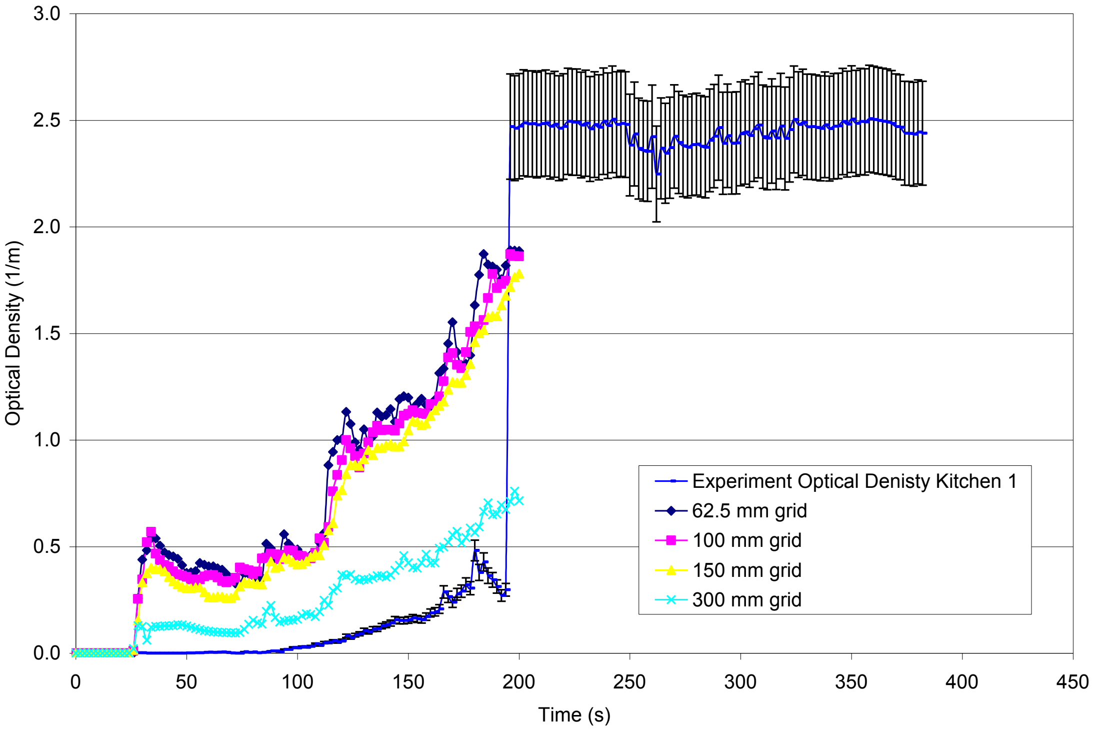
(b)

Figure 36. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #1 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

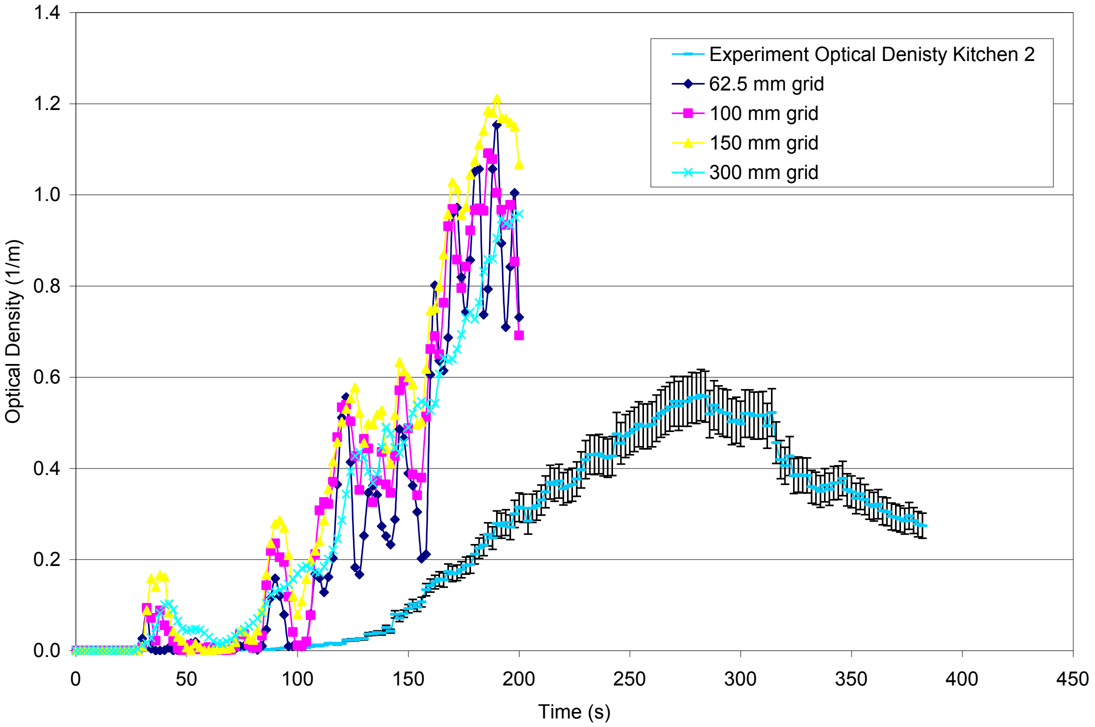


(b)

Figure 37. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #2 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

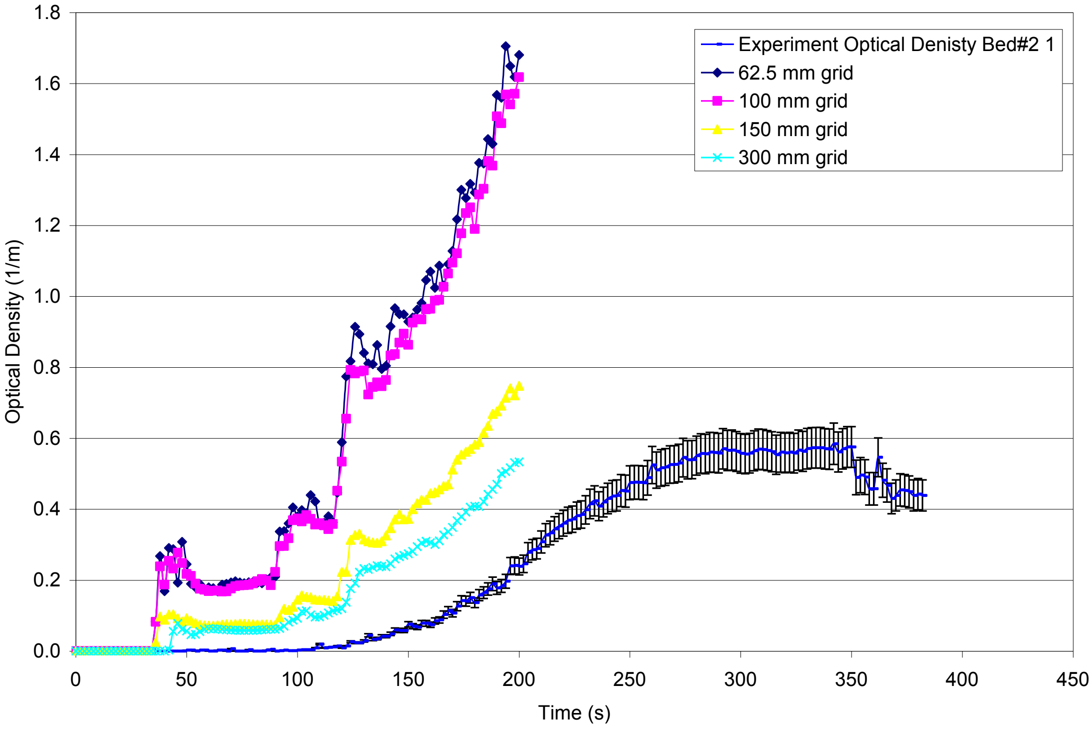


(a)

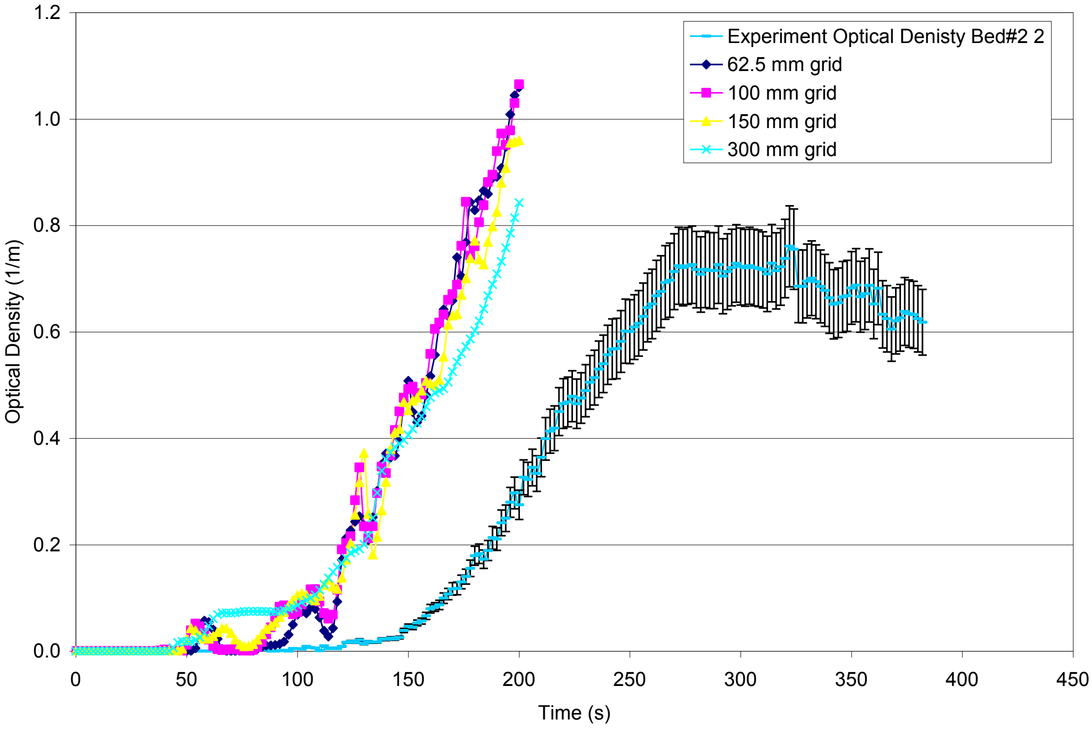


(b)

Figure 38. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Kitchen optical density at locations (a) 20 mm and (b) 900 mm below the ceiling



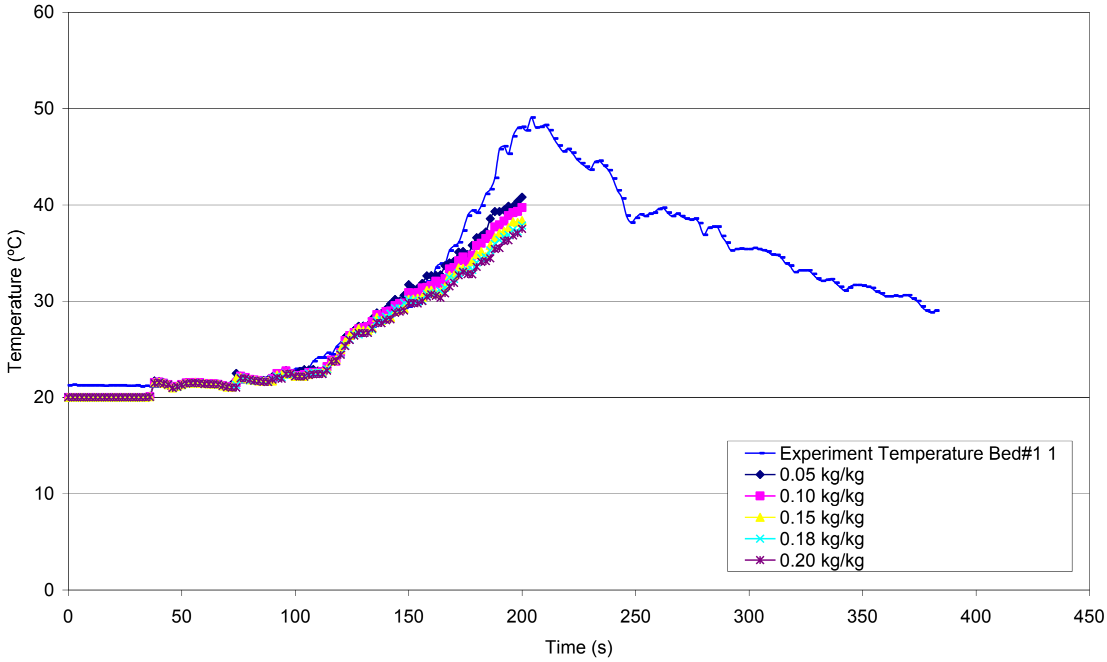
(a)



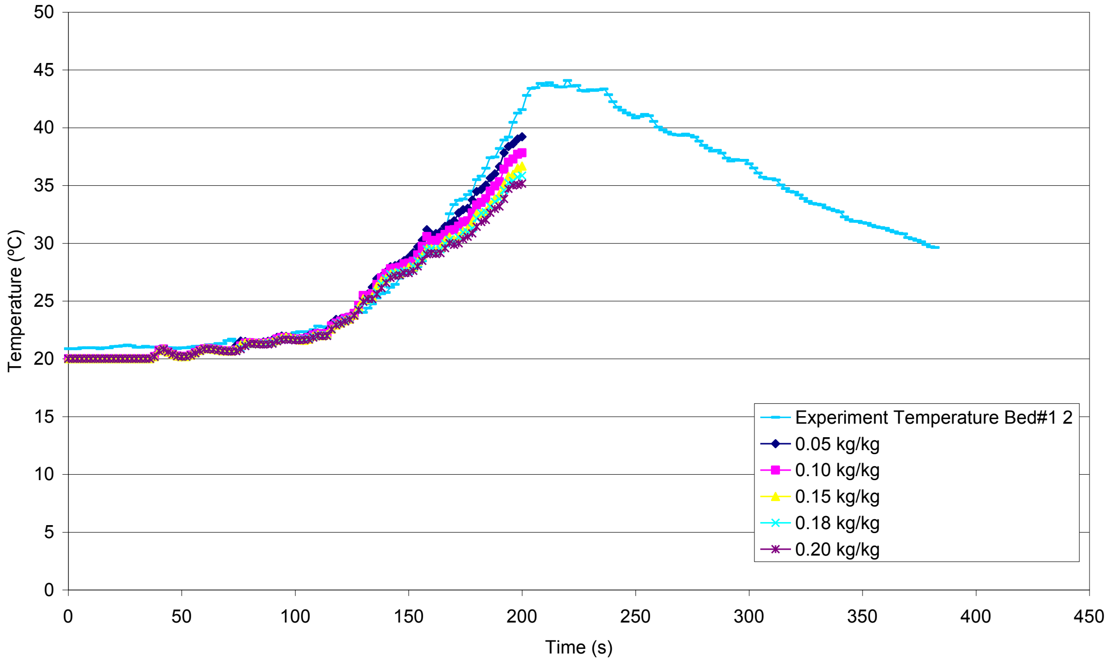
(b)

Figure 39. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #2 optical density at locations (a) 20 mm and (b) 900 mm below the ceiling

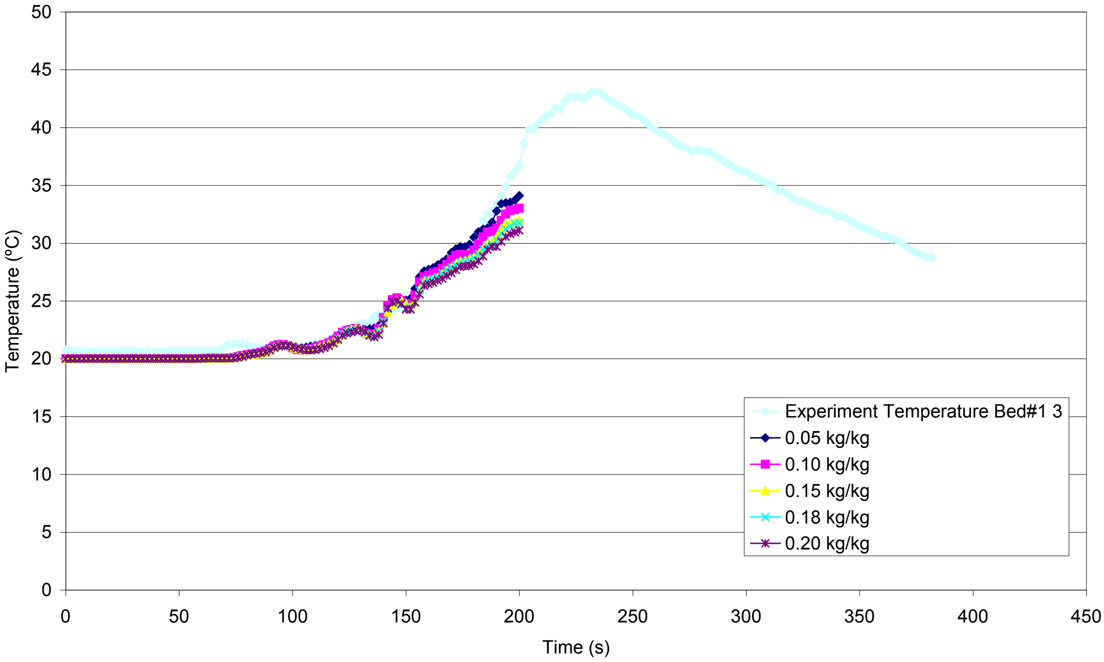
B.10 Additional Results – 100 mm Grid Spacing – Scenarios 2 and 5 to 8



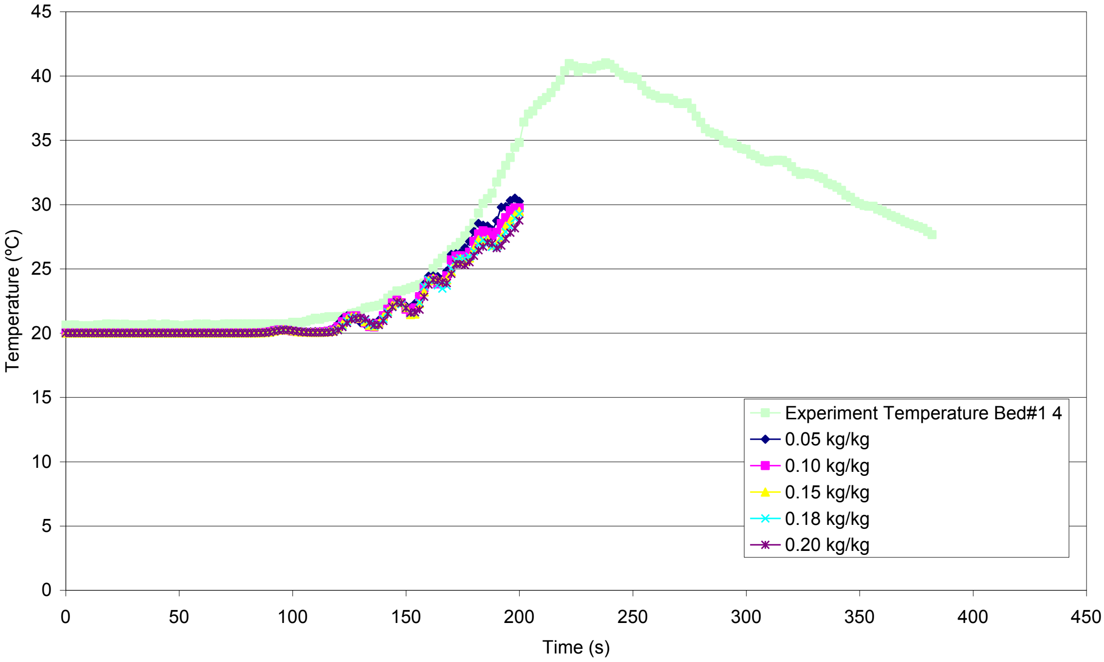
(a)



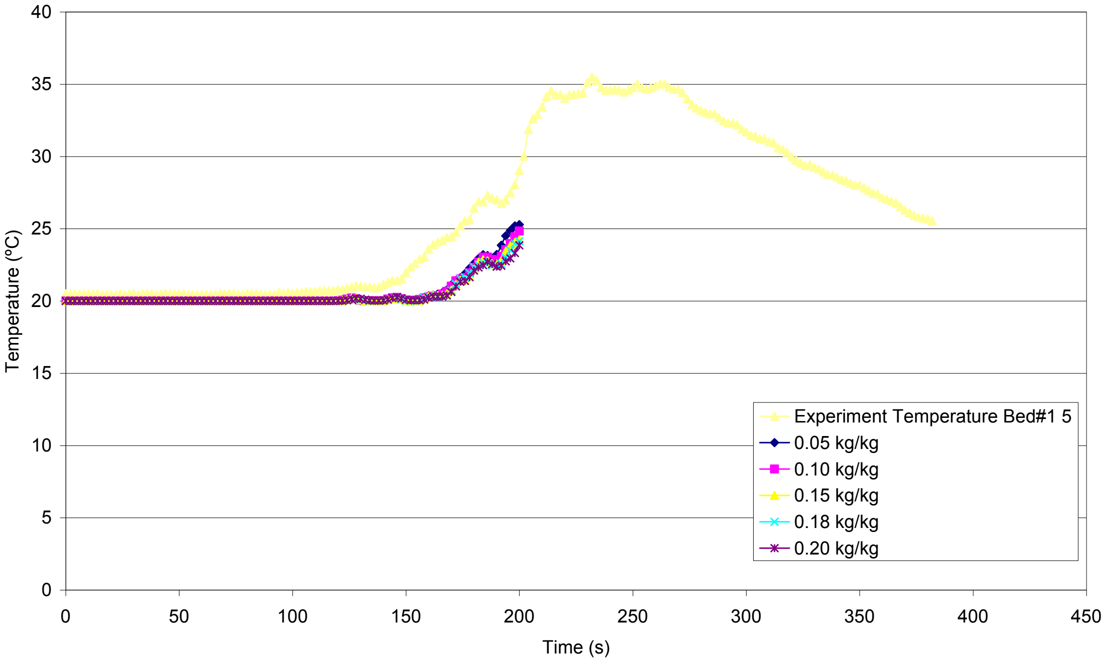
(b)


50
45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

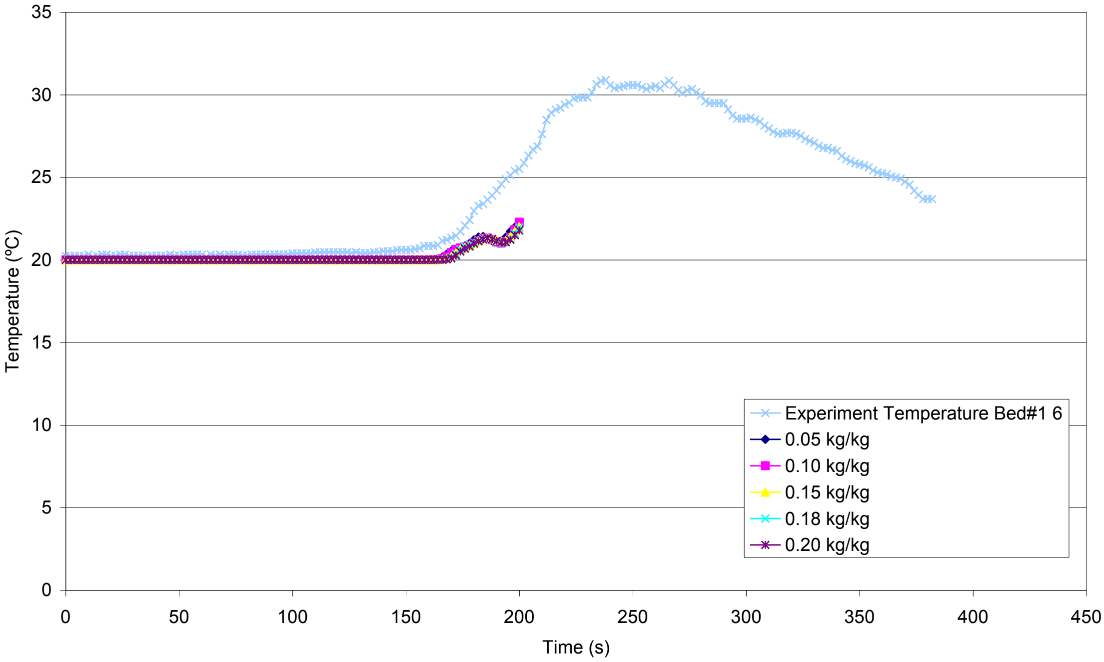
(c)


45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

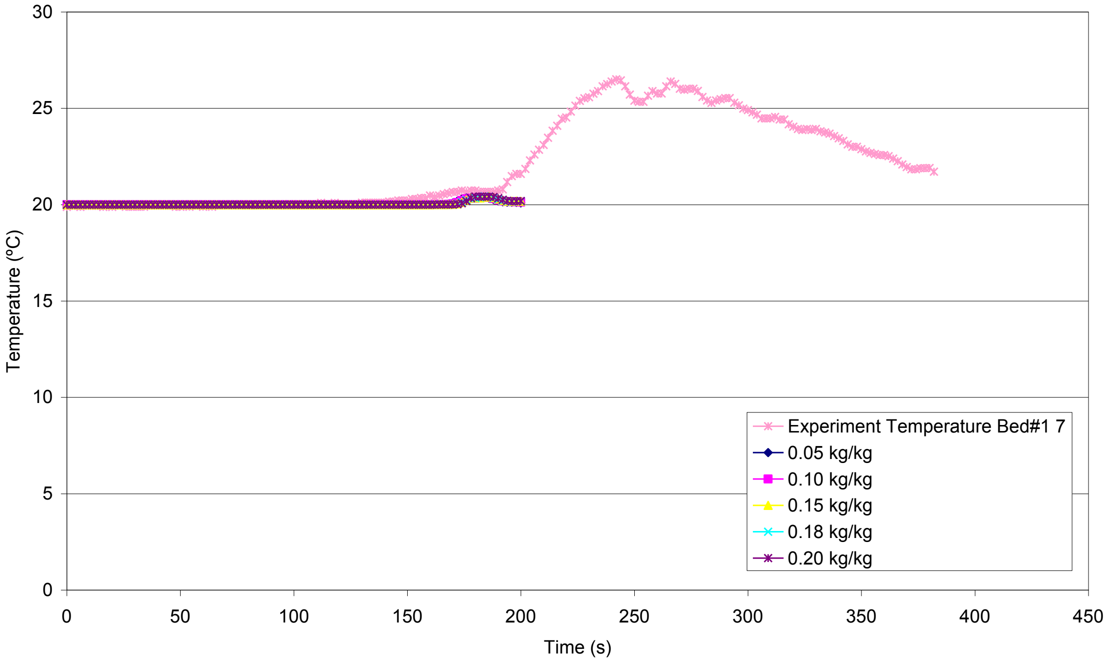
(d)


40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(e)

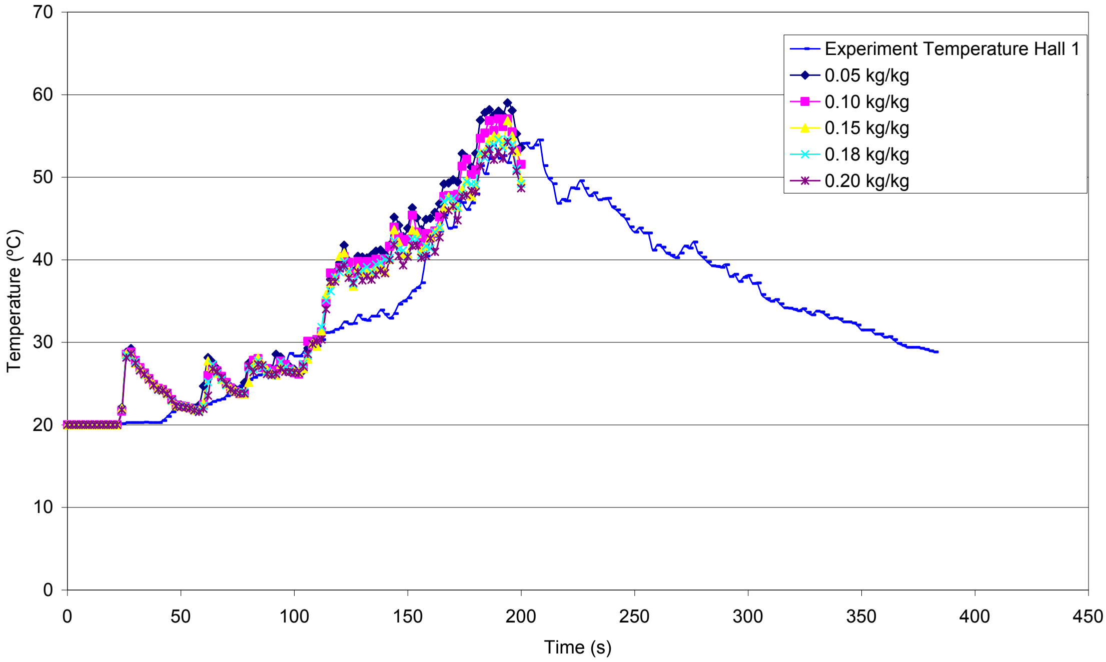

35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#1 6
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(f)

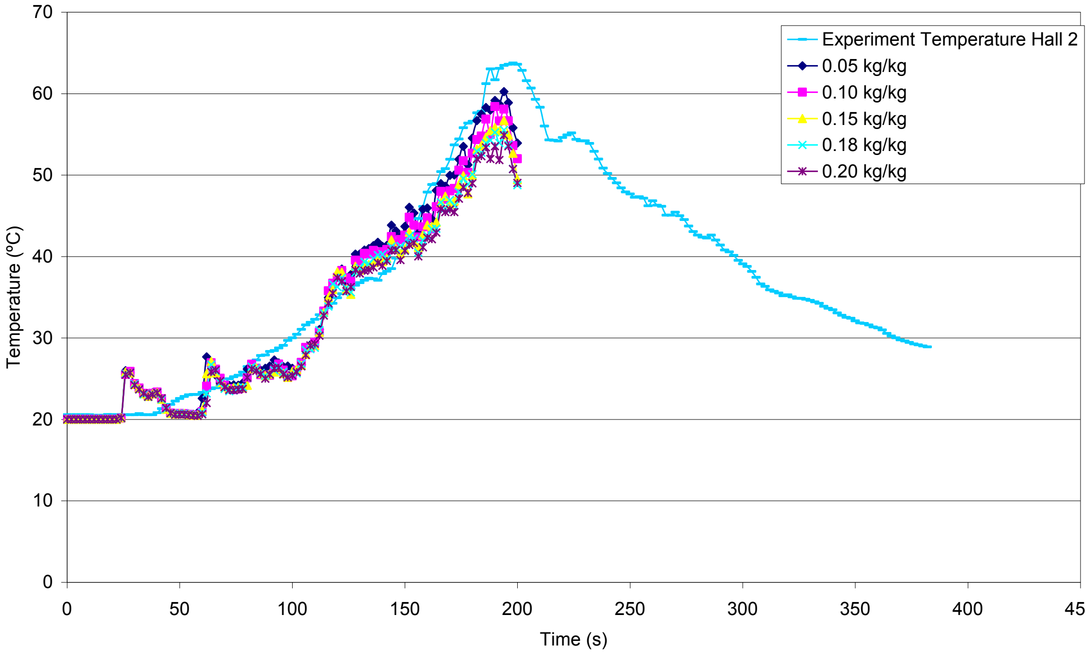


(g)

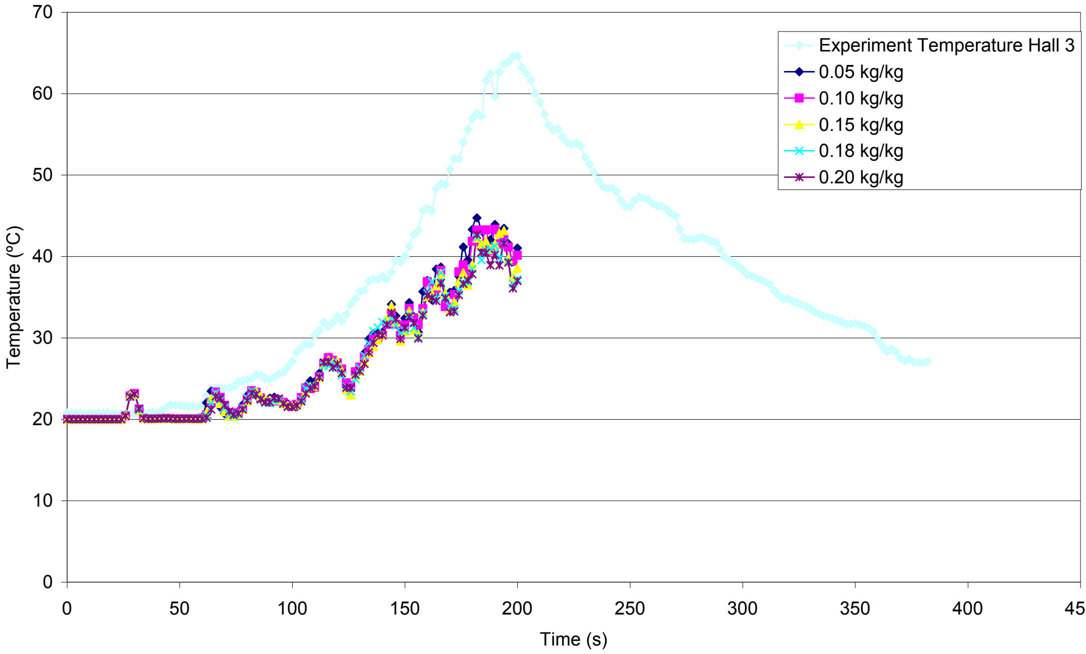
Figure 40. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Bedroom #1 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



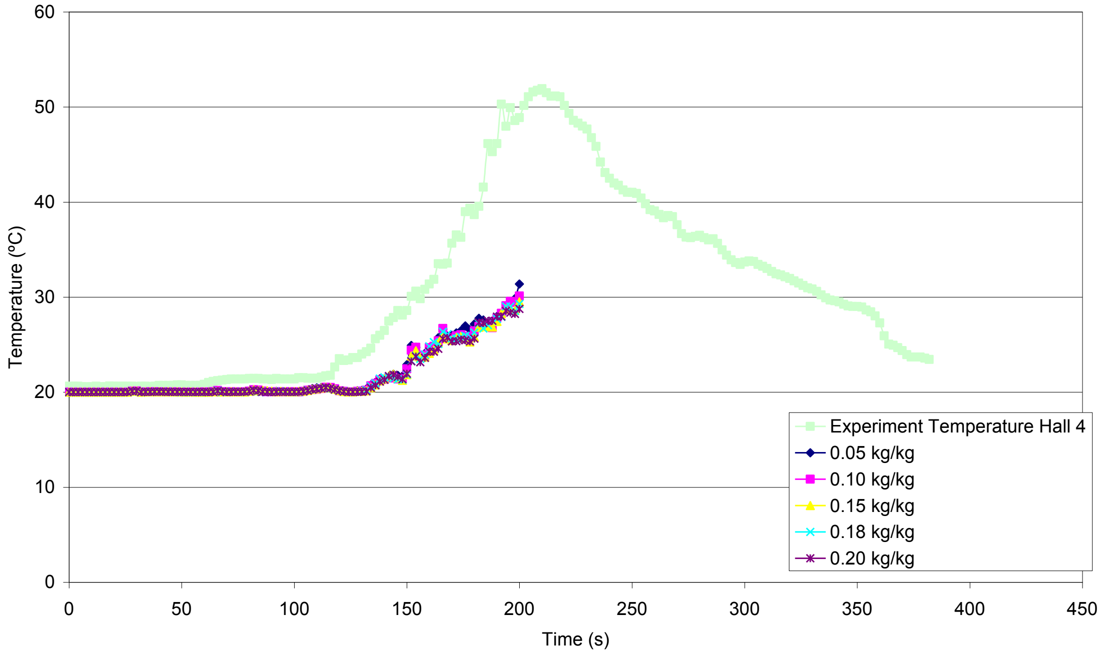
(a)


70
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

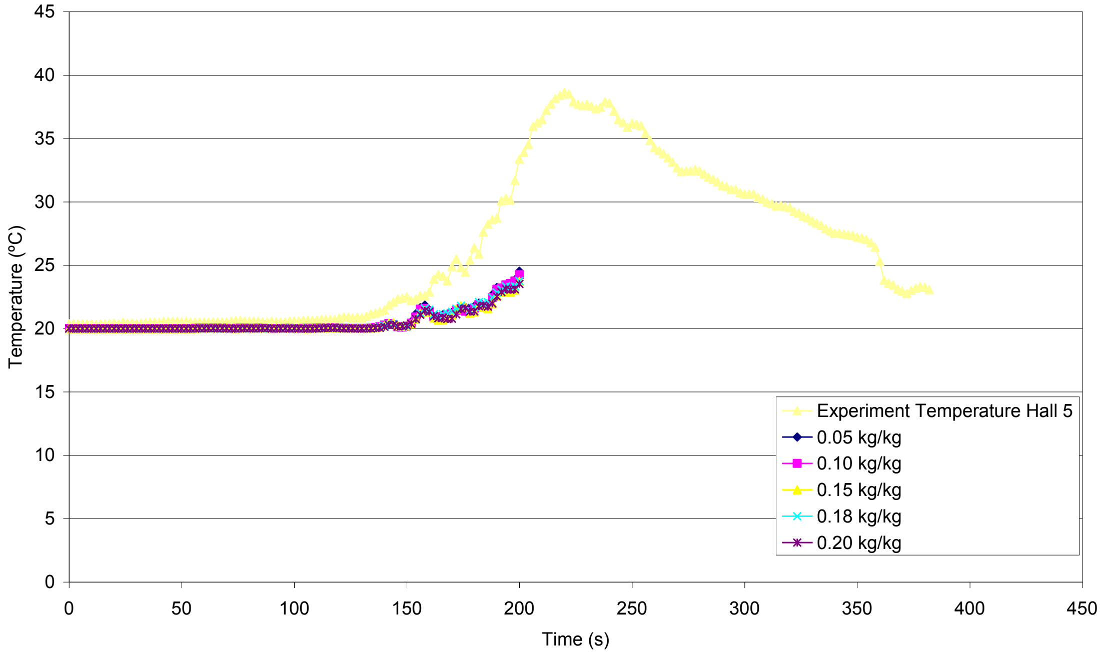
(b)


70
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

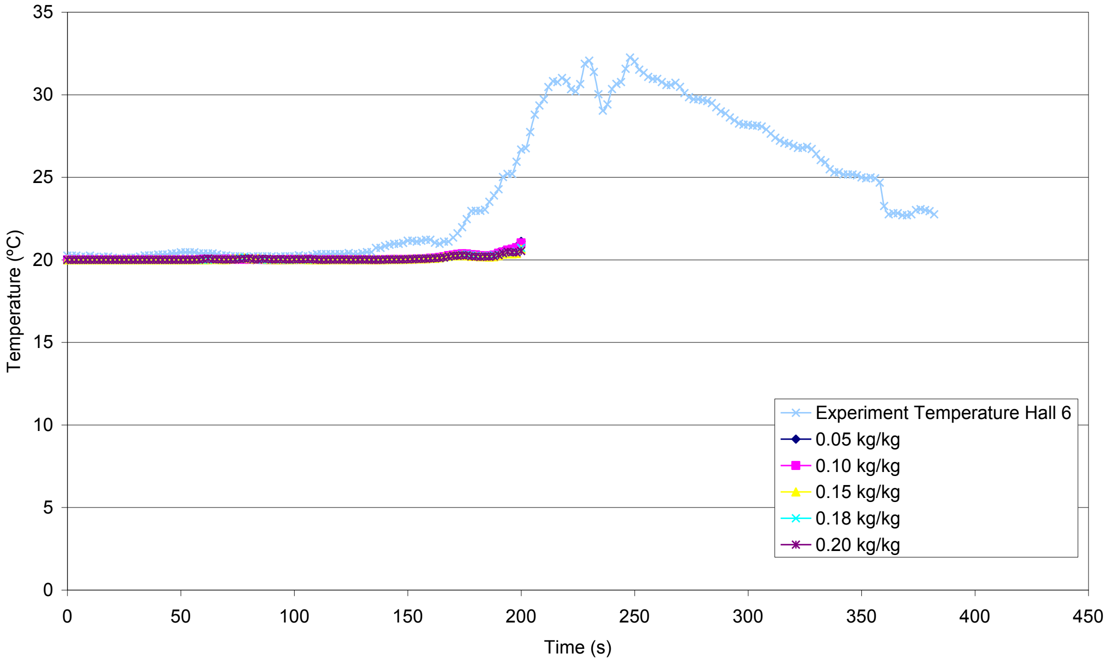
(c)


60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

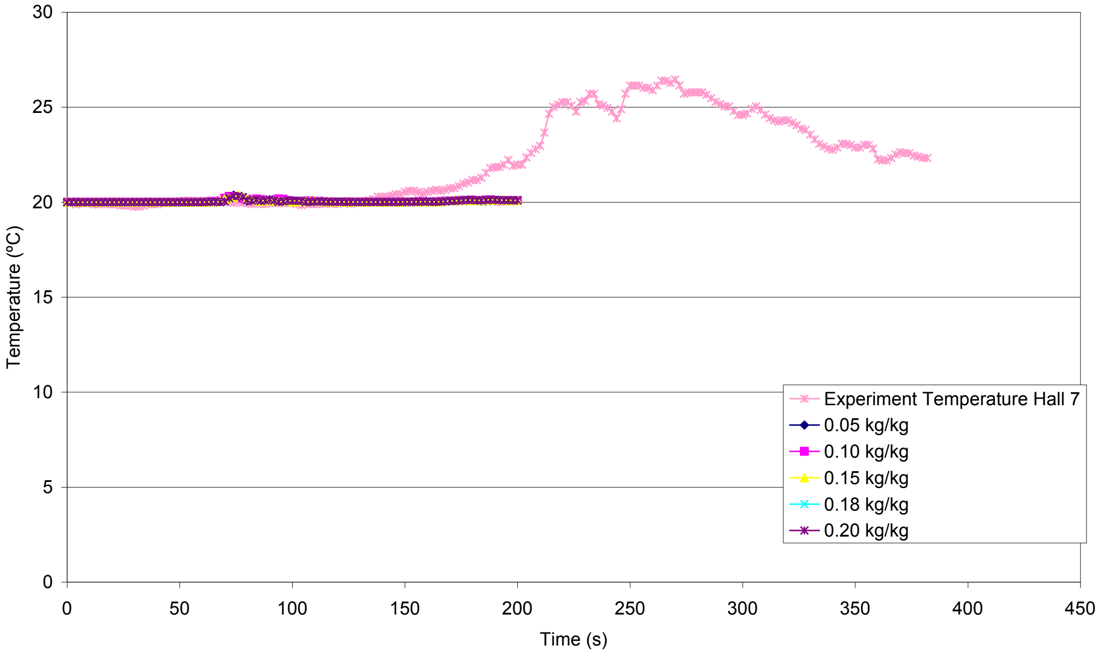
(d)


45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Hall 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(e)

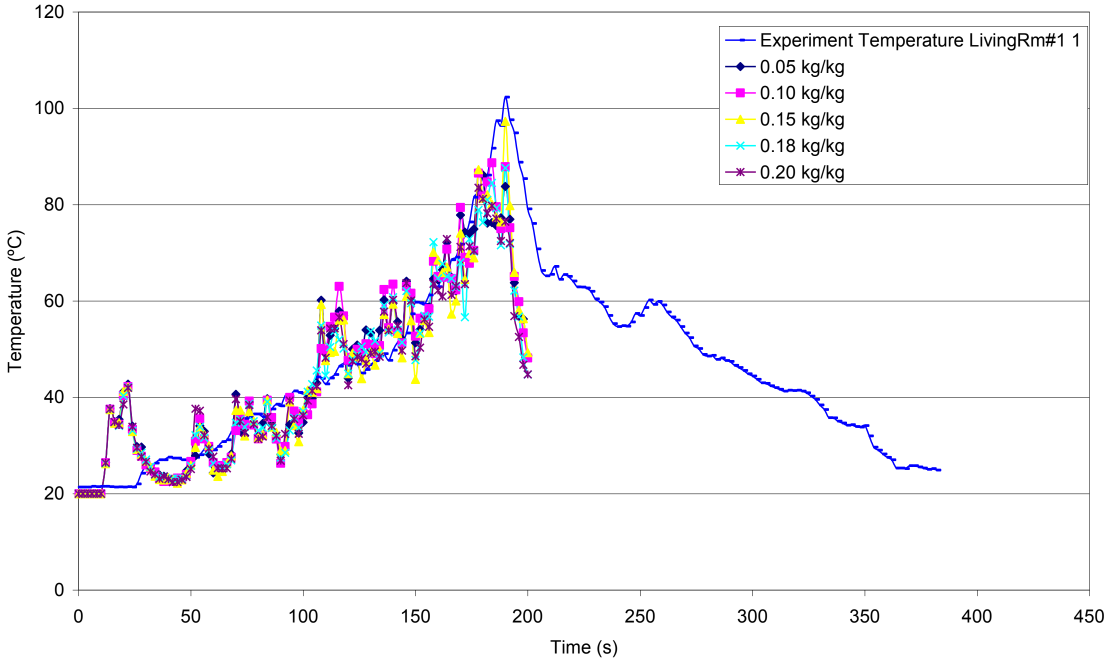


(f)

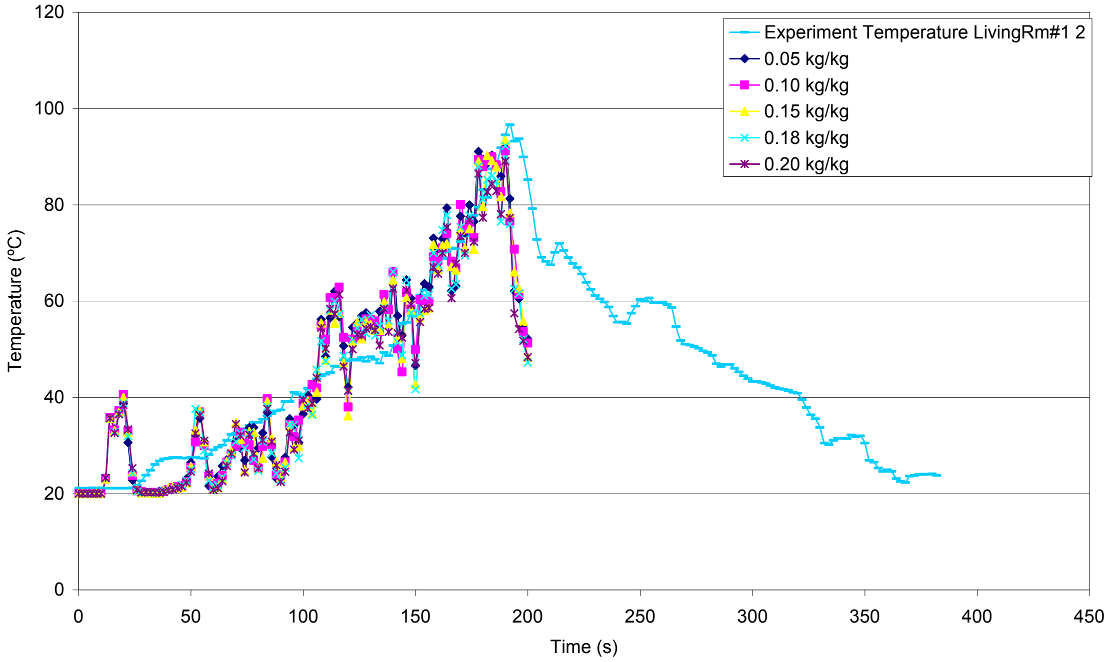


(g)

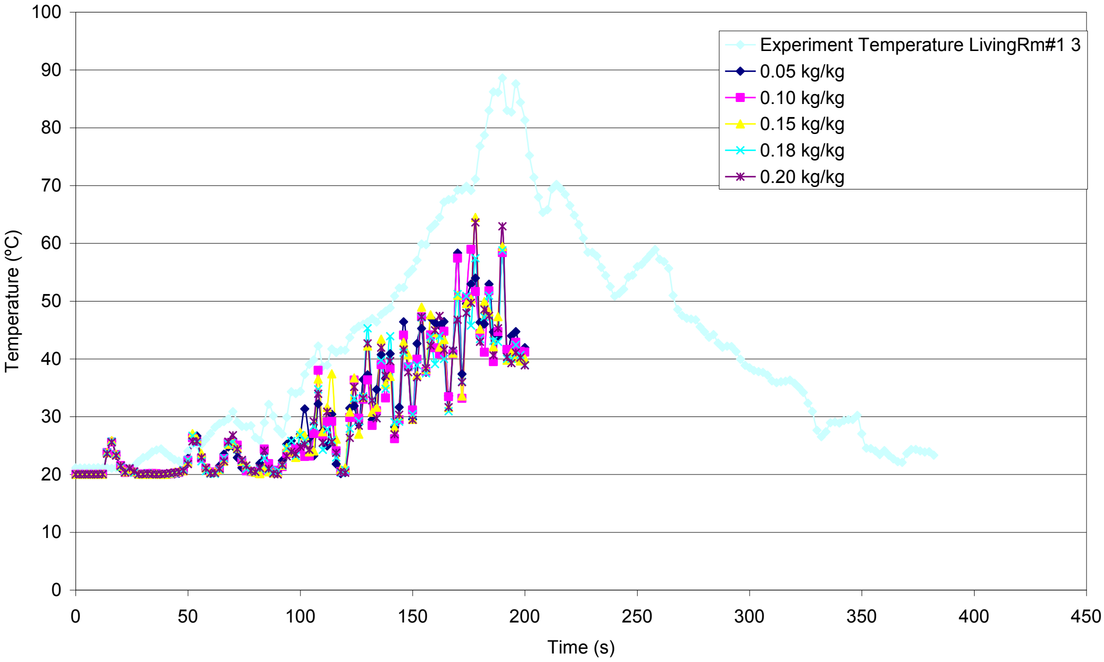
Figure 41. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Hall temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


120
100
80
60
40
20
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#1 1
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

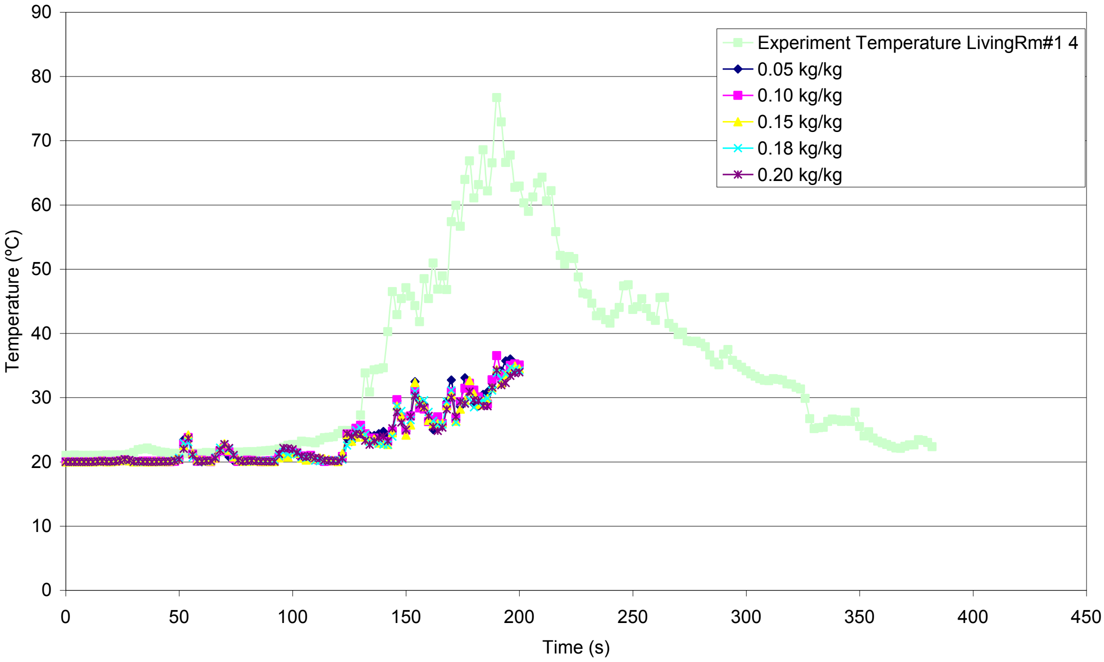
(a)


120
100
80
60
40
20
0
Temperature (°C)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#1 2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

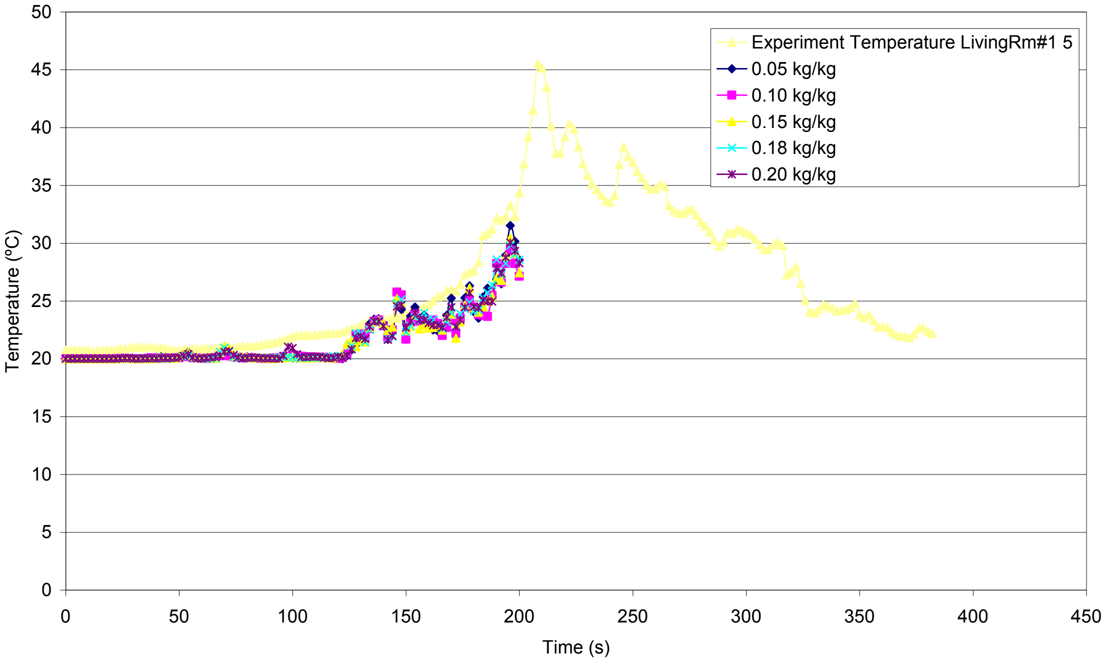
(b)


Experiment Temperature LivingRm#1 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg
Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450

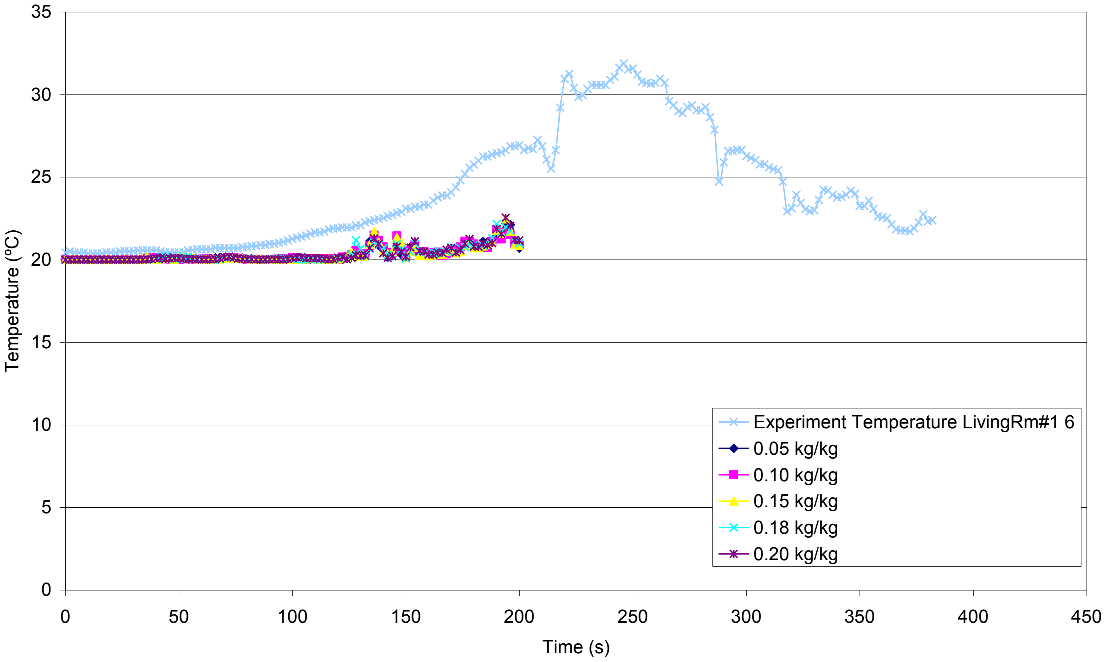
(c)


Experiment Temperature LivingRm#1 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg
Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
400
450

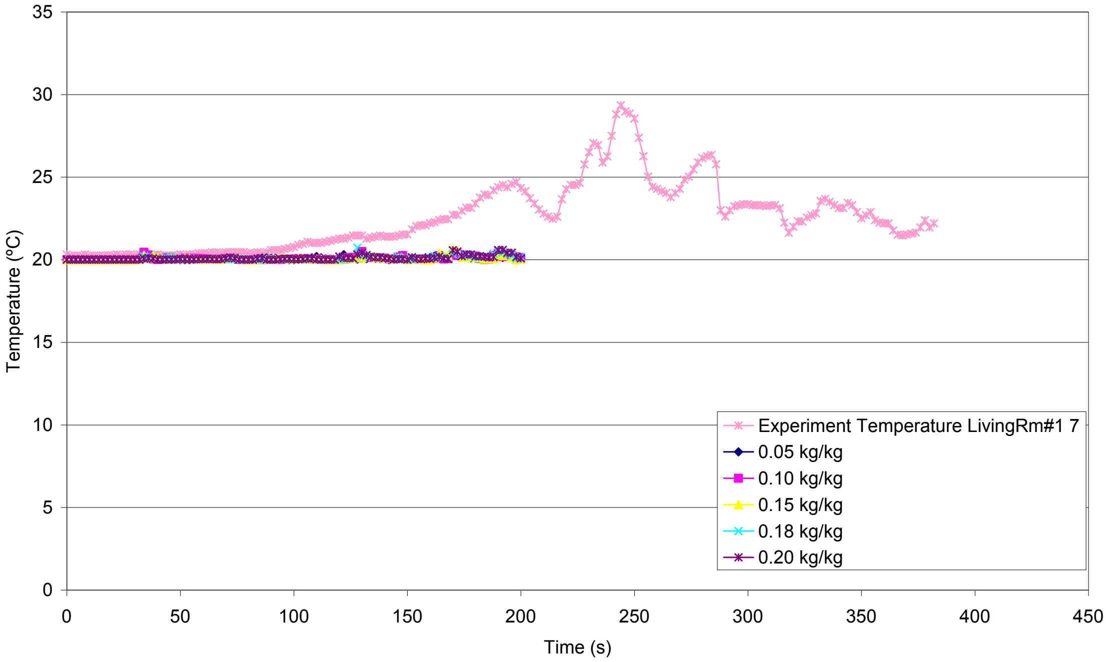
(d)


Temperature (ºC)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#1 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(e)

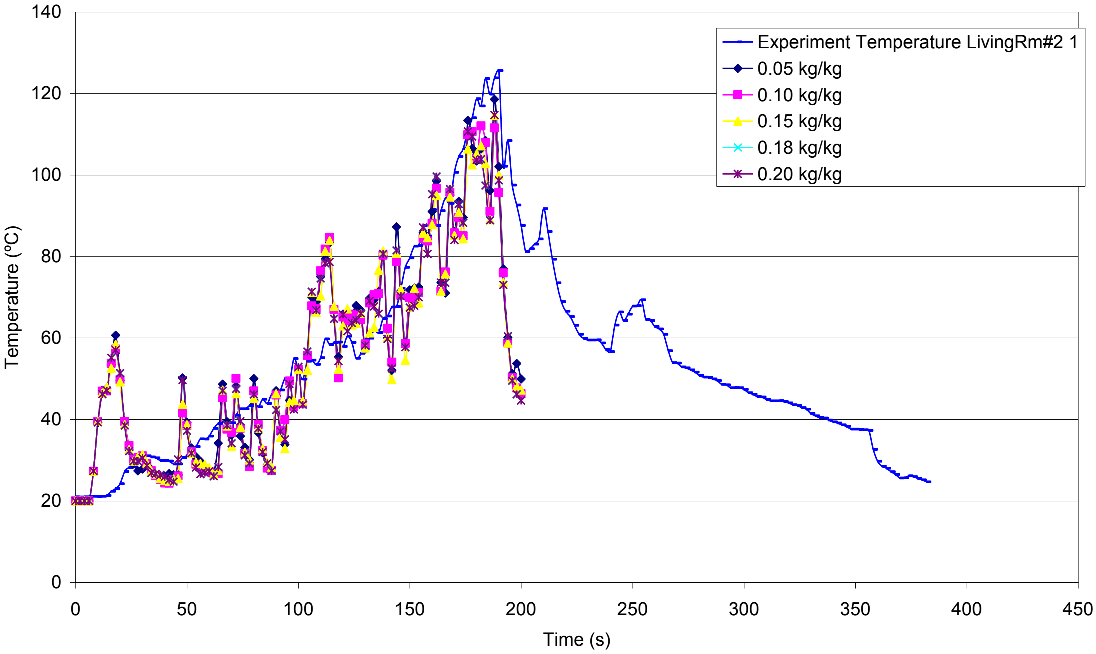

Temperature (ºC)
Time (s)
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#1 6
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(f)

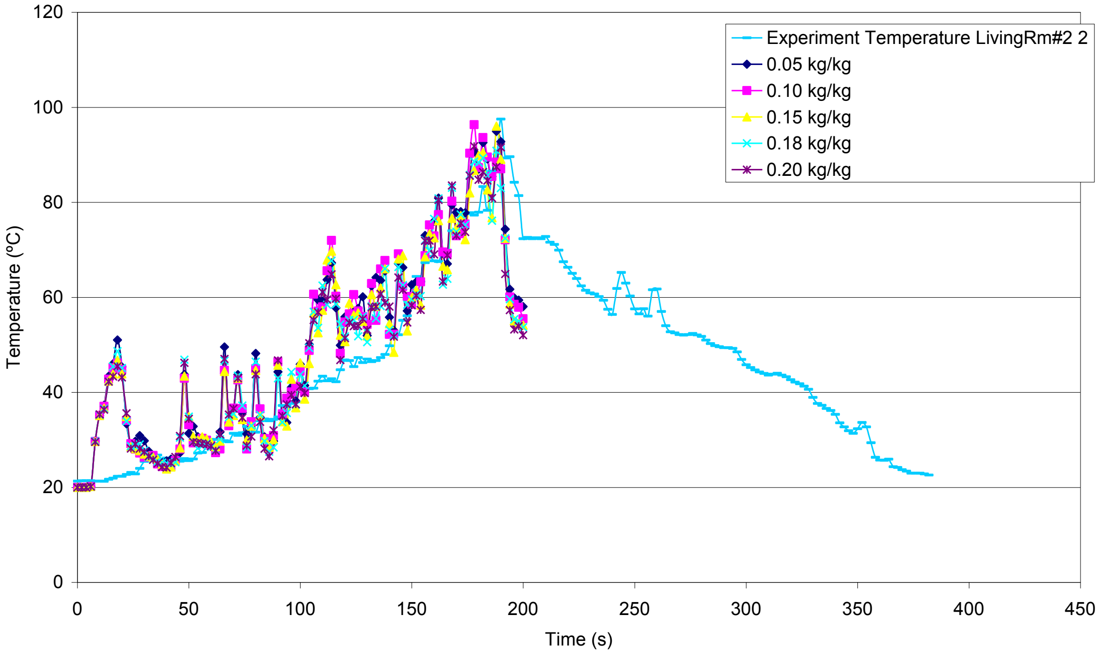


(g)

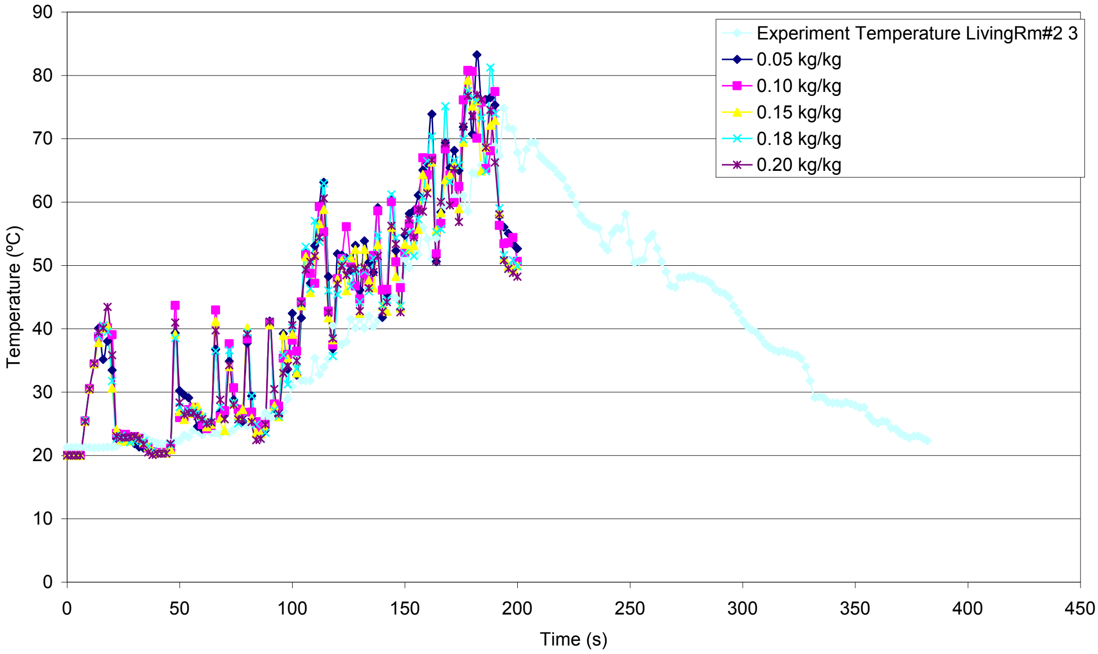
Figure 42. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Living Room #1 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



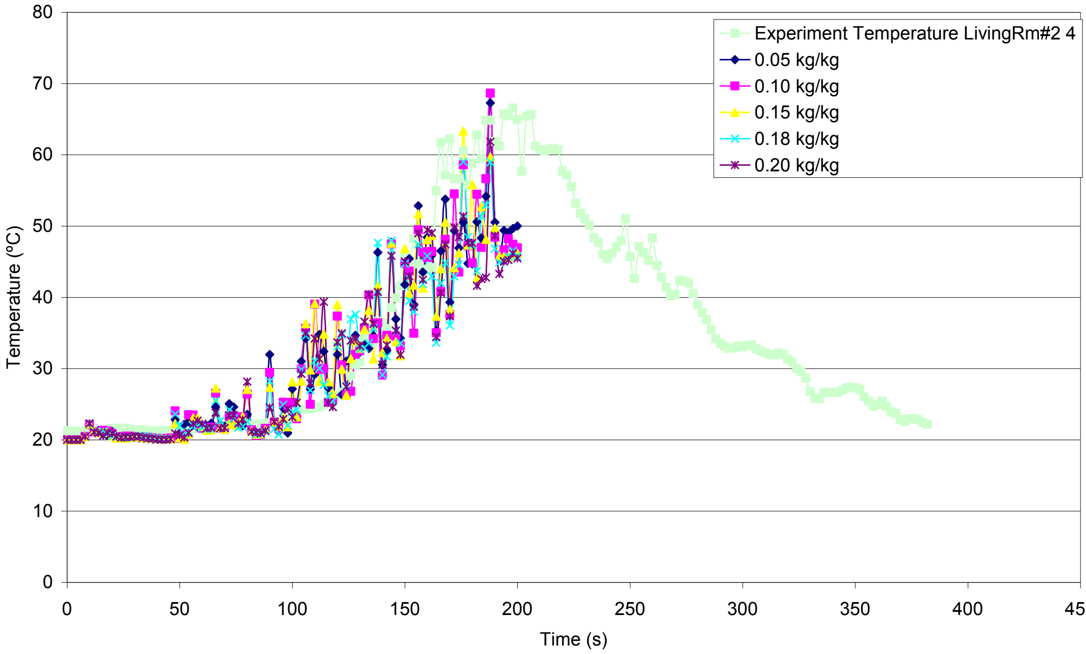
(a)


Temperature (ºC)
Time (s)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

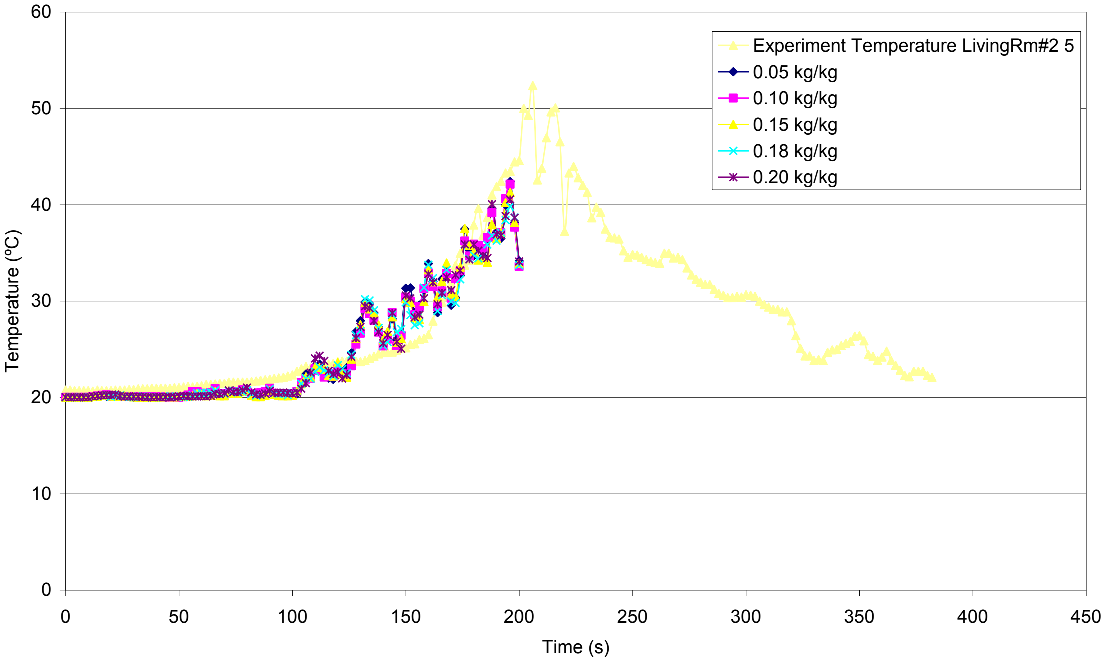
(b)


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
400
450
Experiment Temperature LivingRm#2 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

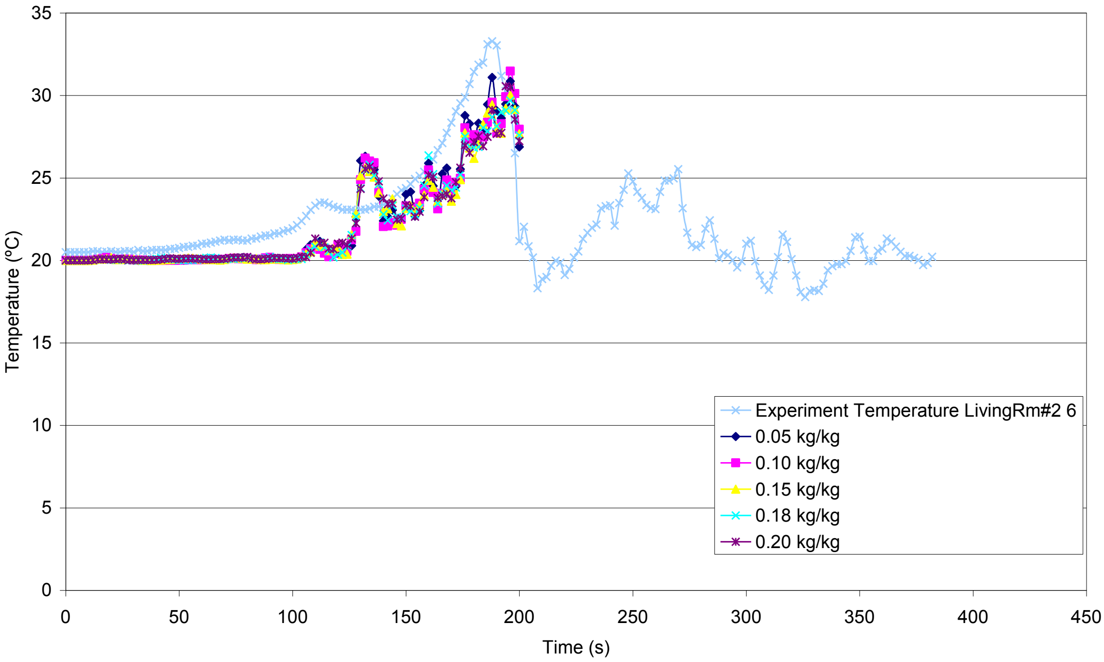
(c)


Temperature (ºC)
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#2 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

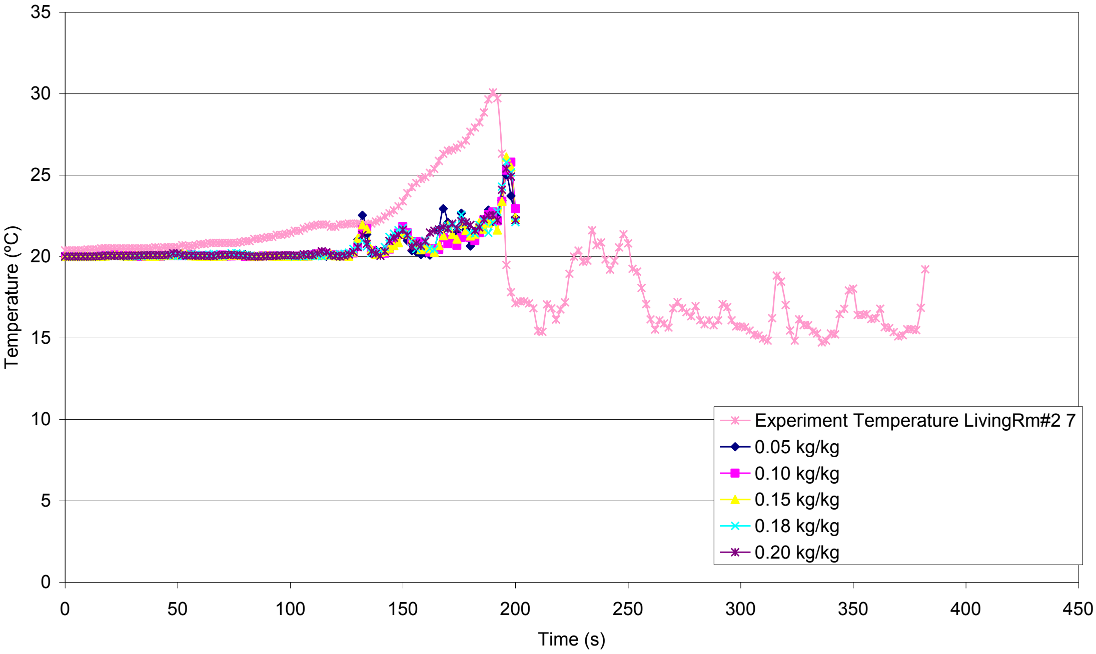
(d)


Temperature (ºC)
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature LivingRm#2 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(e)

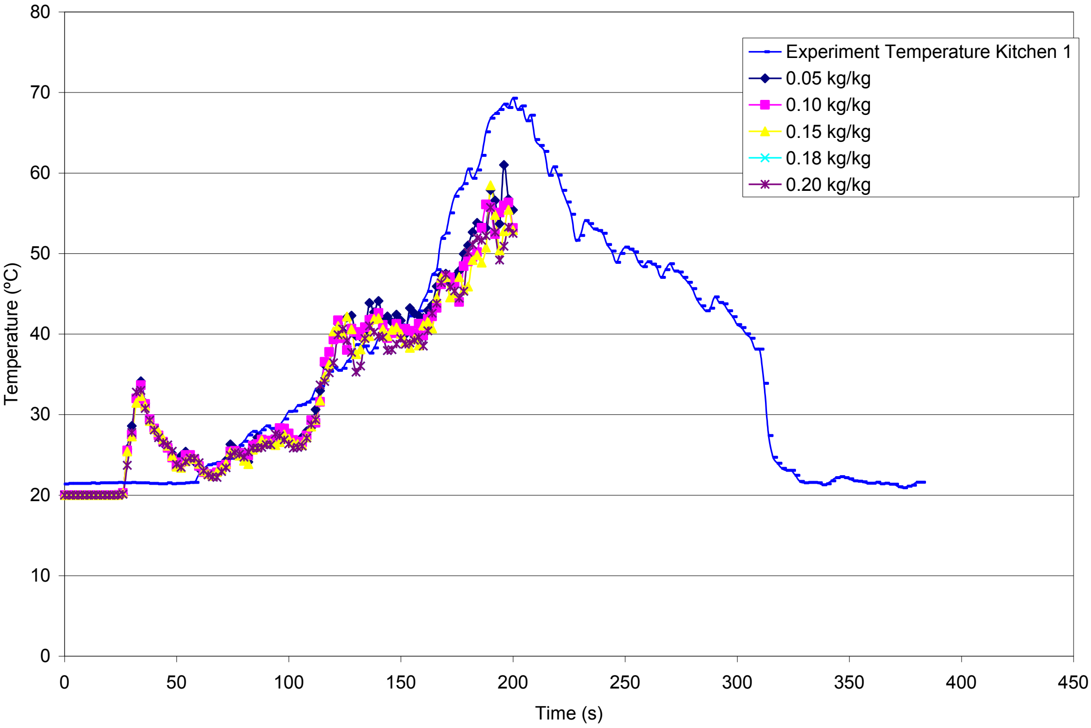


(f)

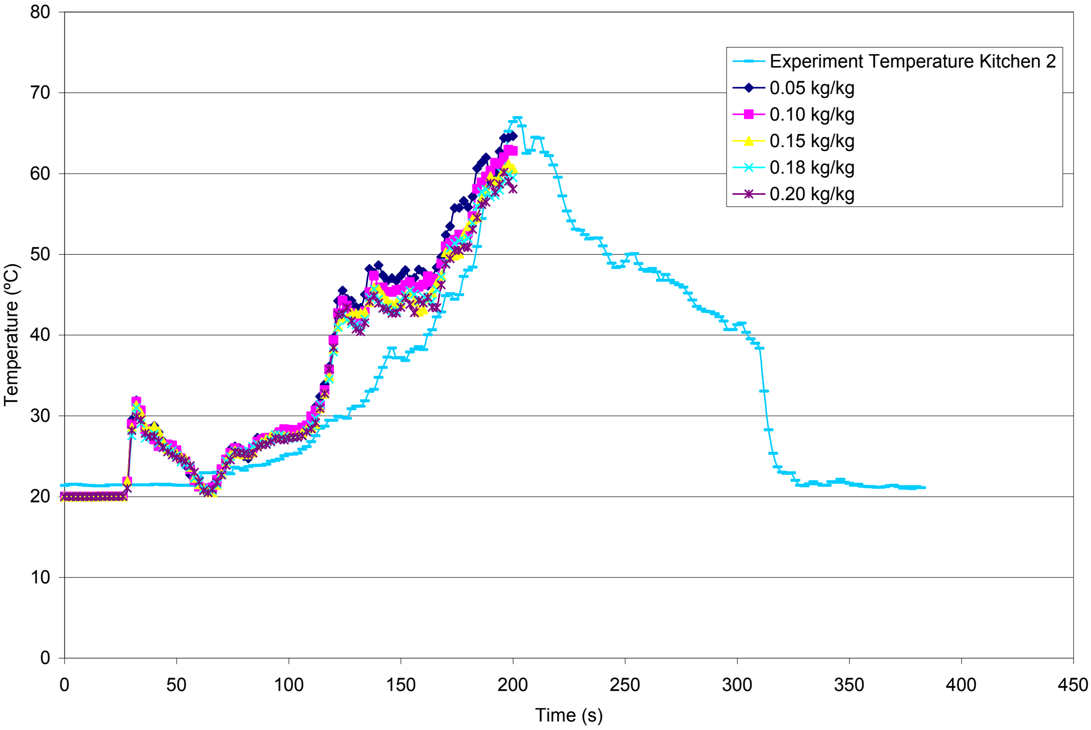


(g)

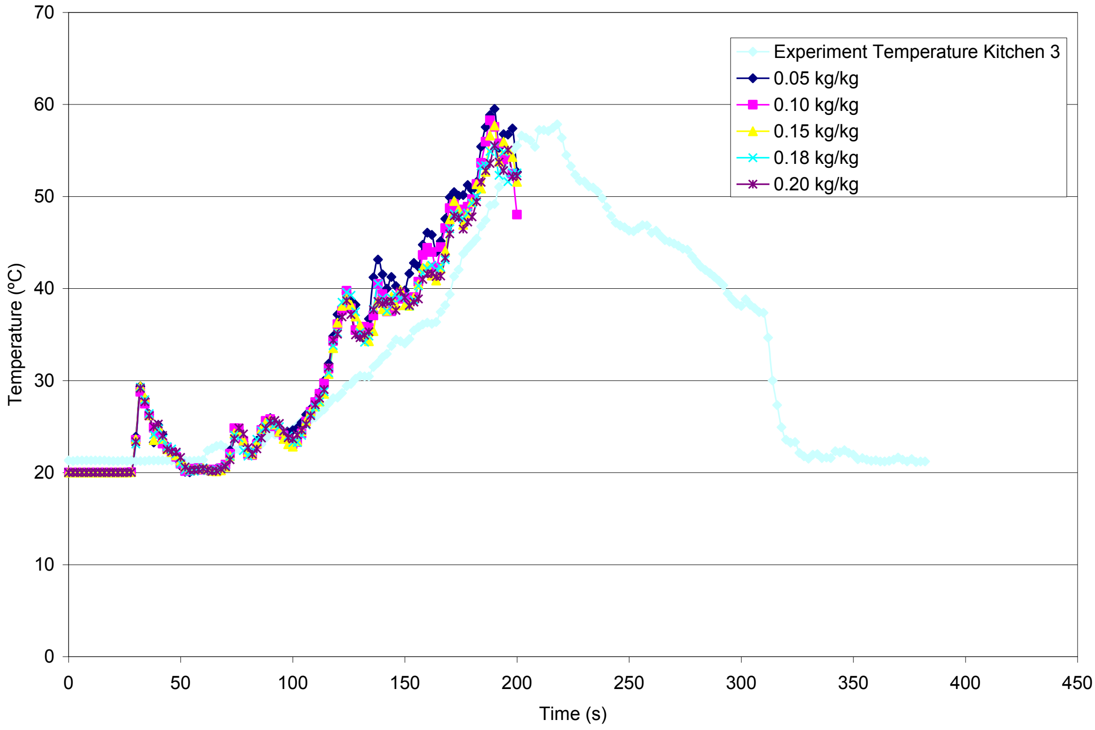
Figure 43. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Living Room #2 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Kitchen 1
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

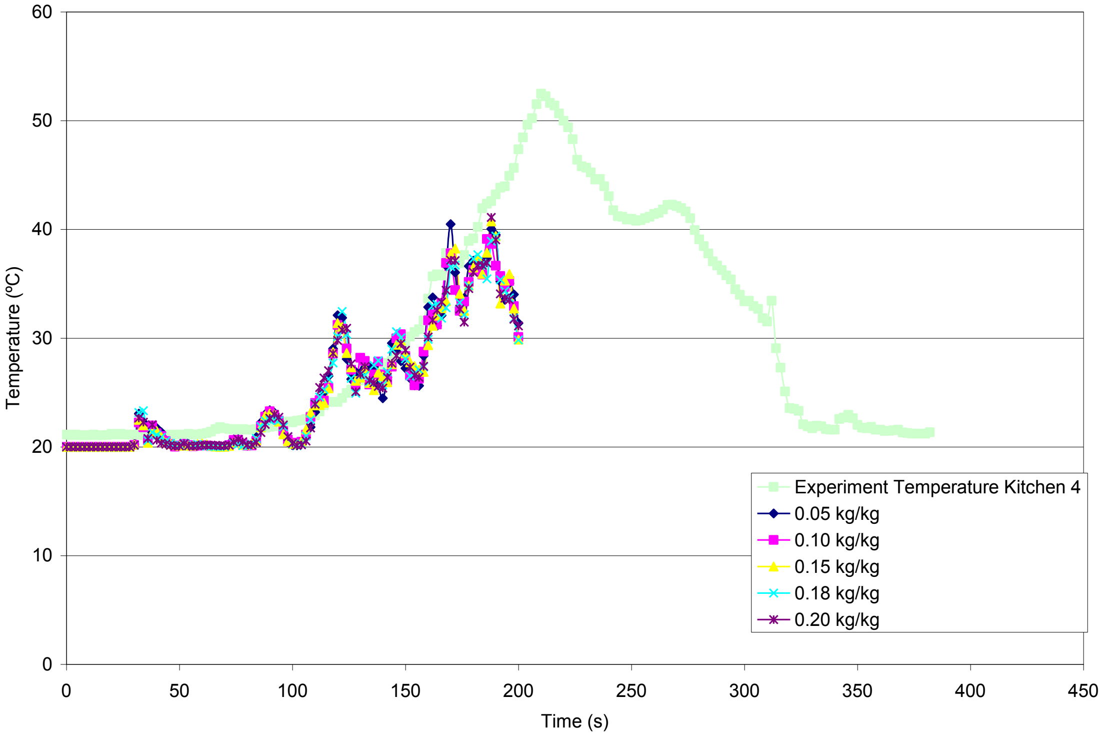
(a)


Temperature (ºC)
Time (s)
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Kitchen 2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

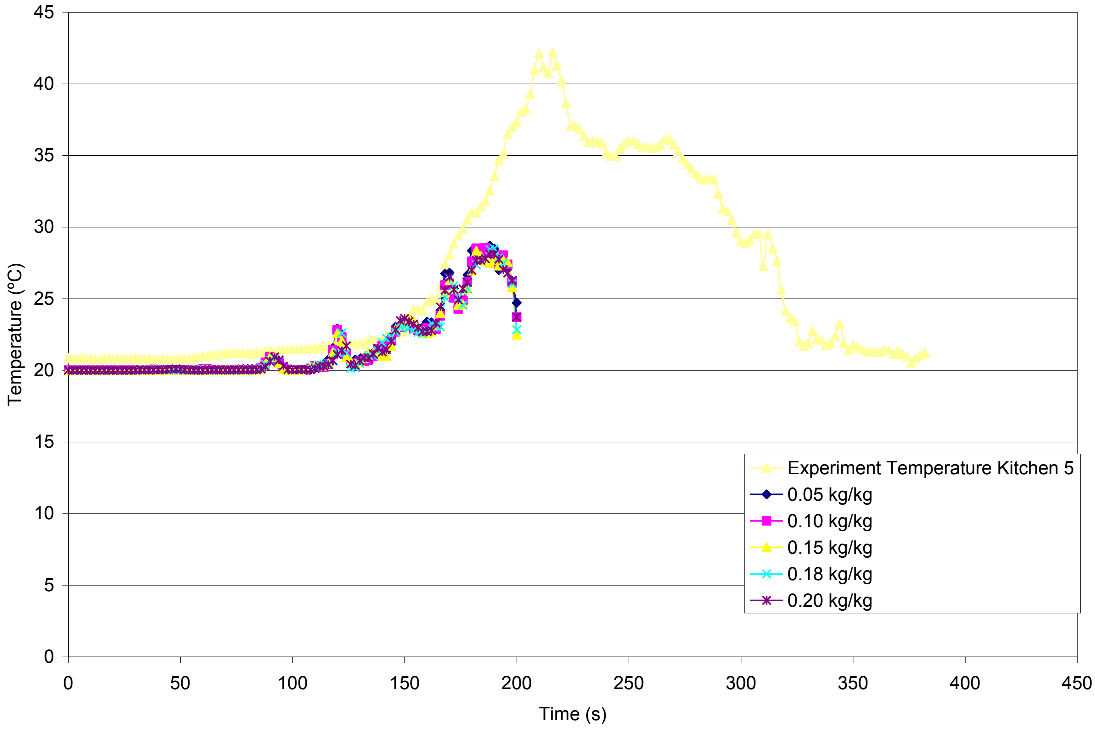
(b)


70
60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

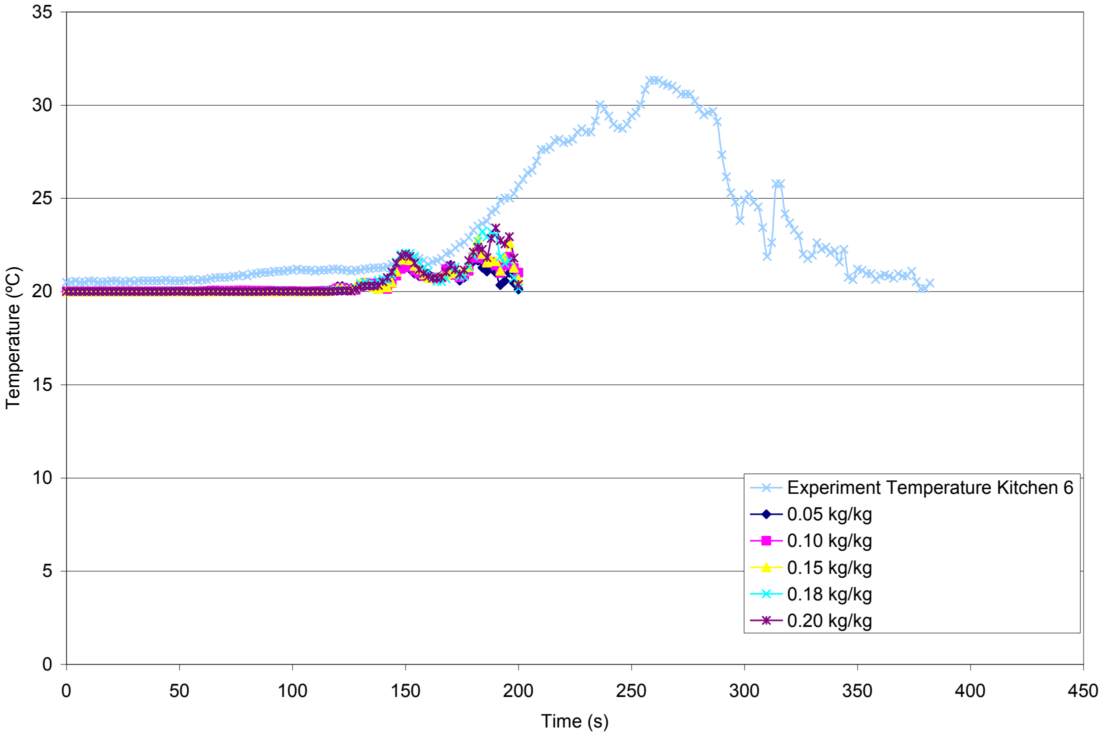
(c)


60
50
40
30
20
10
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

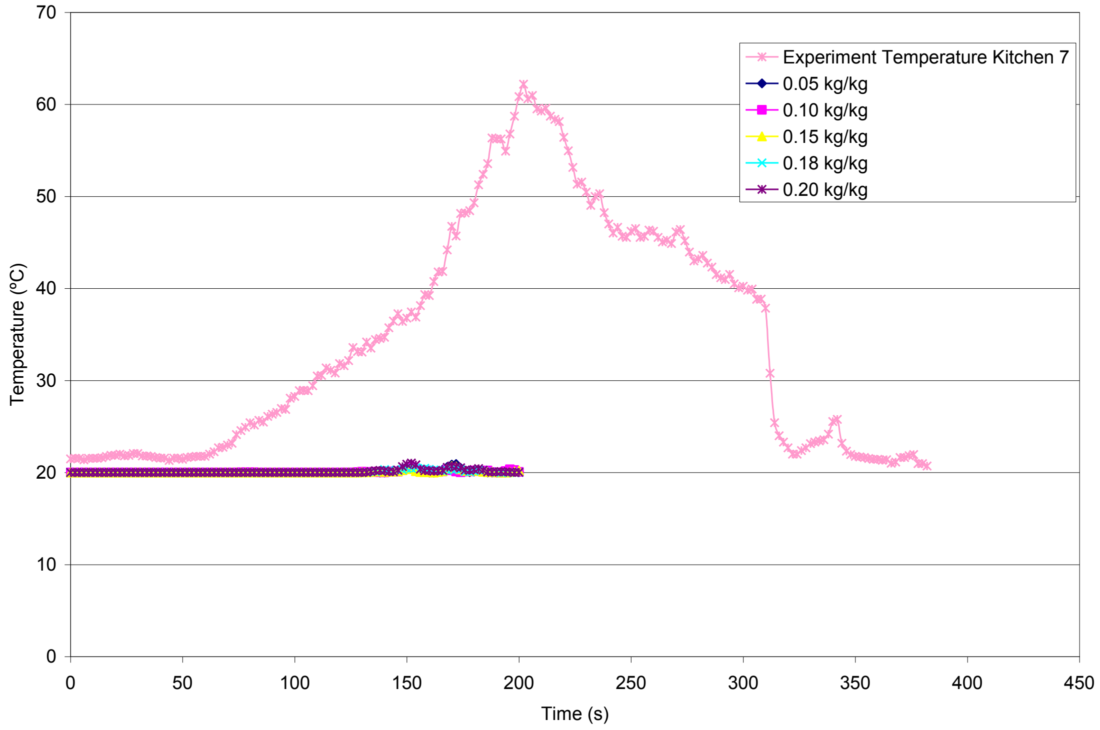
(d)


Temperature (°C)
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(e)

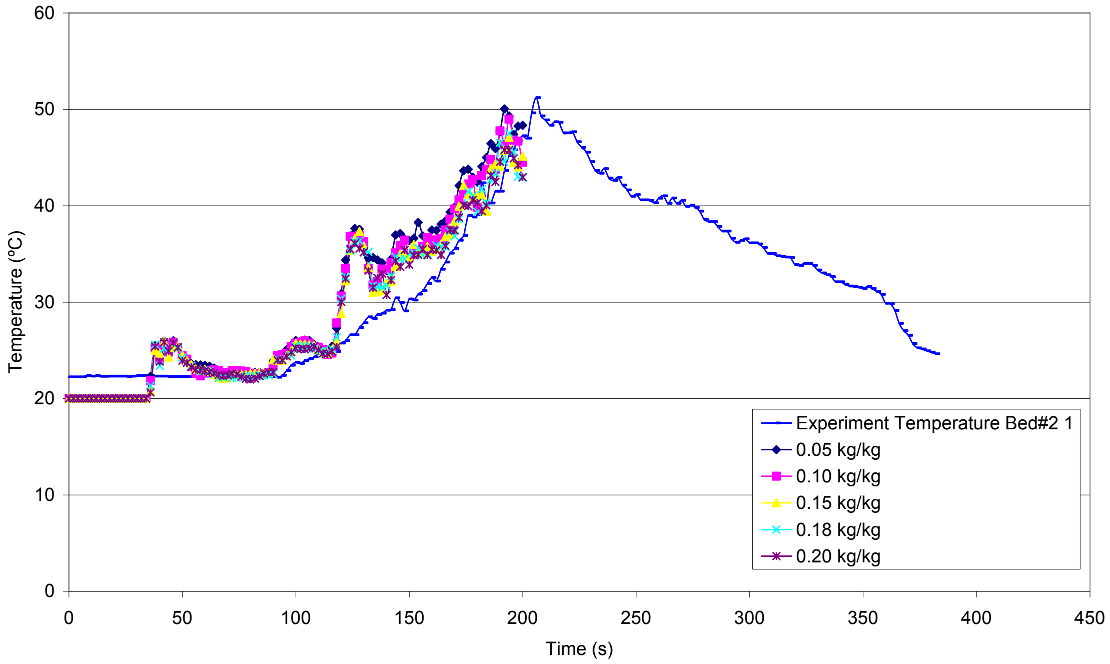

Temperature (°C)
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Kitchen 6
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(f)

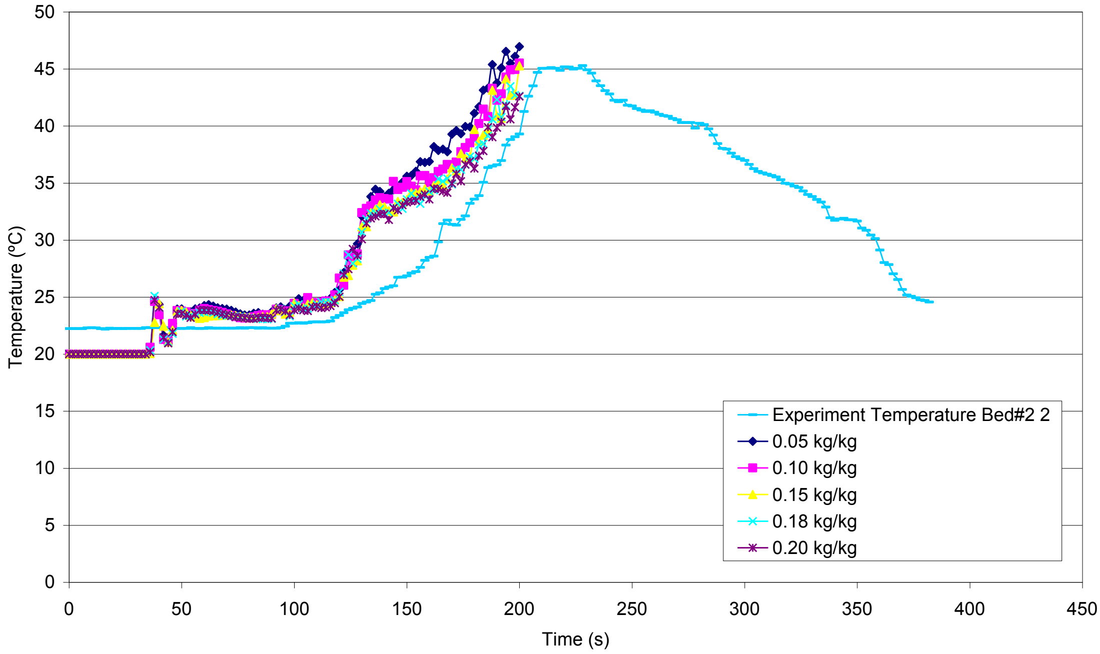


(g)

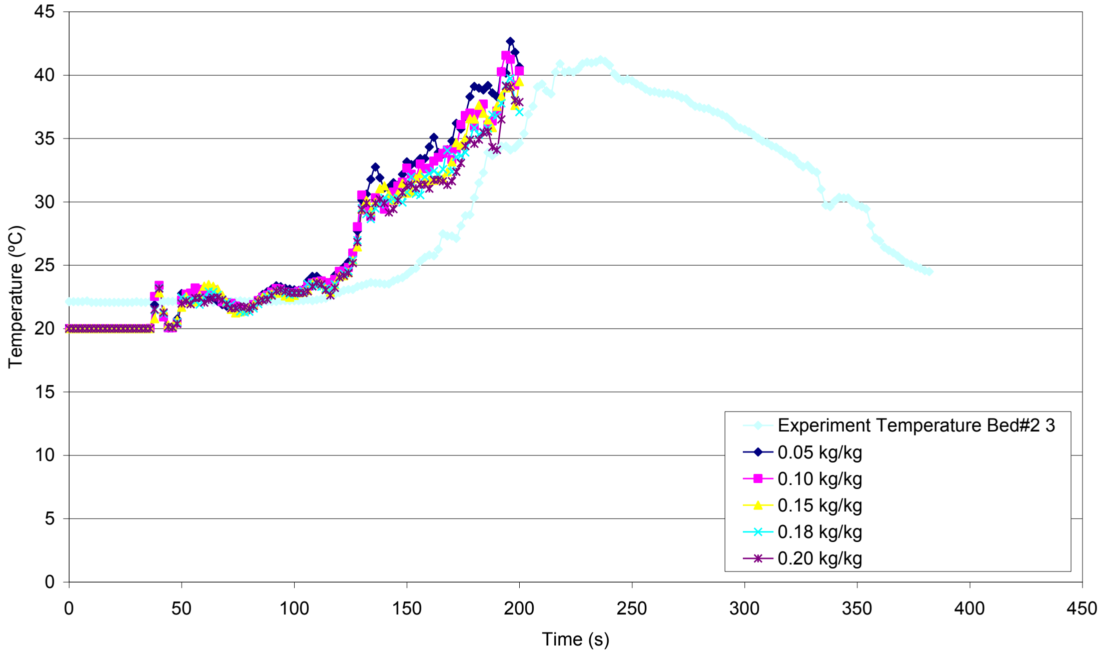
Figure 44. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Kitchen temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling



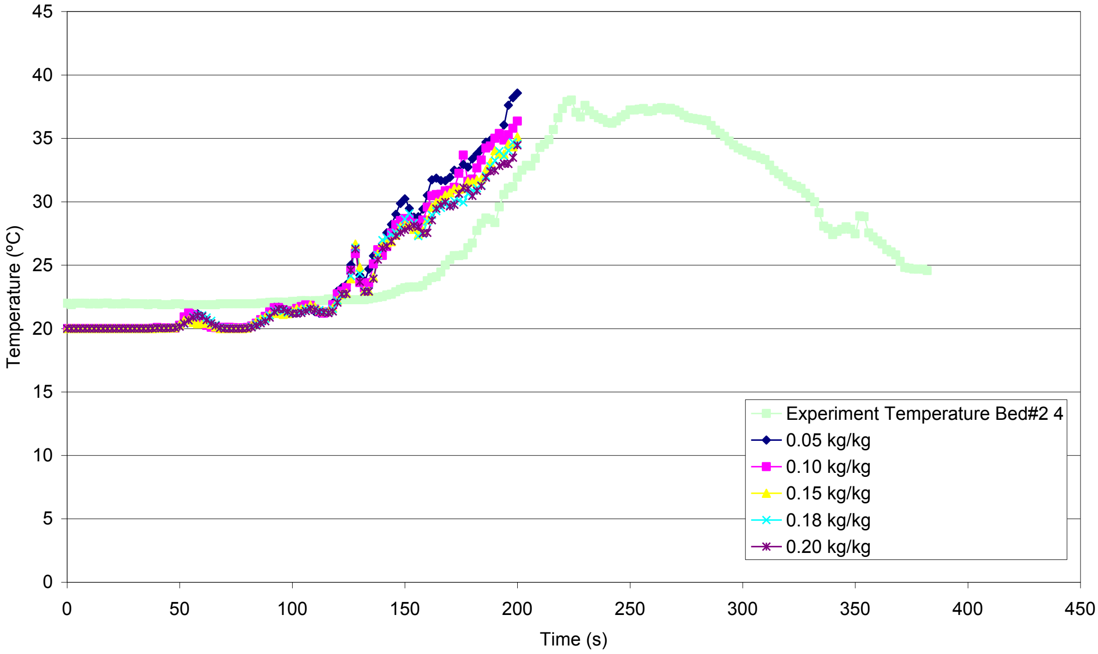
(a)


Temperature (ºC)
0
5
10
15
20
25
30
35
40
45
50
Time (s)
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Bed#2 2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

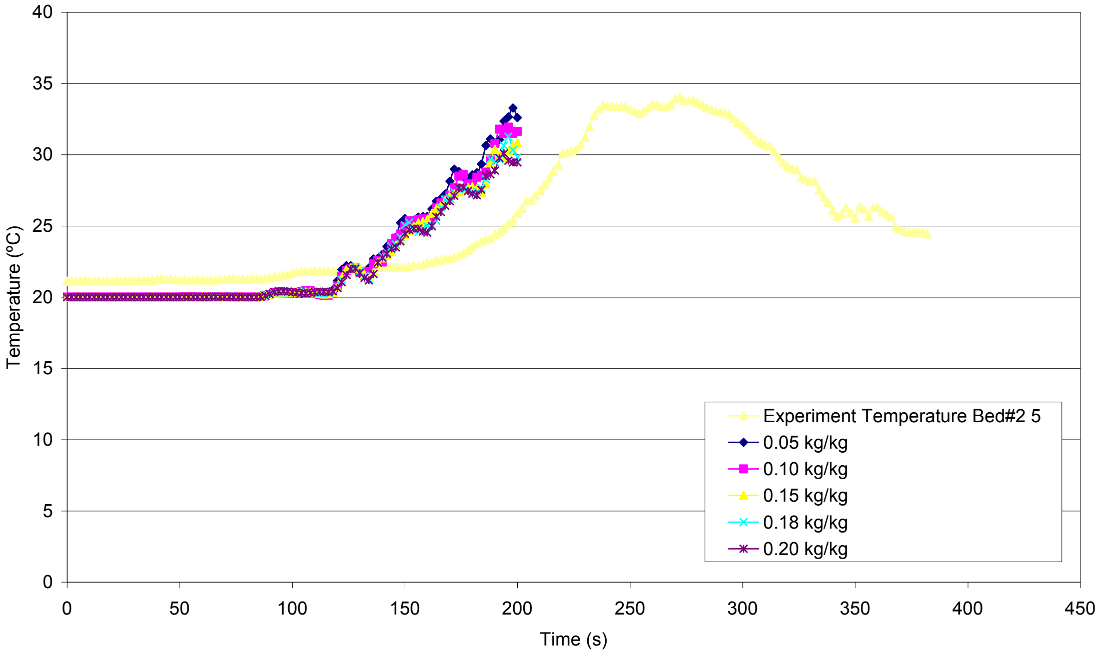
(b)


Temperature (ºC)
0
5
10
15
20
25
30
35
40
45
Time (s)
0
50
100
150
200
250
300
350
400
450
Experiment Temperature Bed#2 3
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

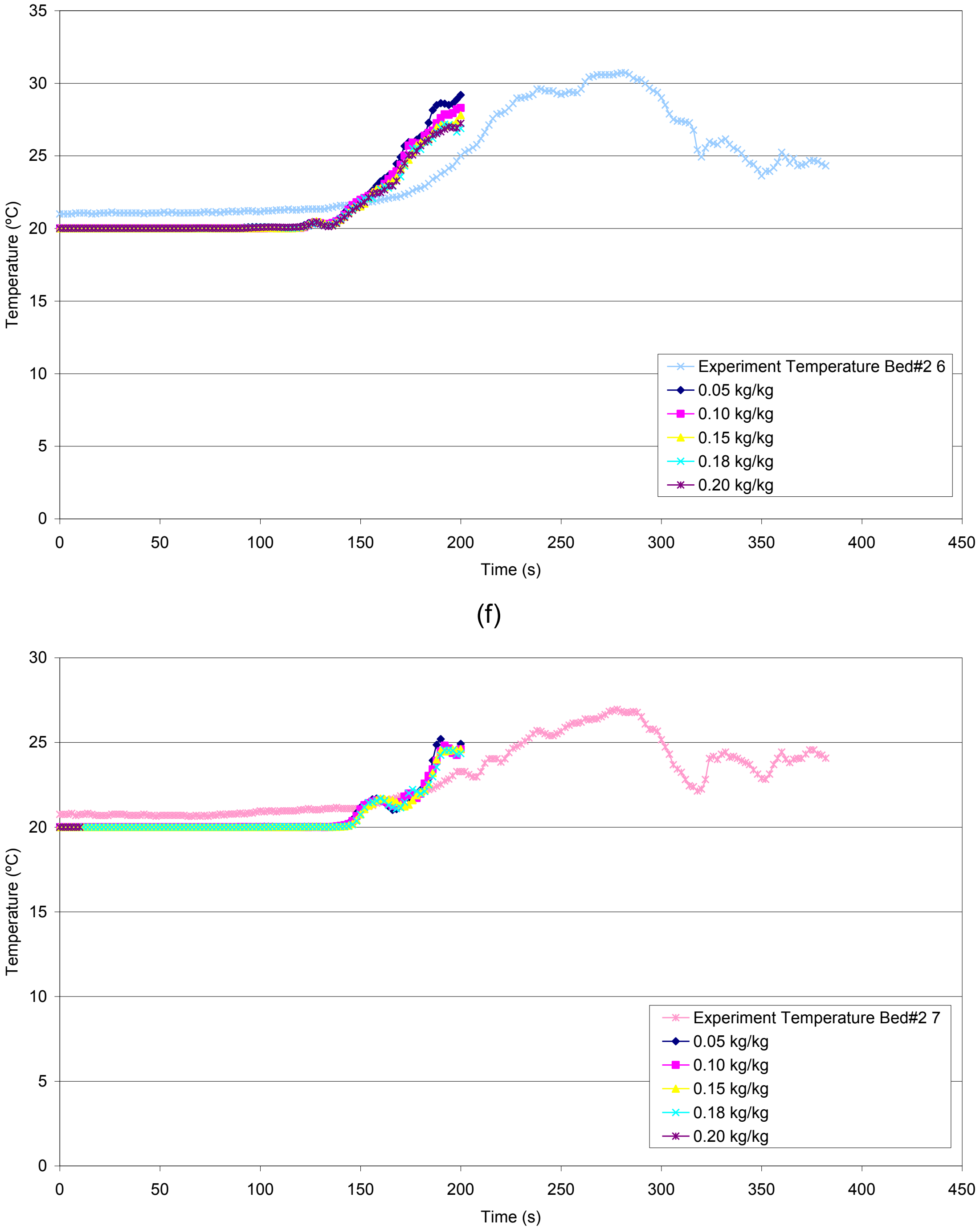
(c)


45
40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 4
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(d)


40
35
30
25
20
15
10
5
0
Temperature (ºC)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment Temperature Bed#2 5
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

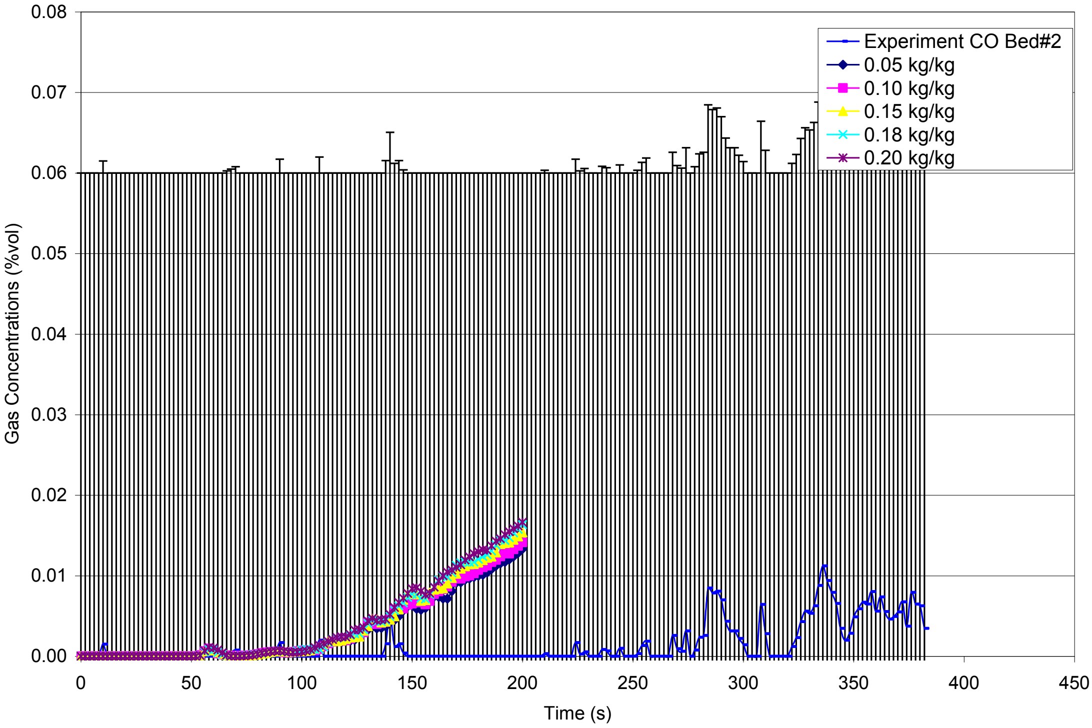
(e)



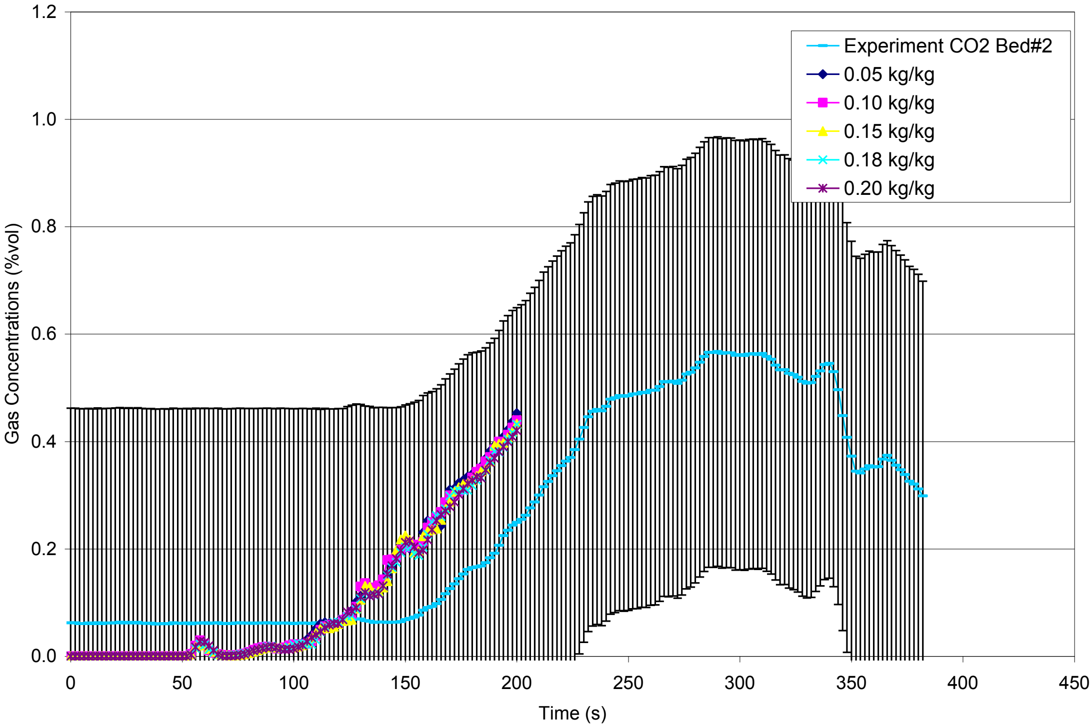
(f)

(g)

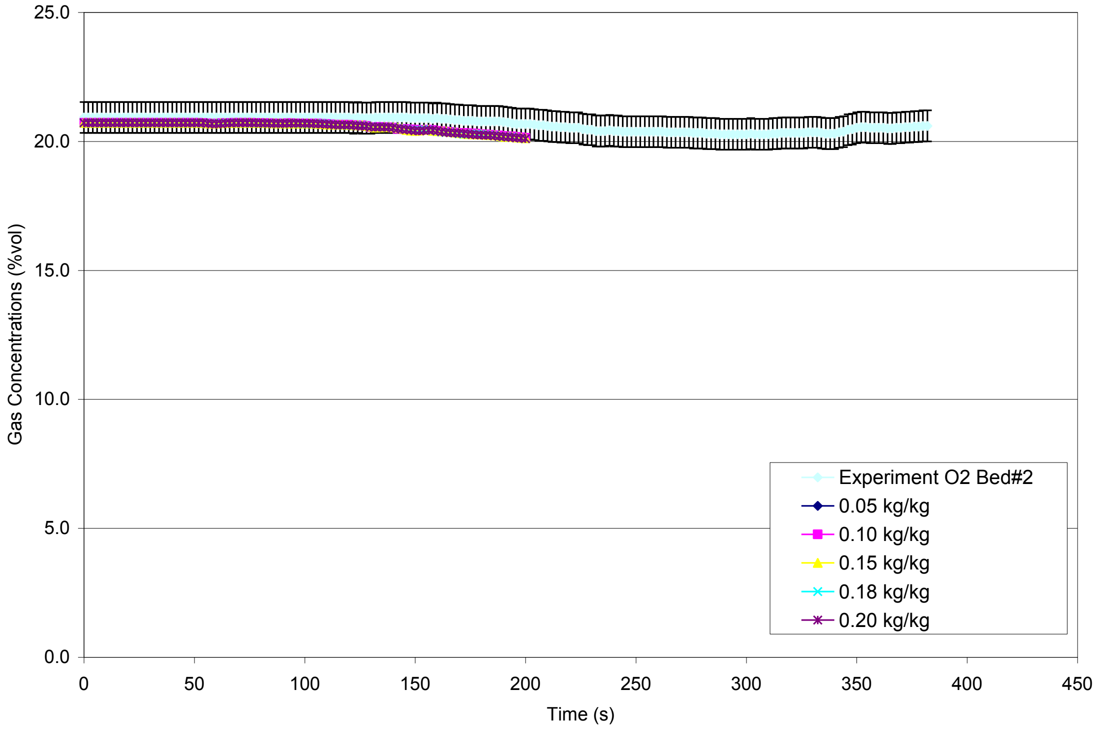
Figure 45. Experiment and model results, using FDS 100 mm grid spacing and soot yield values from 0.05 – 0.20 kg/kg, for Bedroom #2 temperatures at locations of (a) 20 mm, (b) 300 mm, (c) 610 mm, (d) 900 mm, (e) 1200 mm, (f) 1520 mm and (g) 1820 mm below the ceiling


0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Bed#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(a)

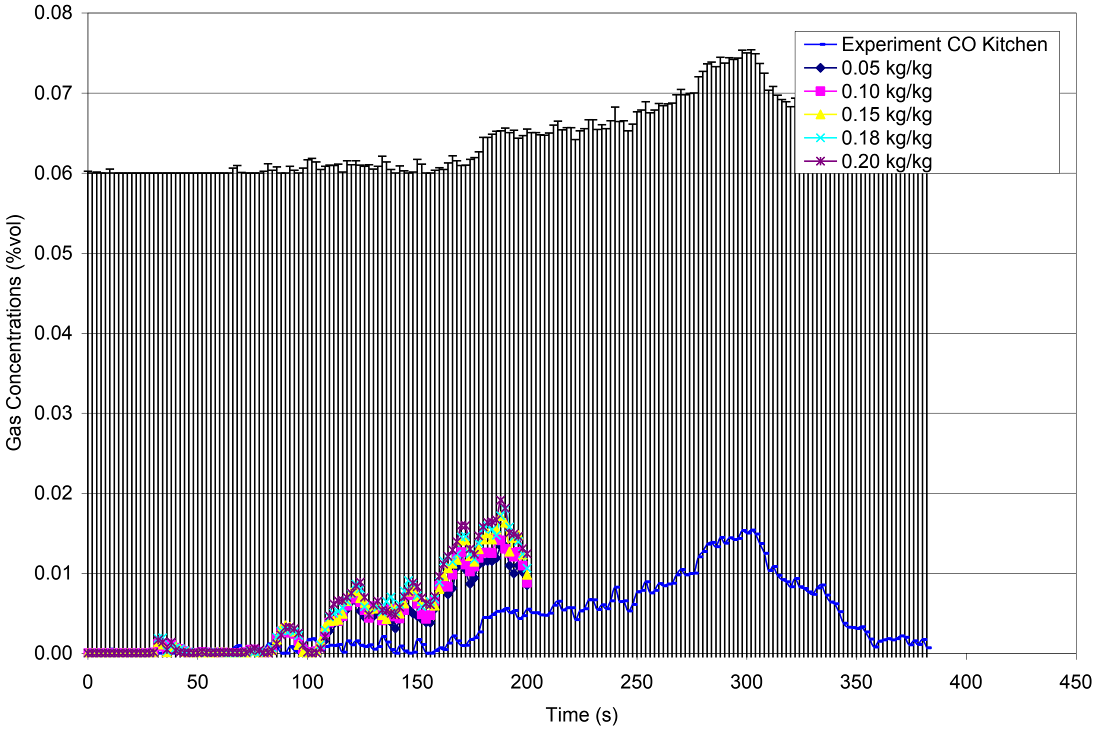

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Gas Concentrations (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Bed#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)

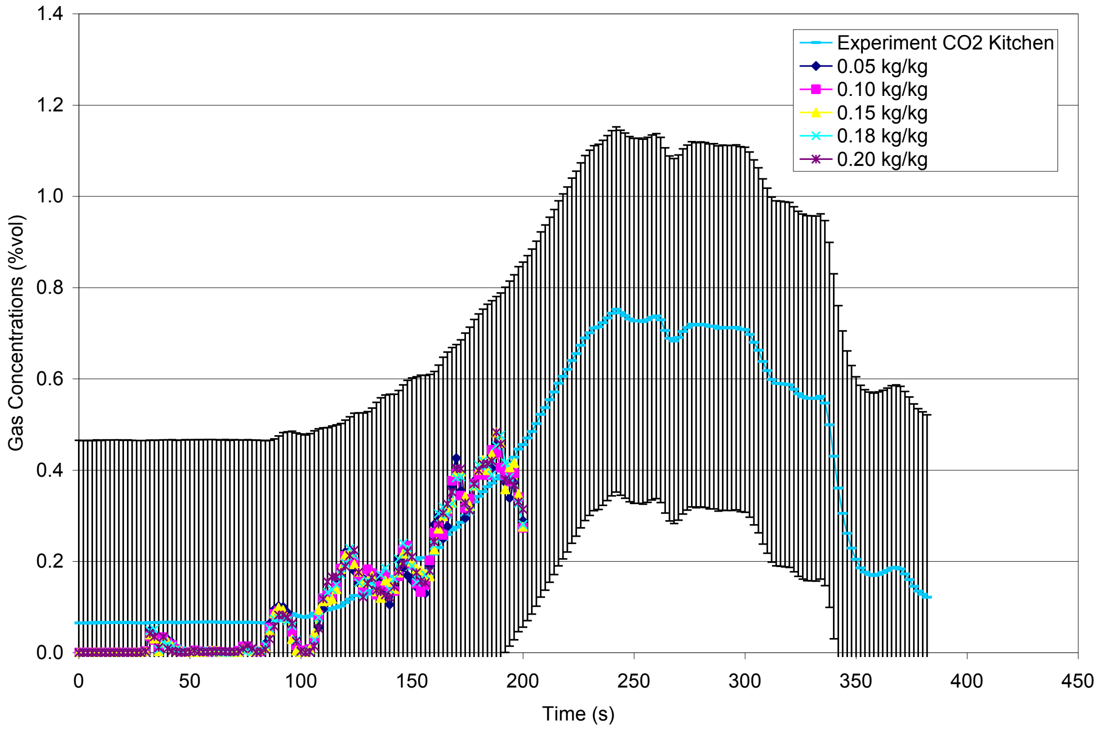


(c)

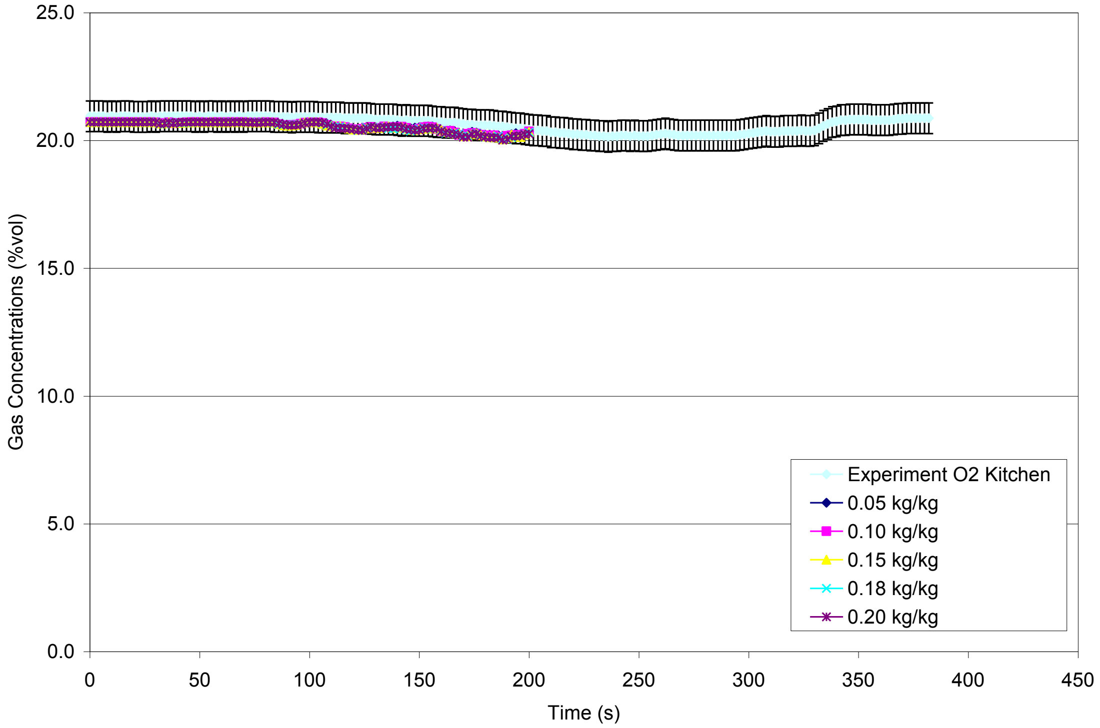
Figure 46. Experiment and model results, using FDS 100 mm grid spacing, for Bedroom #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



(a)

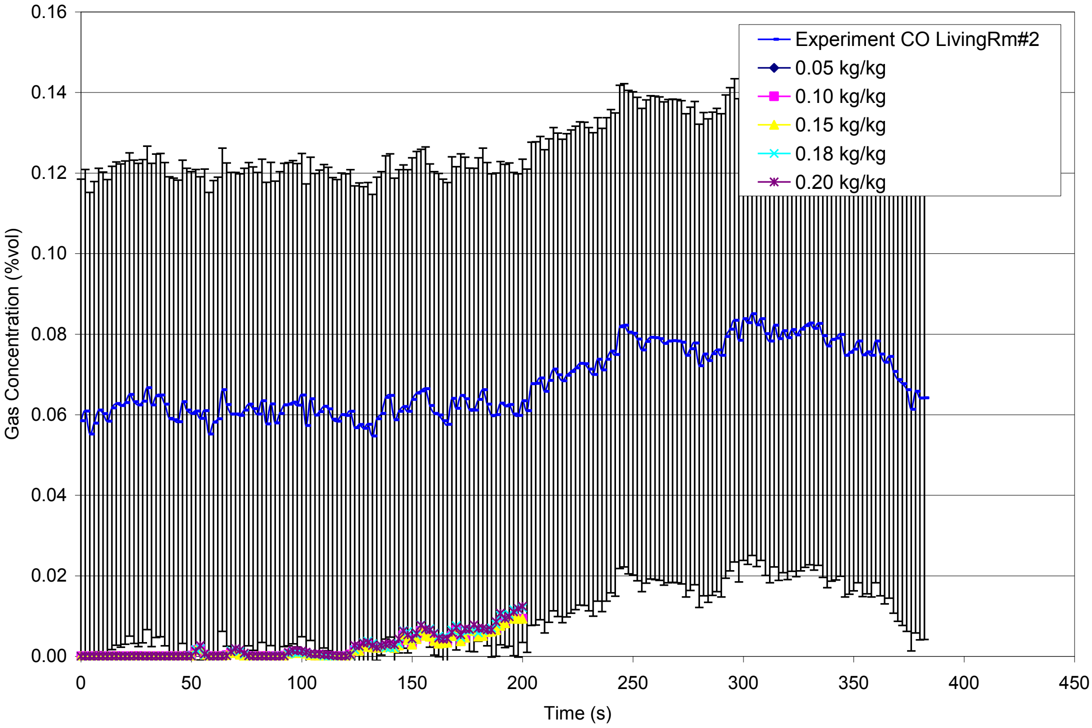


(b)

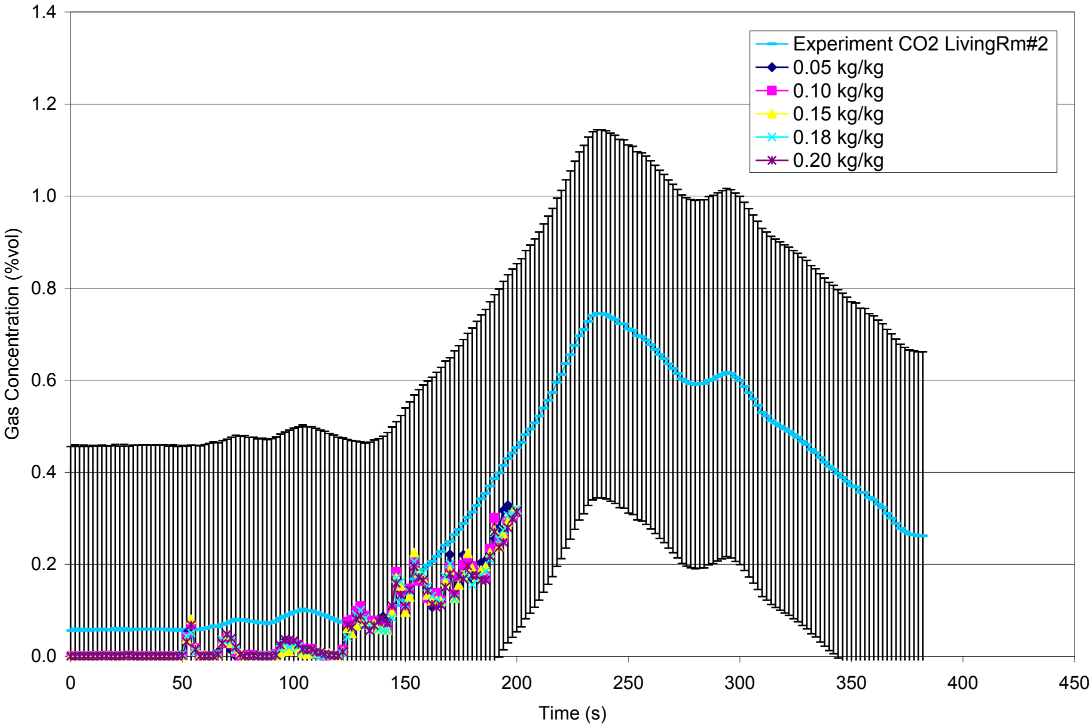


(c)

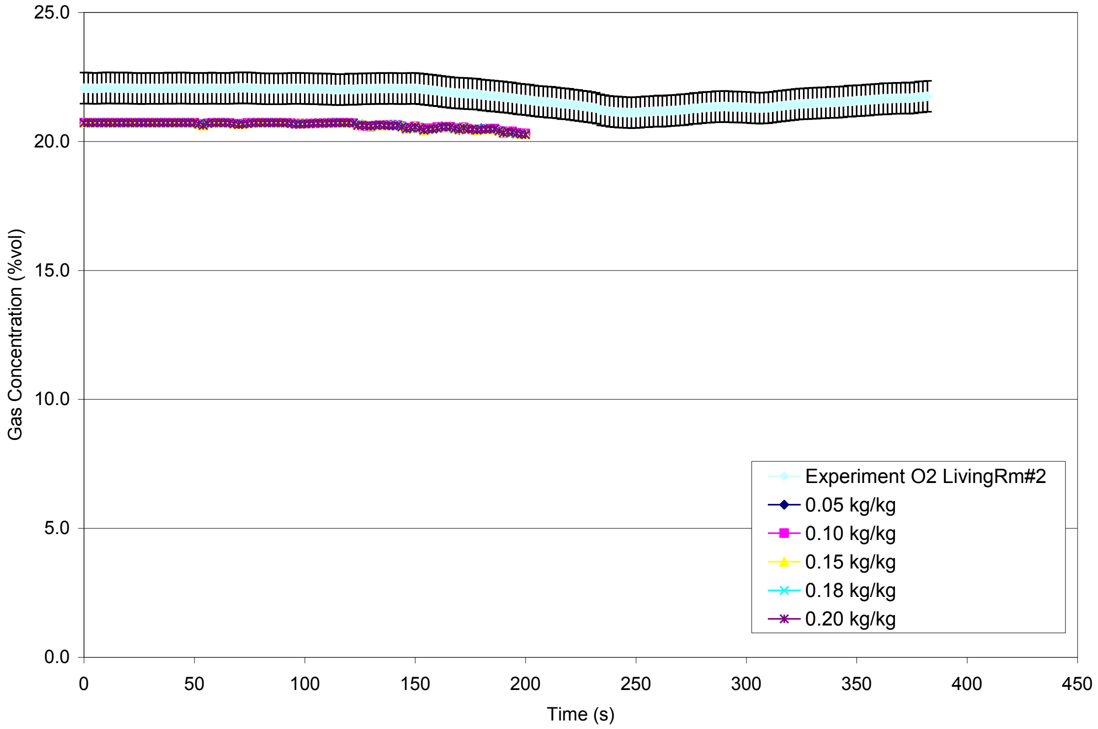
Figure 47. Experiment and model results, using FDS 100 mm grid spacing, for Kitchen (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages


0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Gas Concentration (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO LivingRm#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(a)

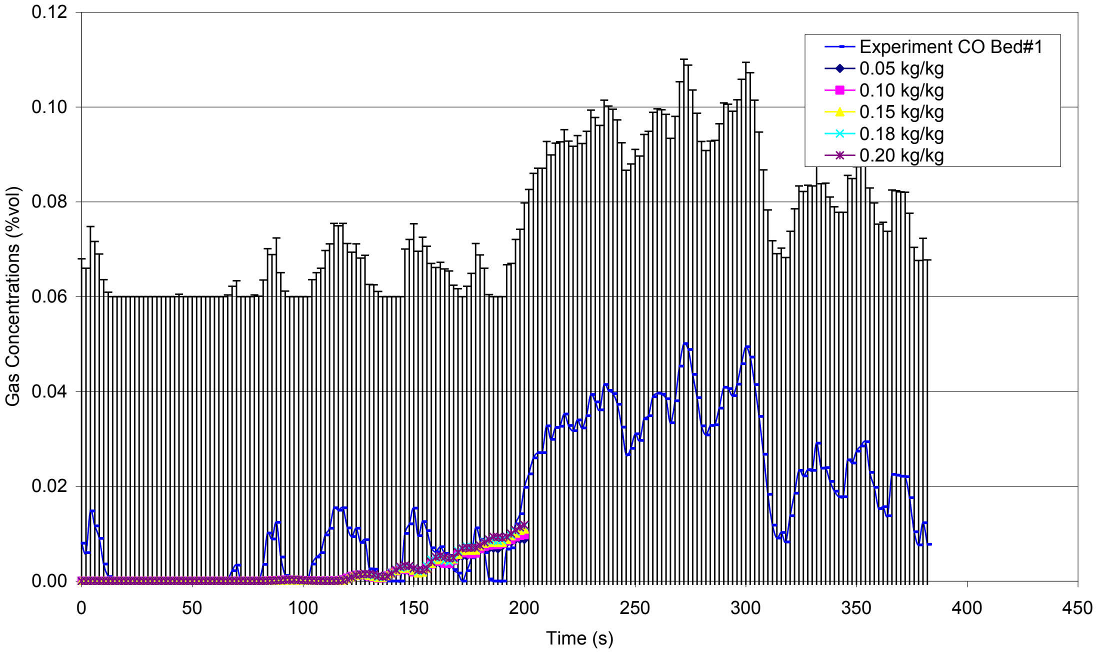

1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Gas Concentration (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 LivingRm#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)

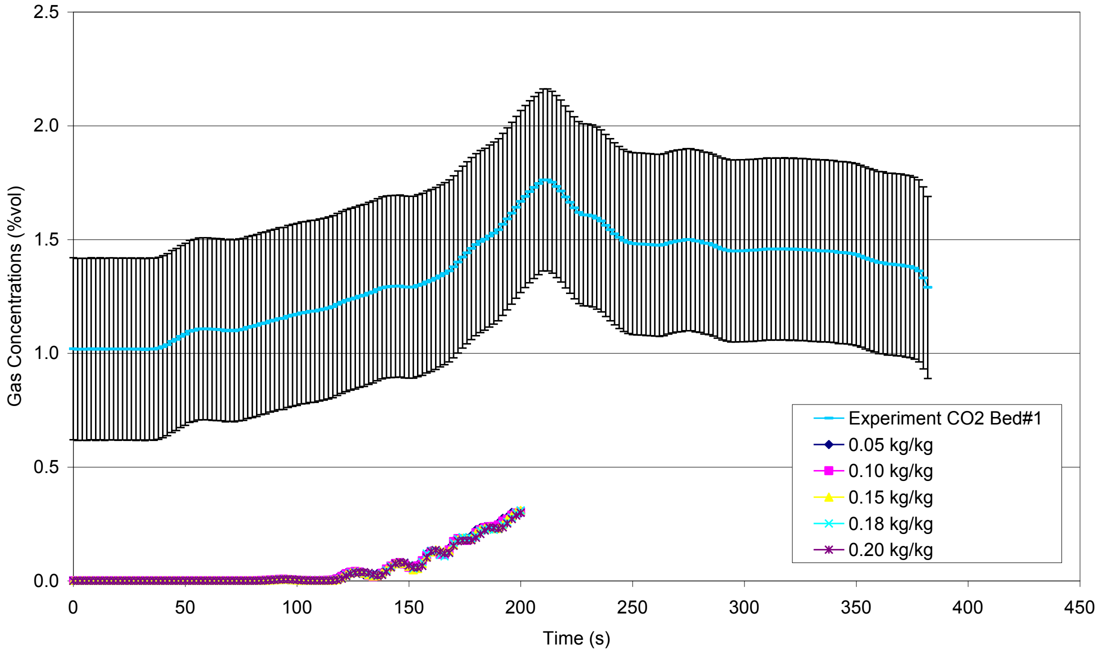


(c)

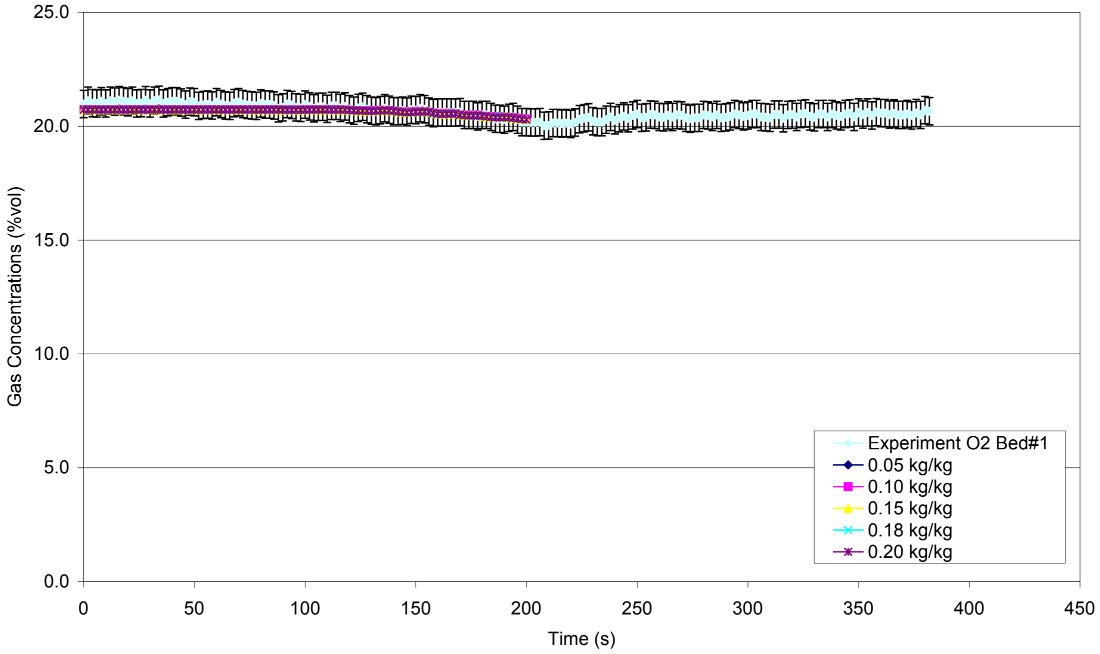
Figure 48. An example of results for a location near to the seat of the fire. Experiment and model results, using FDS 100 mm grid spacing, for Living Room #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



(a)



(b)



(c)

Figure 49. An example of results for a location remote from the seat of the fire. Experiment and model results, using FDS 100 mm grid spacing, for Bedroom #1 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages

APPENDIX C   BRANZFIRE INPUT AND RESULTS

C.1   Scenario 5 – 0.05 kg/kg Soot Yield

C.1.1   Input

```
Wednesday,July 25,2007,09:23 AM
Input Filename: C:\FD0758SmokeYieldValues\BRANZFIRE\BRANZFIRE with CO2 yield (revised 17-07-07)\Smoke 0_05 b.mod

BRANZFIRE Multi-Compartment Fire Model (Ver 2007.2)

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=====================================================================
Description of Rooms
=====================================================================
Room  1  : Living room /Kitchen
        Room Length (m) =                   8.34
        Room Width (m) =                   4.17
        Maximum Room Height (m) =                2.40
        Minimum Room Height (m) =               2.10
        Floor Elevation (m) =               0.000
        Room  1  has a sloping ceiling.

        Wall Surface is concrete
        Wall Density (kg/m3) =                2300.0
        Wall Conductivity (W/m.K) =               1.200
        Wall Emissivity =                0.50
        Wall Thickness (mm) =                 100.0

        Ceiling Surface is concrete
        Ceiling Density (kg/m3) =                2300.0
        Ceiling Conductivity (W/m.K) =              1.200
        Ceiling Emissivity =                0.50
        Ceiling Thickness (mm) =                 100.0

        Floor Surface is concrete
        Floor Density (kg/m3) =                2300.0
        Floor Conductivity (W/m.K) =               1.200
        Floor Emissivity =                0.50
        Floor Thickness = (mm)                 100.0

Room  2  : Bedroom #2
        Room Length (m) =                   3.38
        Room Width (m) =                   4.17
        Maximum Room Height (m) =                2.40
        Minimum Room Height (m) =               2.10
        Floor Elevation (m) =               0.000
        Room  2  has a sloping ceiling.

        Wall Surface is concrete
        Wall Density (kg/m3) =                2300.0
        Wall Conductivity (W/m.K) =               1.200
        Wall Emissivity =                0.50
        Wall Thickness (mm) =                 100.0

        Ceiling Surface is concrete
        Ceiling Density (kg/m3) =                2300.0
        Ceiling Conductivity (W/m.K) =              1.200
        Ceiling Emissivity =                0.50
        Ceiling Thickness (mm) =                 100.0

        Floor Surface is concrete
        Floor Density (kg/m3) =                2300.0
        Floor Conductivity (W/m.K) =               1.200
        Floor Emissivity =                0.50
        Floor Thickness = (mm)                 100.0
```

```
Room  3  : Bathroom
        Room Length (m) =                      2.16
        Room Width (m) =                      2.13
        Maximum Room Height (m) =                     2.40
        Minimum Room Height (m) =                     2.10
        Floor Elevation (m) =                 0.000
        Room  3  has a flat ceiling.

        Wall Surface is concrete
        Wall Density (kg/m3) =                 2300.0
        Wall Conductivity (W/m.K) =               1.200
        Wall Emissivity =                   0.50
        Wall Thickness (mm) =                   100.0

        Ceiling Surface is concrete
        Ceiling Density (kg/m3) =                 2300.0
        Ceiling Conductivity (W/m.K) =               1.200
        Ceiling Emissivity =                   0.50
        Ceiling Thickness (mm) =                   100.0

        Floor Surface is concrete
        Floor Density (kg/m3) =                 2300.0
        Floor Conductivity (W/m.K) =               1.200
        Floor Emissivity =                   0.50
        Floor Thickness = (mm)                   100.0

Room  4  : Hall
        Room Length (m) =                      4.02
        Room Width (m) =                      0.81
        Maximum Room Height (m) =                     2.10
        Minimum Room Height (m) =                     2.10
        Floor Elevation (m) =                 0.000
        Room  4  has a flat ceiling.

        Wall Surface is concrete
        Wall Density (kg/m3) =                 2300.0
        Wall Conductivity (W/m.K) =               1.200
        Wall Emissivity =                   0.50
        Wall Thickness (mm) =                   100.0

        Ceiling Surface is concrete
        Ceiling Density (kg/m3) =                 2300.0
        Ceiling Conductivity (W/m.K) =               1.200
        Ceiling Emissivity =                   0.50
        Ceiling Thickness (mm) =                   100.0

        Floor Surface is concrete
        Floor Density (kg/m3) =                 2300.0
        Floor Conductivity (W/m.K) =               1.200
        Floor Emissivity =                   0.50
        Floor Thickness = (mm)                   100.0

Room  5  : Bedroom #1
        Room Length (m) =                      3.18
        Room Width (m) =                      4.17
        Maximum Room Height (m) =                     2.40
        Minimum Room Height (m) =                     2.10
        Floor Elevation (m) =                 0.000
        Room  5  has a sloping ceiling.

        Wall Surface is concrete
        Wall Density (kg/m3) =                 2300.0
        Wall Conductivity (W/m.K) =               1.200
        Wall Emissivity =                   0.50
        Wall Thickness (mm) =                   100.0

        Ceiling Surface is concrete
        Ceiling Density (kg/m3) =                 2300.0
        Ceiling Conductivity (W/m.K) =               1.200
        Ceiling Emissivity =                   0.50
        Ceiling Thickness (mm) =                   100.0

        Floor Surface is concrete
        Floor Density (kg/m3) =                 2300.0
        Floor Conductivity (W/m.K) =               1.200
        Floor Emissivity =                   0.50
```

```
     Floor Thickness = (mm)                100.0

======================================================================
Wall Vents
======================================================================
From room 1  to  2 , Vent No 1
          Vent Width (m) =              0.800
          Vent Height (m) =             1.800
          Vent Sill Height (m) =         0.000
          Vent Soffit Height (m) =        1.800
          Opening Time (sec) =            0
          Closing Time (sec) =           250

From room 1  to  3 , Vent No 1
          Vent Width (m) =              0.800
          Vent Height (m) =             0.100
          Vent Sill Height (m) =         0.000
          Vent Soffit Height (m) =        0.100
          Opening Time (sec) =            0
          Closing Time (sec) =           250

From room  1  to  4 , Vent No 1
          Vent Width (m) =              0.800
          Vent Height (m) =             1.800
          Vent Sill Height (m) =         0.000
          Vent Soffit Height (m) =        1.800
          Opening Time (sec) =            0
          Closing Time (sec) =           250

From room  1  to outside, Vent No 1
          Vent Width (m) =              0.000
          Vent Height (m) =             0.000
          Vent Sill Height (m) =         0.000
          Vent Soffit Height (m) =        0.000
          Opening Time (sec) =            0
          Closing Time (sec) =           0

From room  3  to outside, Vent No 1
          Vent Width (m) =              0.250
          Vent Height (m) =             0.250
          Vent Sill Height (m) =         1.500
          Vent Soffit Height (m) =        1.750
          Opening Time (sec) =            0
          Closing Time (sec) =           250

From room  4  to  5 , Vent No 1
          Vent Width (m) =              0.800
          Vent Height (m) =             1.800
          Vent Sill Height (m) =         0.000
          Vent Soffit Height (m) =        1.800
          Opening Time (sec) =            0
          Closing Time (sec) =           250

======================================================================
Ceiling/Floor Vents
======================================================================
======================================================================
Ambient Conditions
======================================================================
Interior Temp (C) =                     20.0
Exterior Temp (C) =                      18.0
Relative Humidity (%) =                   65

======================================================================
Tenability Parameters
======================================================================
Monitoring Height for Visibility and FED (m) =        2.00
Occupant Activity Level =                   Light
Visibility calculations assume:              reflective signs
FED Start Time (sec)                       0
FED End Time (sec)                          10000

======================================================================
Sprinkler / Detector Parameters
======================================================================
No thermal detector or sprinkler installed.
```

```
======================================================================
Mechanical Ventilation (to/from outside)
======================================================================
Mechanical Ventilation not installed in Room 1
Mechanical Ventilation not installed in Room 2
Mechanical Ventilation not installed in Room 3
Mechanical Ventilation not installed in Room 4
Mechanical Ventilation not installed in Room 5

======================================================================
Description of the Fire
======================================================================
Radiant Loss Fraction =                          0.52
CO Yield pre-flashover(kg/kg) =                     0.040
CO Yield post-flashover(kg/kg) =                    0.200
Soot Yield pre-flashover(kg/kg) =                   0.050
Soot Yield post-flashover(kg/kg) =                  0.200
Smoke Emission Coefficient (1/m) =                   1.20
Characteristic Mass Loss per Unit Area (kg/s.m2) =       0.011
Air Entrainment in Plume uses McCaffrey (default)

Burning Object No 1

       Located in Room                  1
       Energy Yield (kJ/g) =            20.0
       CO2 Yield (kg/kg fuel) =           1.240
       HCN Yield (kg/kg fuel) =           0.000
       Fire Height (m) =              0.410
       Fire Location (m) =             Centre

       Time (sec)          Heat Release (kW)
        0              0
        16             61
        18             0
        44             61
        46             0
        62             61
        64             0
        68             61
        70             0
        76             61
        78             0
        86             61
        88             0
        92             61
        94             0
        96             61
        100             0
        102             122
        104             61
        112             122
        114             0
        116             61
        120             61
        122             61
        126             61
        128             0
        130             122
        132             0
        134             122
        136             61
        138             0
        140             61
        142             122
        144             0
        146             61
        148             61
        150             61
        152             61
        154             122
        156             61
        158             122
        160             122
        162             0
```

```
          164            122
          166            122
          168            61
          170            122
          172            61
          174            183
          176            122
          178            122
          180            122
          182            122
          184            61
          186            183
          188            61
          190            0

======================================================================
Postflashover Inputs
======================================================================
Postflashover model is OFF.
```

C.2 Scenario 2 – 0.10 kg/kg Soot Yield

C.2.1 Input

Same as Section C.1.1, except:

```
Soot Yield pre-flashover(kg/kg) =                            0.100
Soot Yield post-flashover(kg/kg) =                           0.200
```

C.3 Scenario 6 – 0.15 kg/kg Soot Yield

C.3.1 Input

Same as Section C.1.1, except:

```
Soot Yield pre-flashover(kg/kg) =                            0.150
Soot Yield post-flashover(kg/kg) =                           0.300
```

C.4 Scenario 7 – 0.18 kg/kg Soot Yield

C.4.1 Input

Same as Section C.1.1, except:

```
Soot Yield pre-flashover(kg/kg) =                            0.180
Soot Yield post-flashover(kg/kg) =                           0.360
```

C.5 Scenario 8 – 0.20 kg/kg Soot Yield

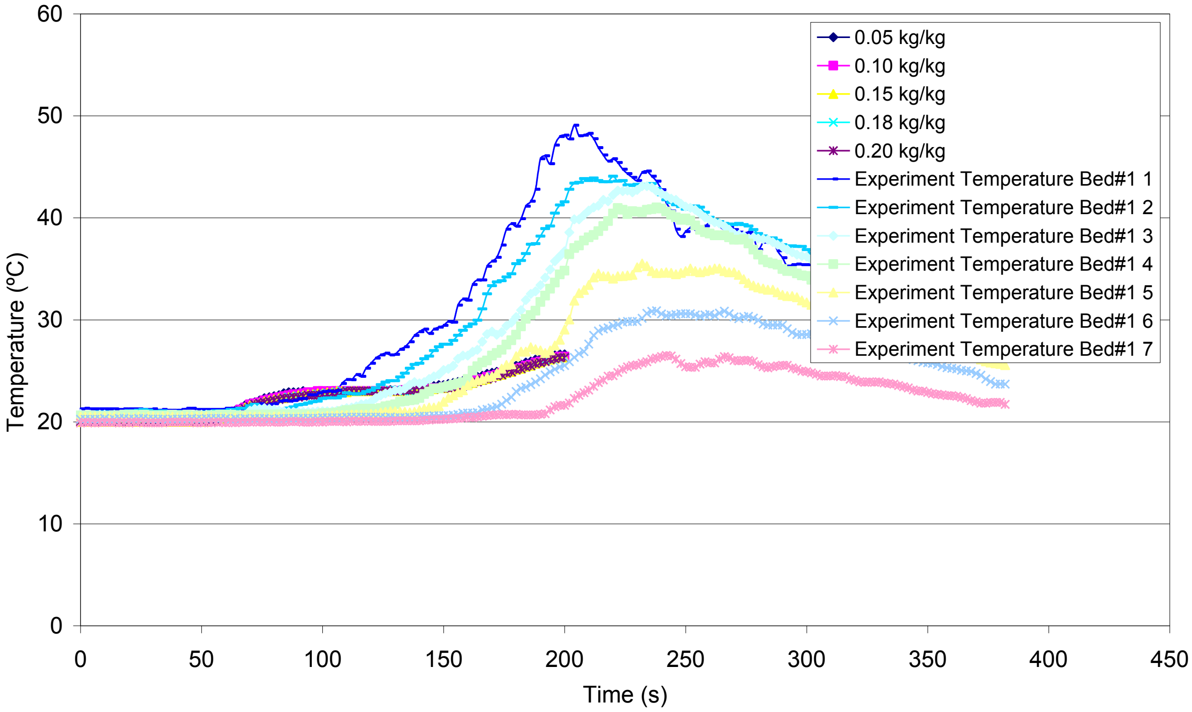
C.5.1 Input

Same as Section C.1.1, except:

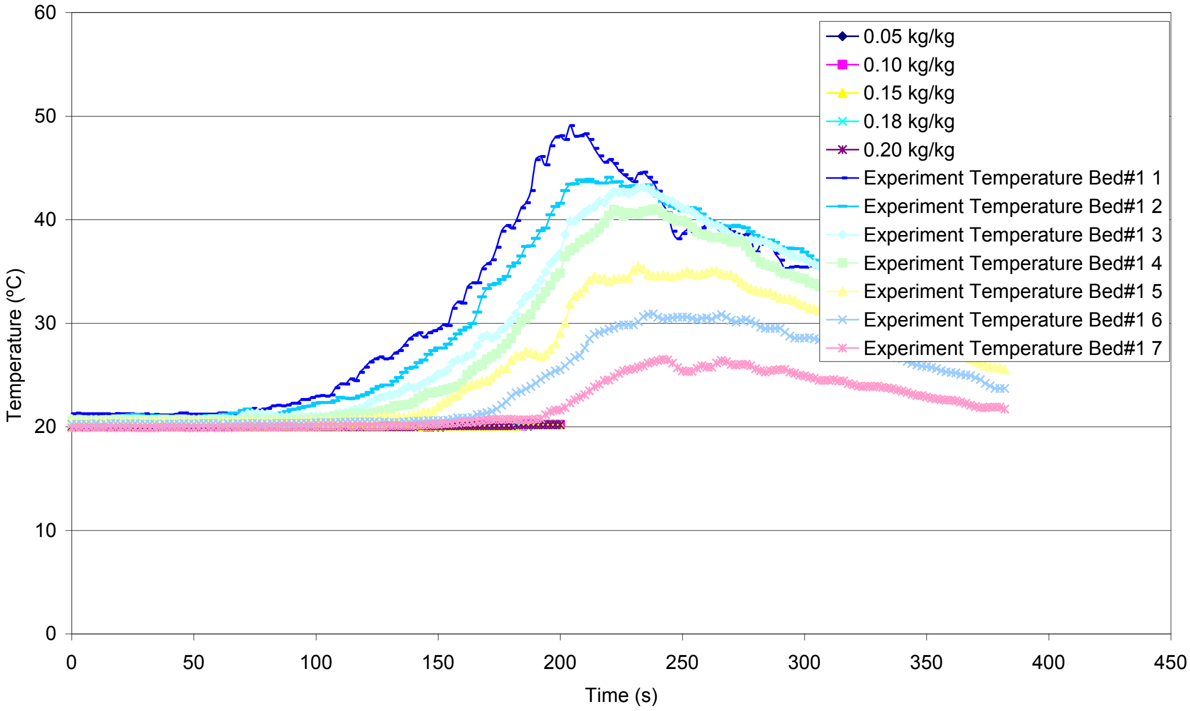
```
Soot Yield pre-flashover(kg/kg) =                            0.200
Soot Yield post-flashover(kg/kg) =                           0.400
```

C.6 Results

In this section the results indicated as “0.05 kg/kg”, “0.10 kg/kg”, “0.15 kg/kg”, “0.18 kg/kg” and “0.20 kg/kg” denote BRANZFIRE results corresponding to the soot yield values. In the case of model values for upper and lower temperatures, no variation is expected since only the soot yield value has been changed.

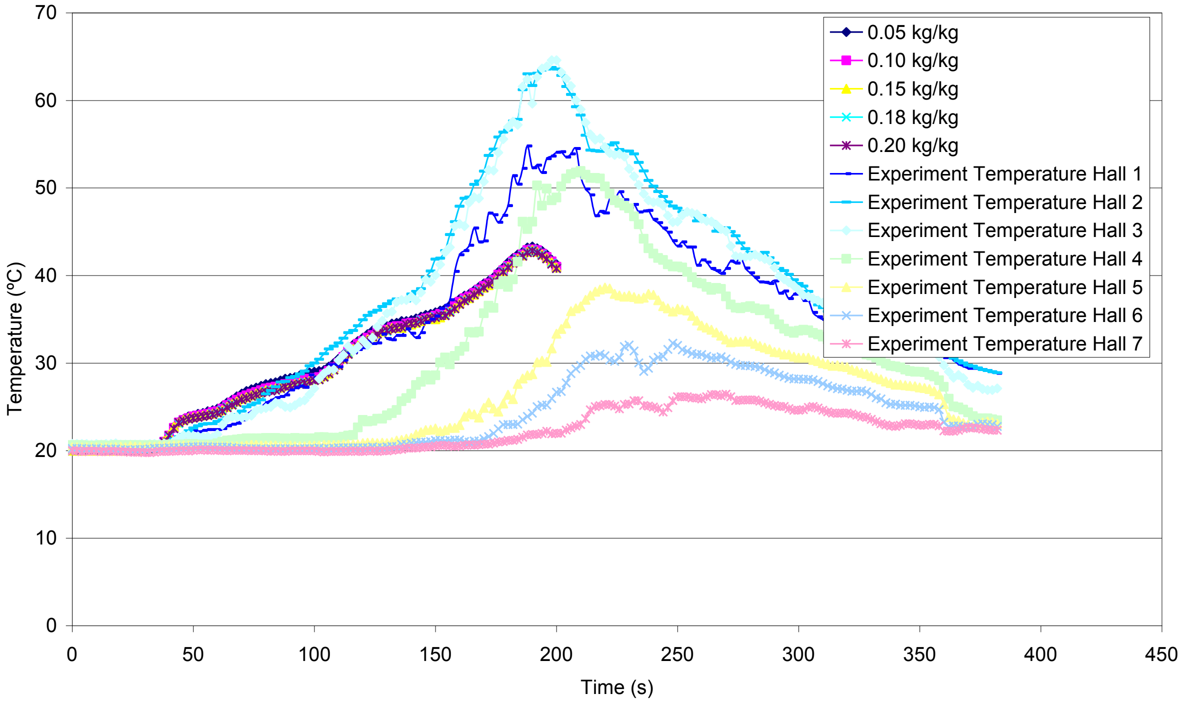


(a)

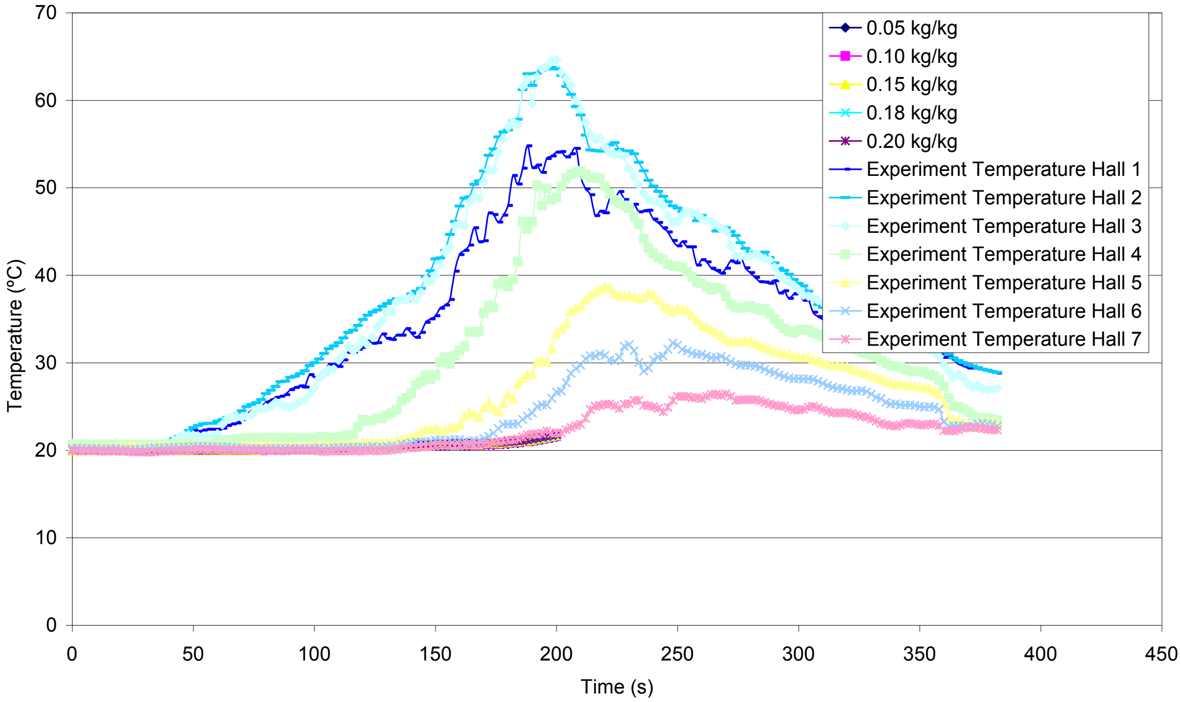


(b)

Figure 50. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Bedroom #1 temperatures

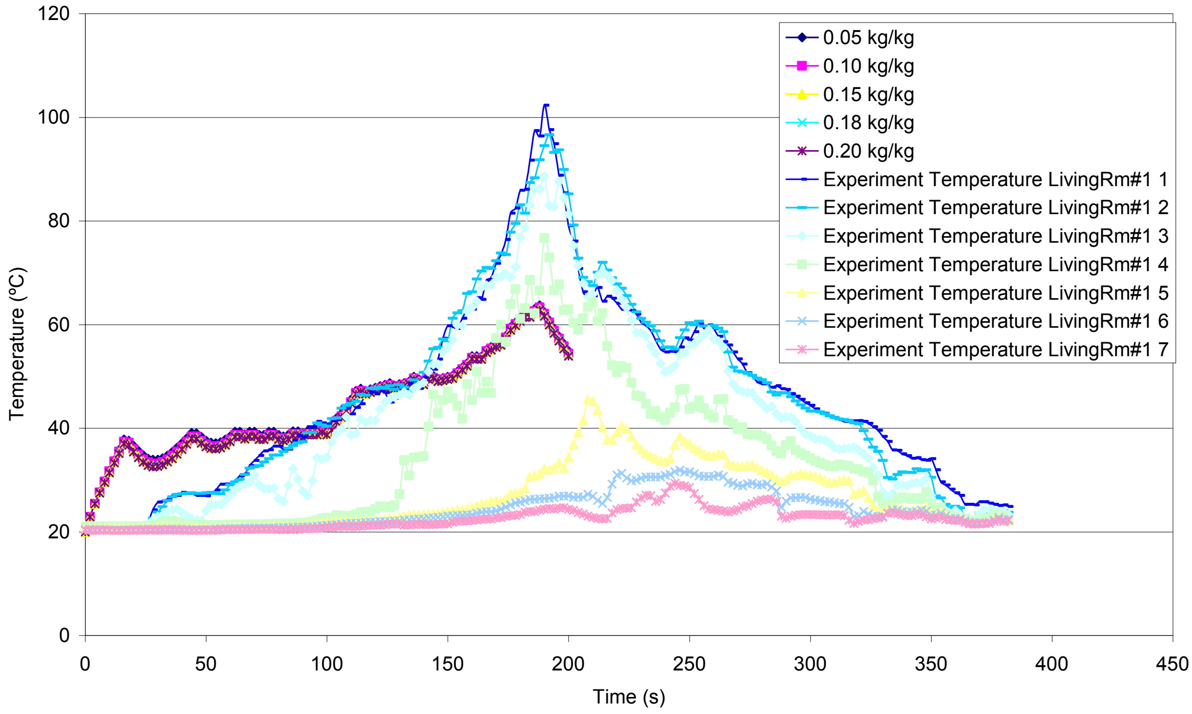


(a)

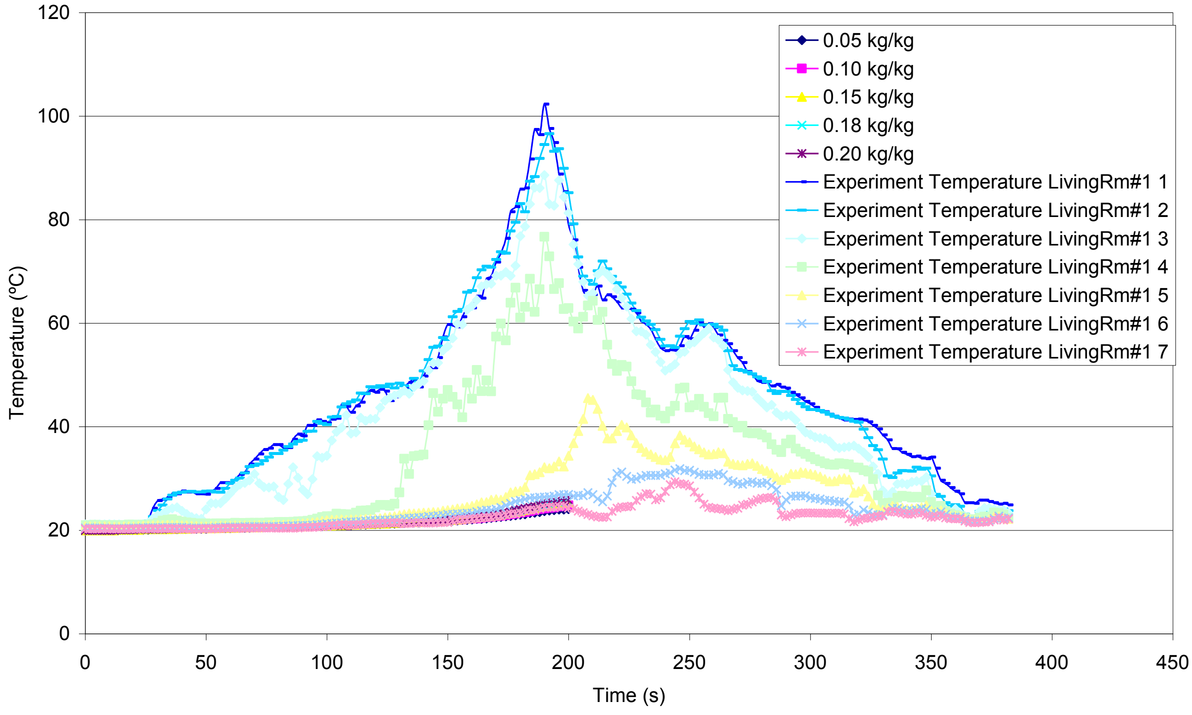


(b)

Figure 51. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Hall temperatures

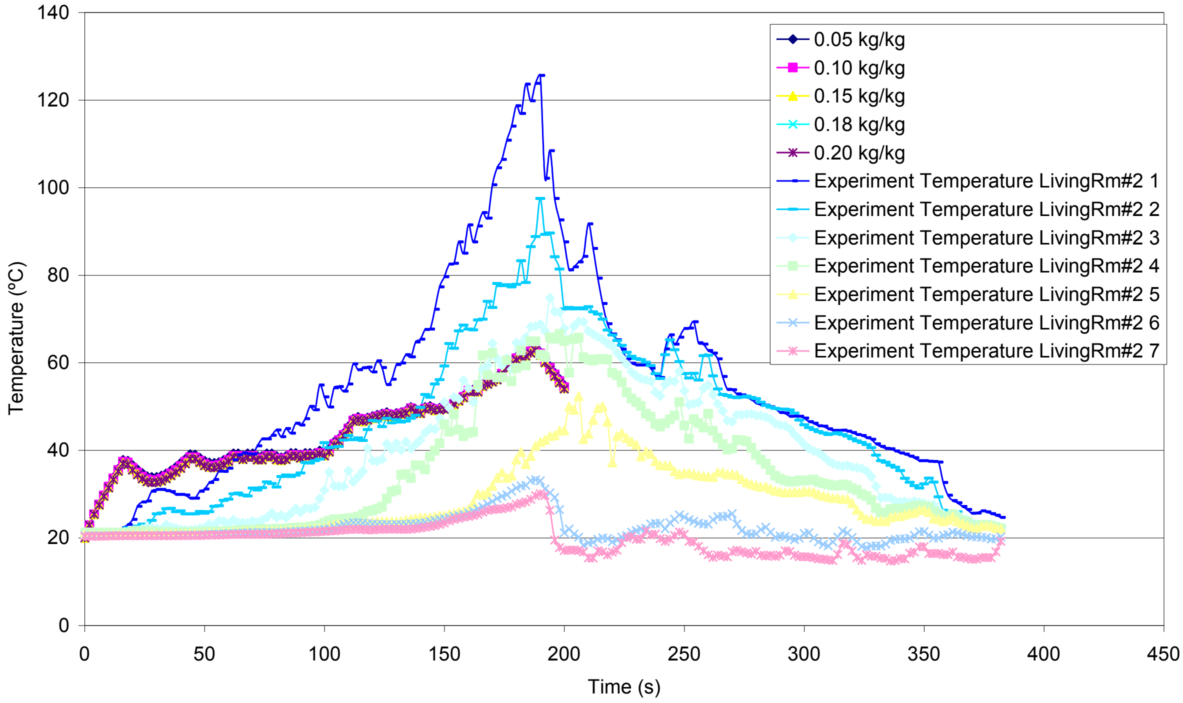


(a)

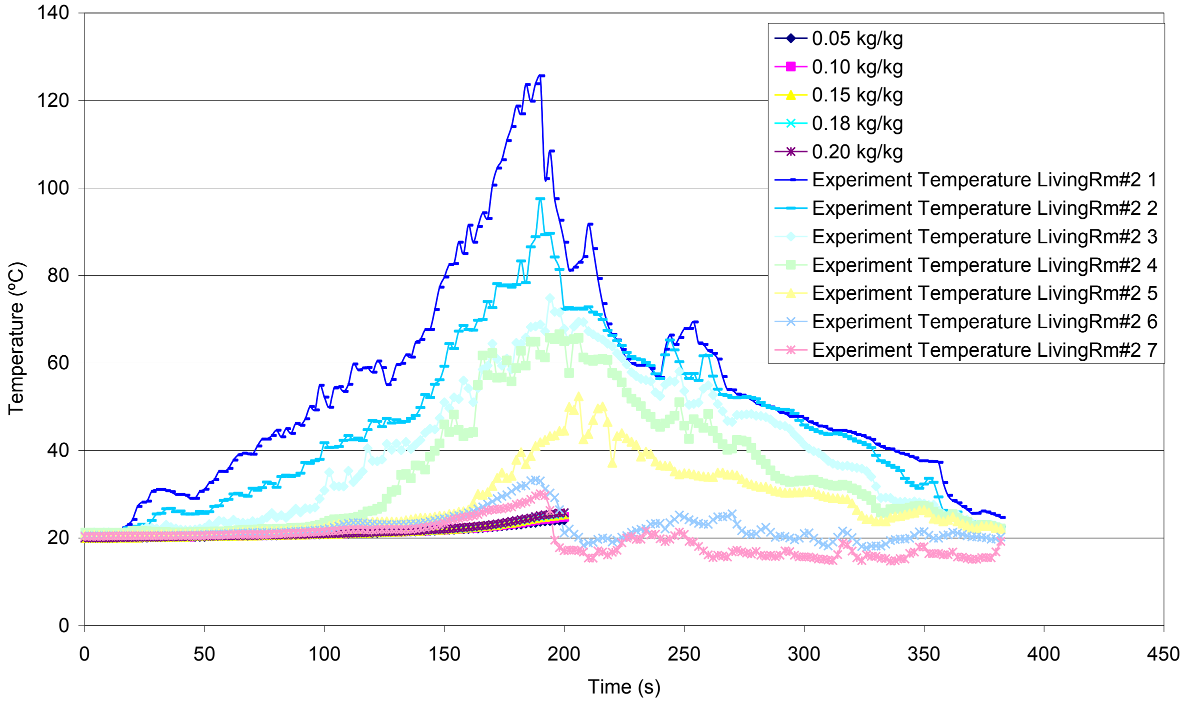


(b)

Figure 52. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Living Room #1 temperatures

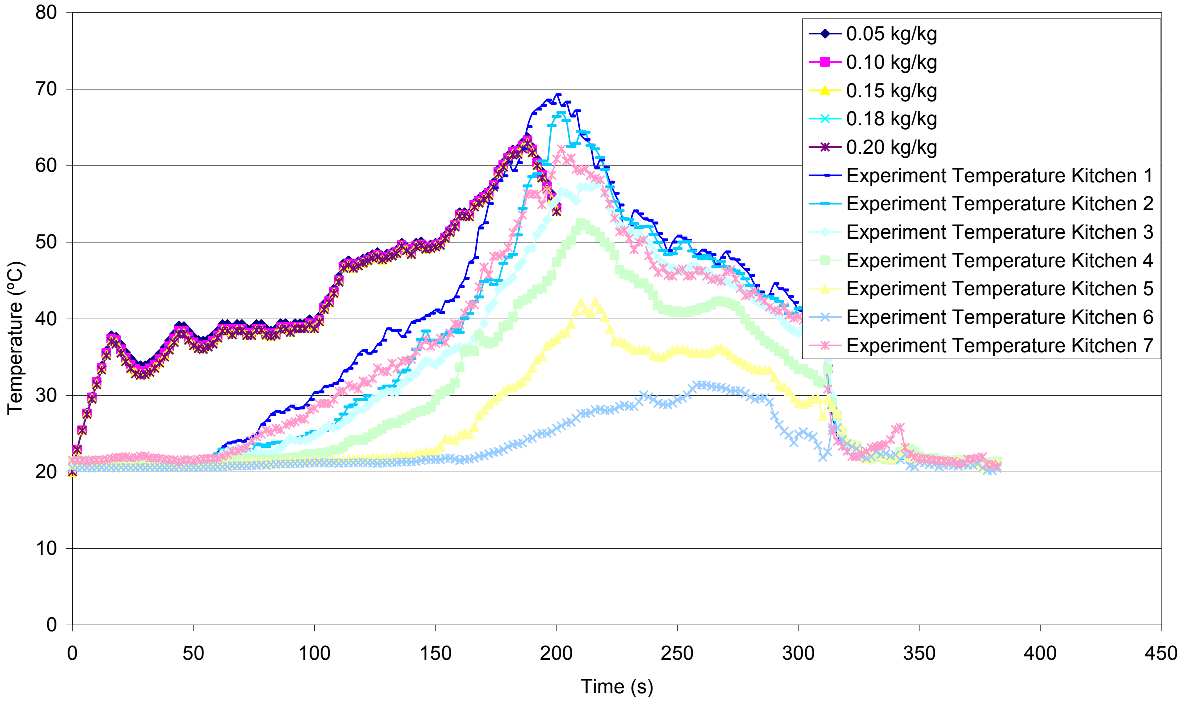


(a)

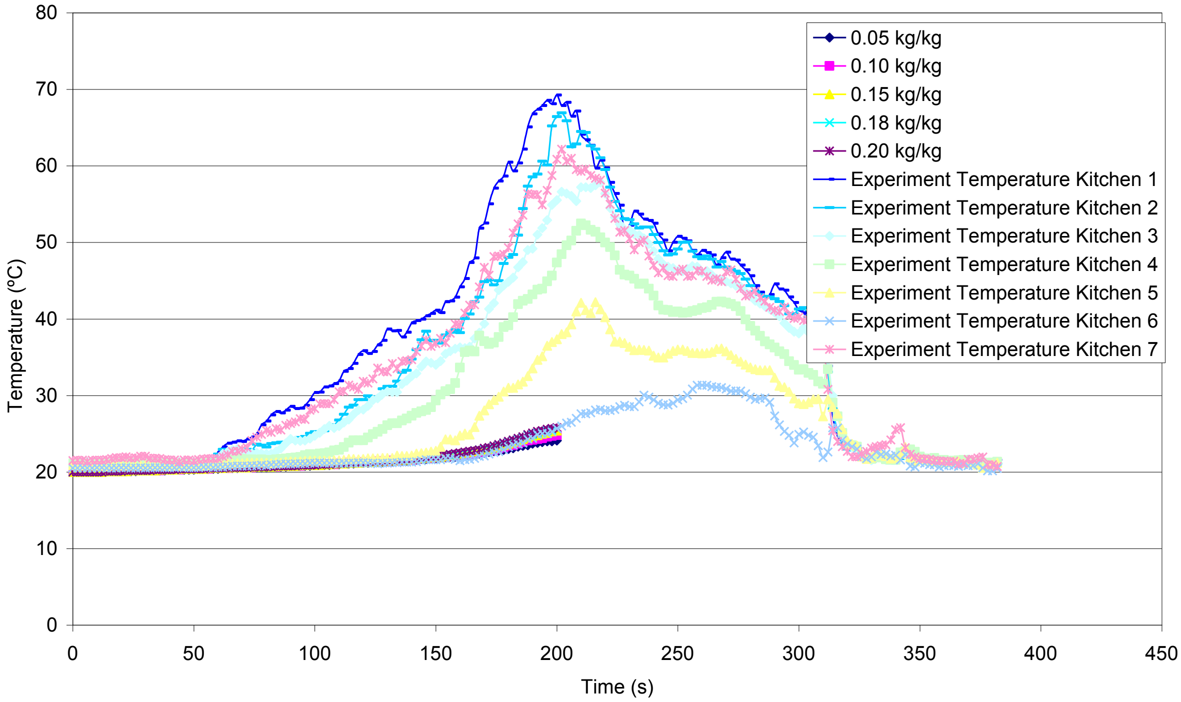


(b)

Figure 53. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Living Room #2 temperatures.

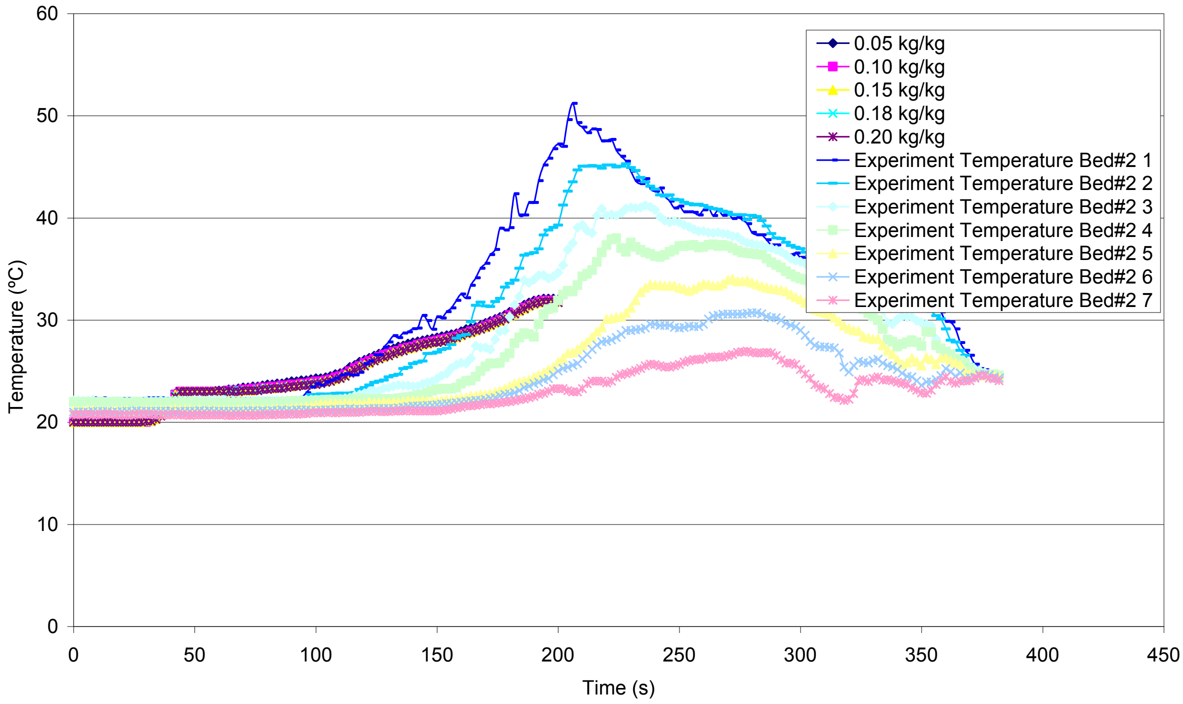


(a)

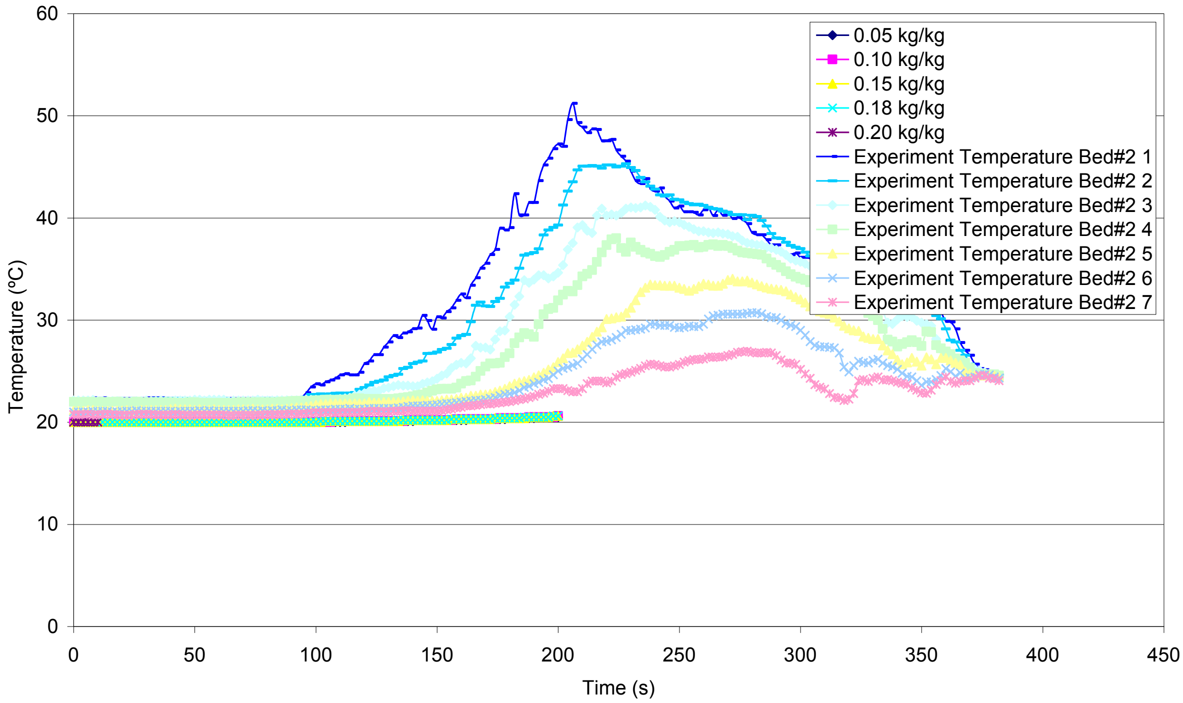


(b)

Figure 54. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Kitchen temperatures

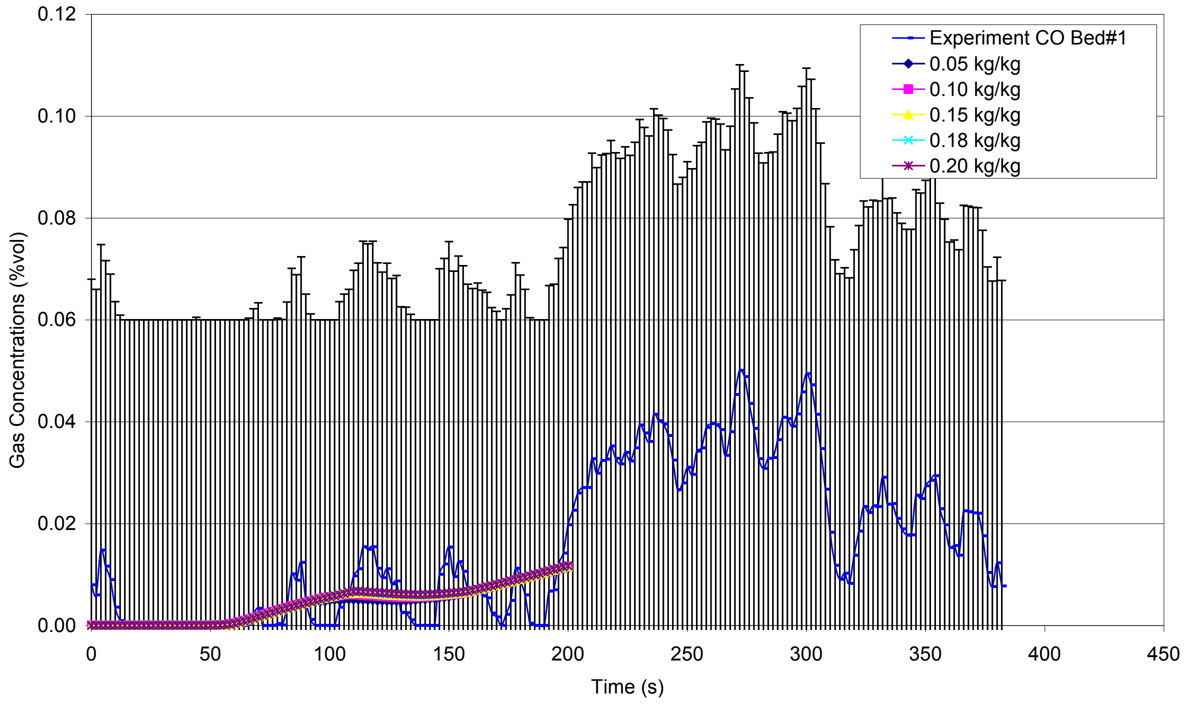


(a)

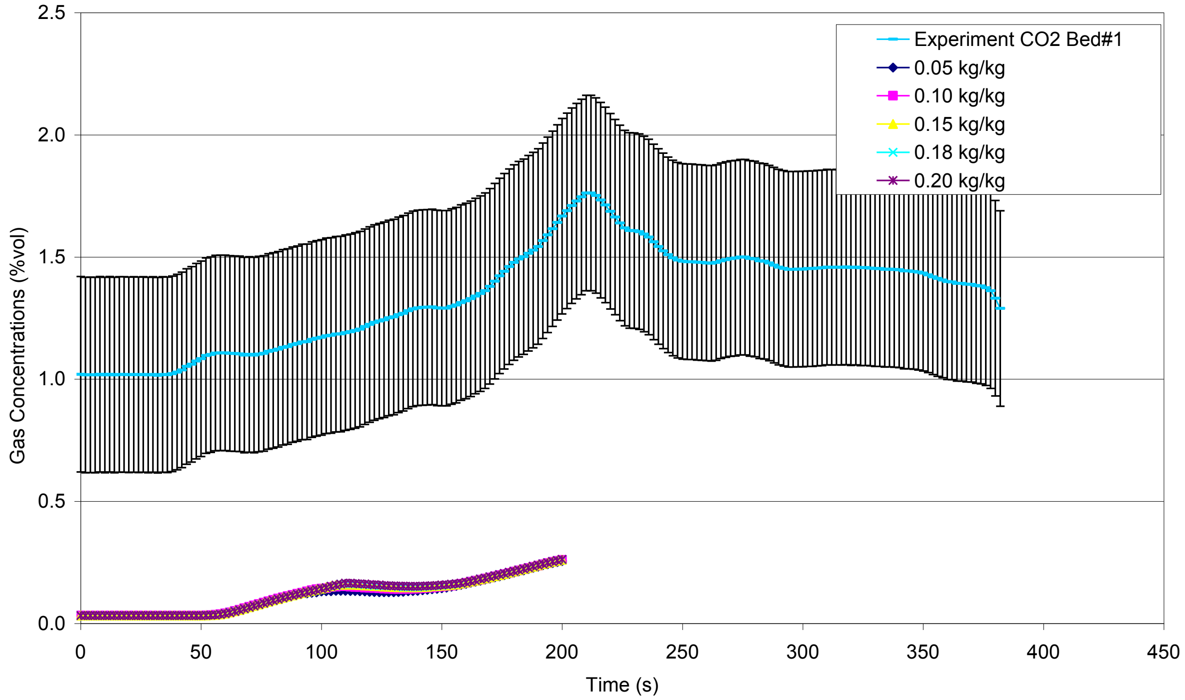


(b)

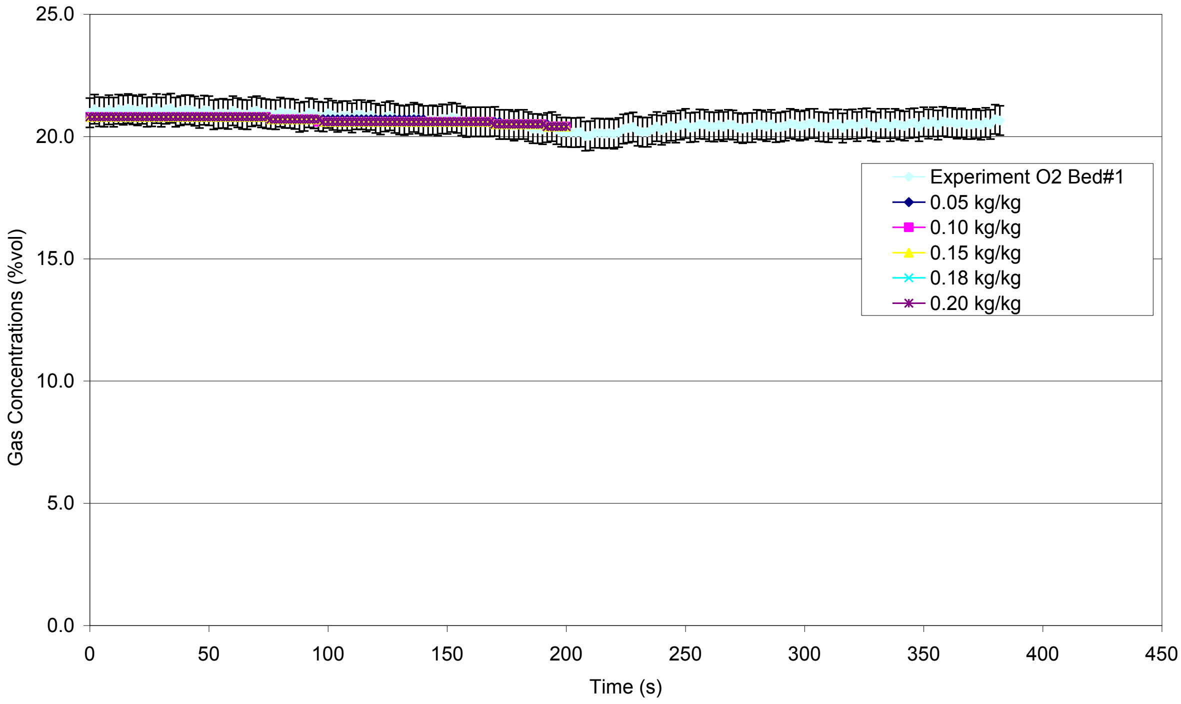
Figure 55. Experiment and BRANZFIRE (a) upper layer and (b) lower layer results for Bedroom #2 temperatures


Gas Concentrations (%vol)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Bed#1
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(a)

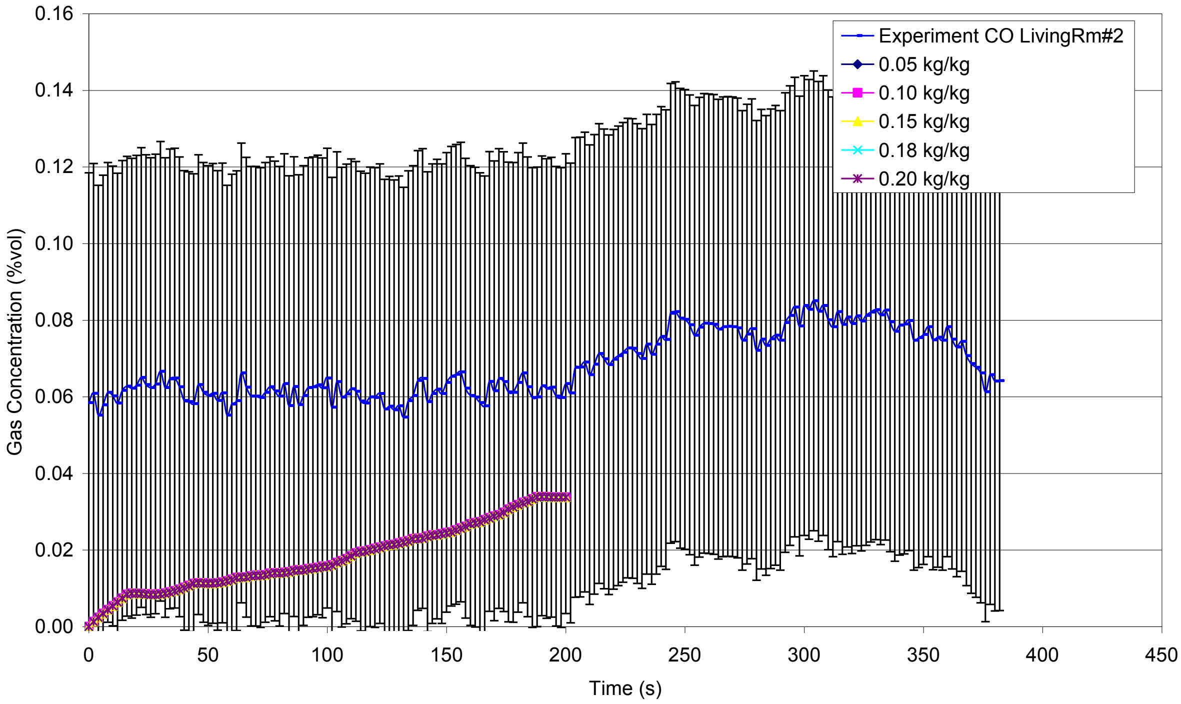

Gas Concentrations (%vol)
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Bed#1
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)

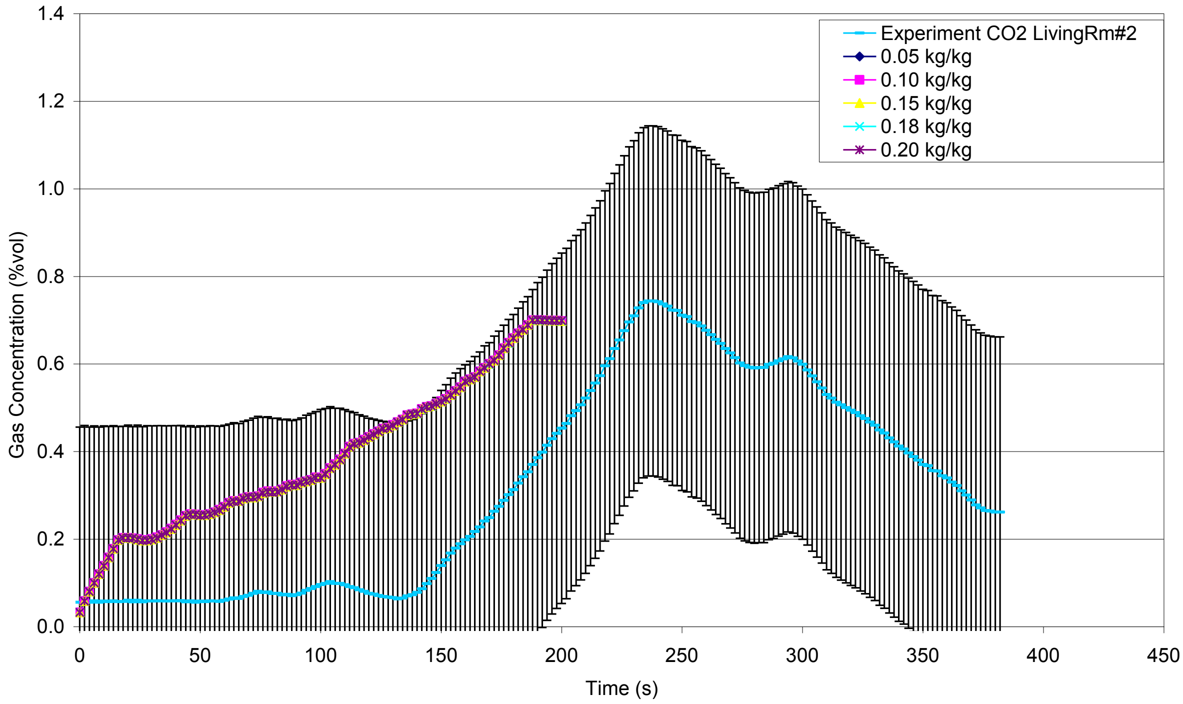


(c)

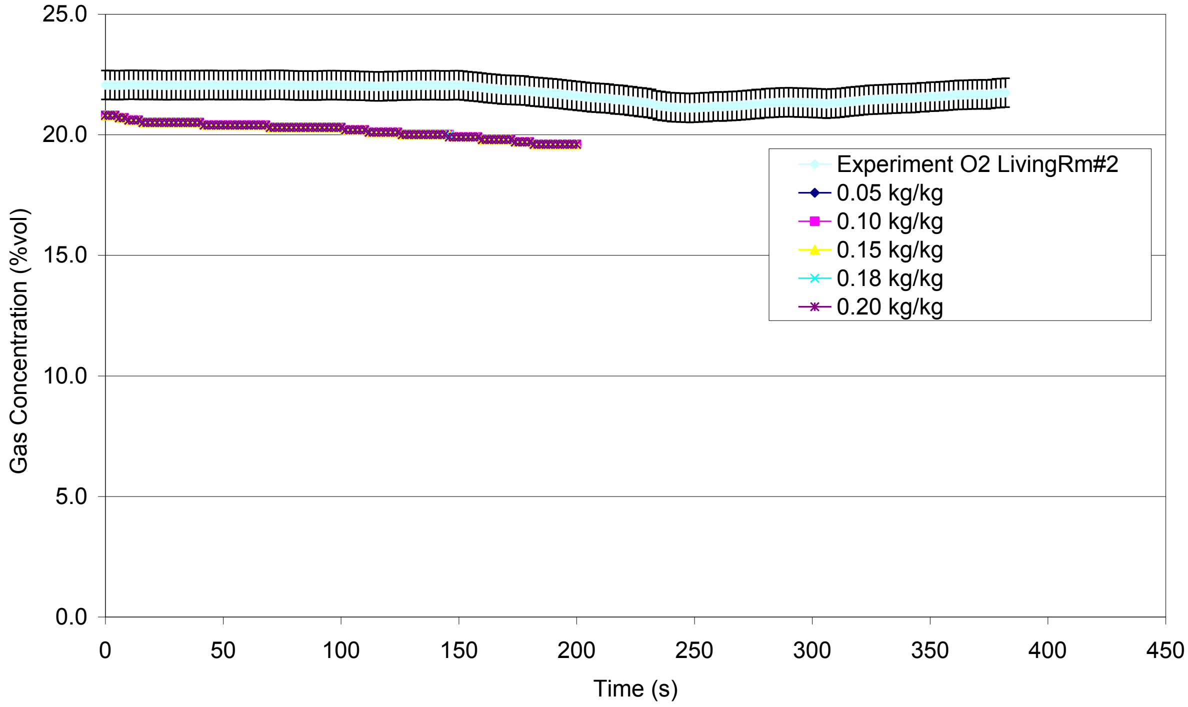
Figure 56. Experiment and BRANZFIRE upper layer results for Bedroom #1 volume percentage for (a) carbon monoxide, (b) carbon dioxide and (c) oxygen



(a)

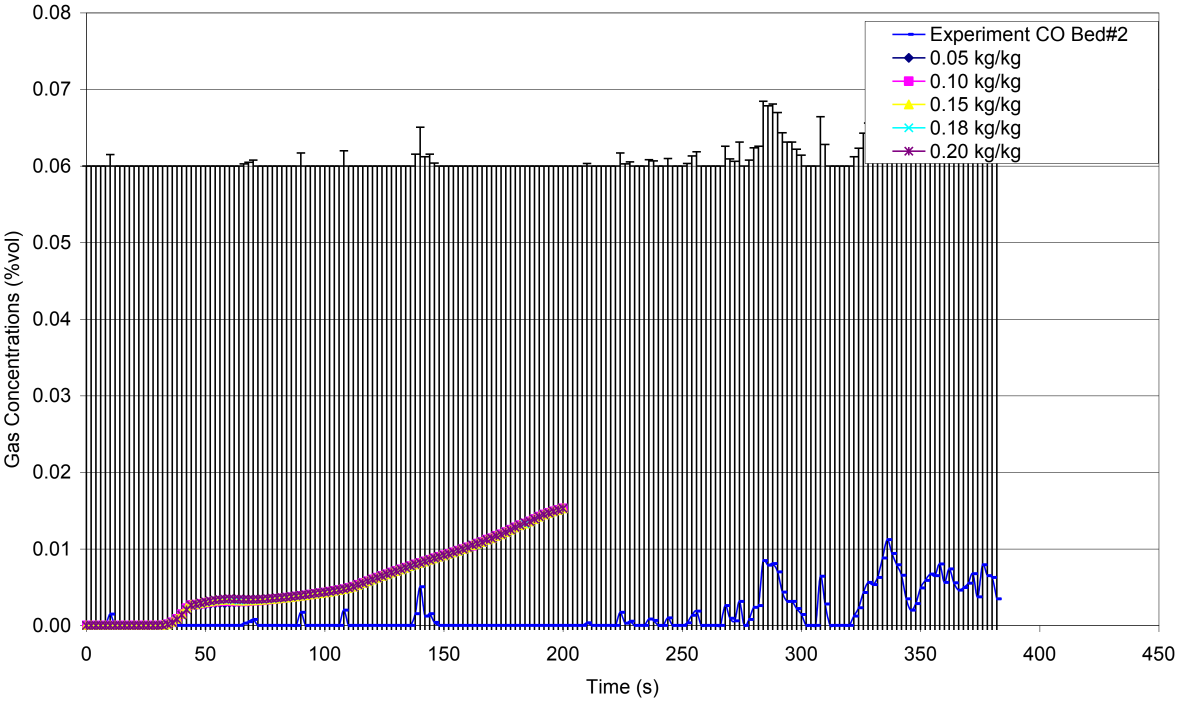


(b)

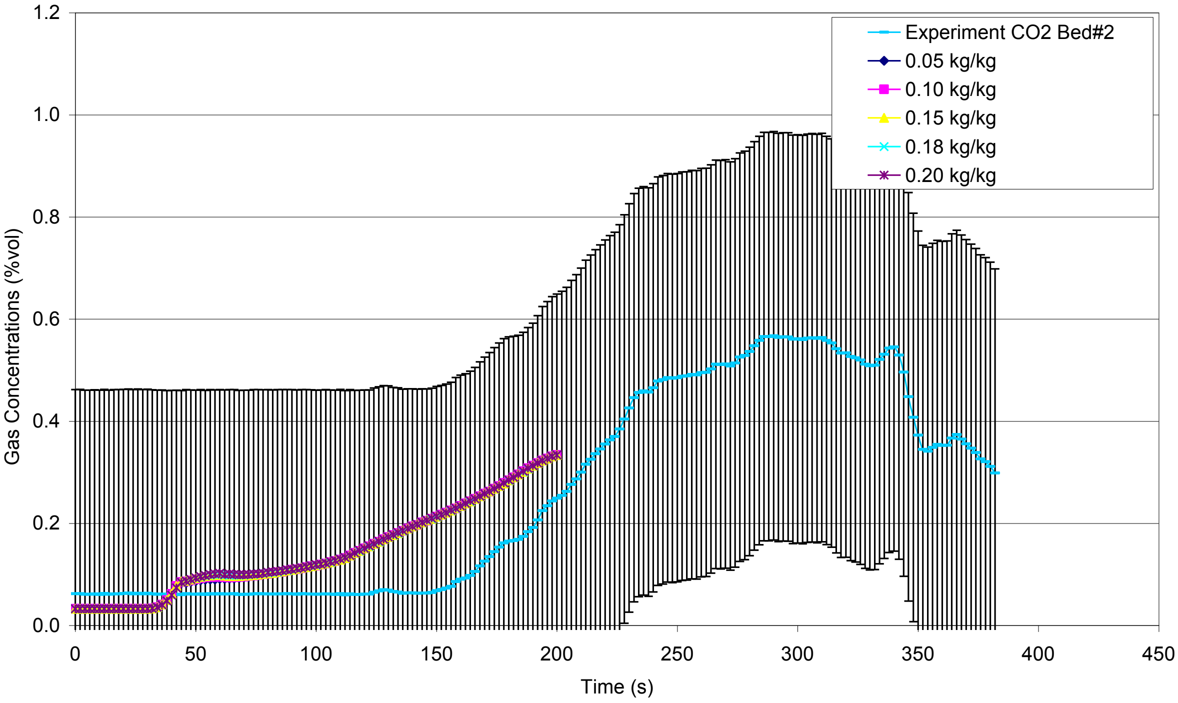


(c)

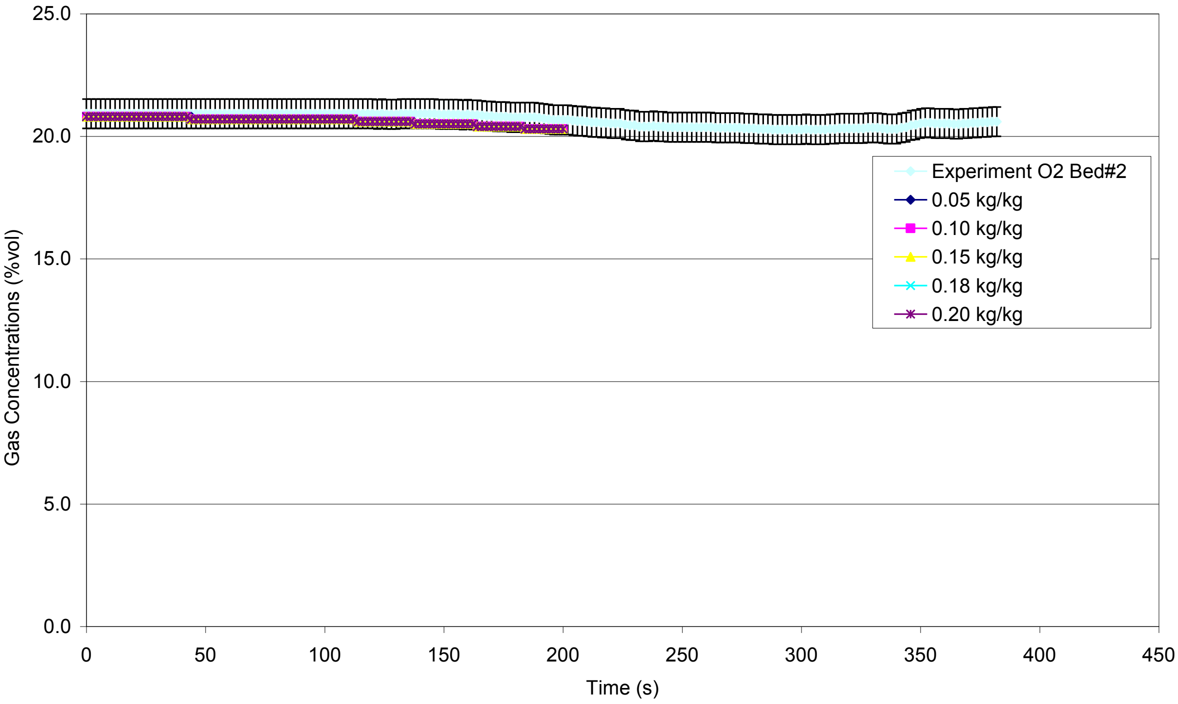
Figure 57. An example of results for a location near to the seat of the fire. Experiment and BRANZFIRE upper layer results for Living Room #2 volume percentage for (a) carbon monoxide, (b) carbon dioxide and (c) oxygen


Gas Concentrations (%vol)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Bed#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(a)

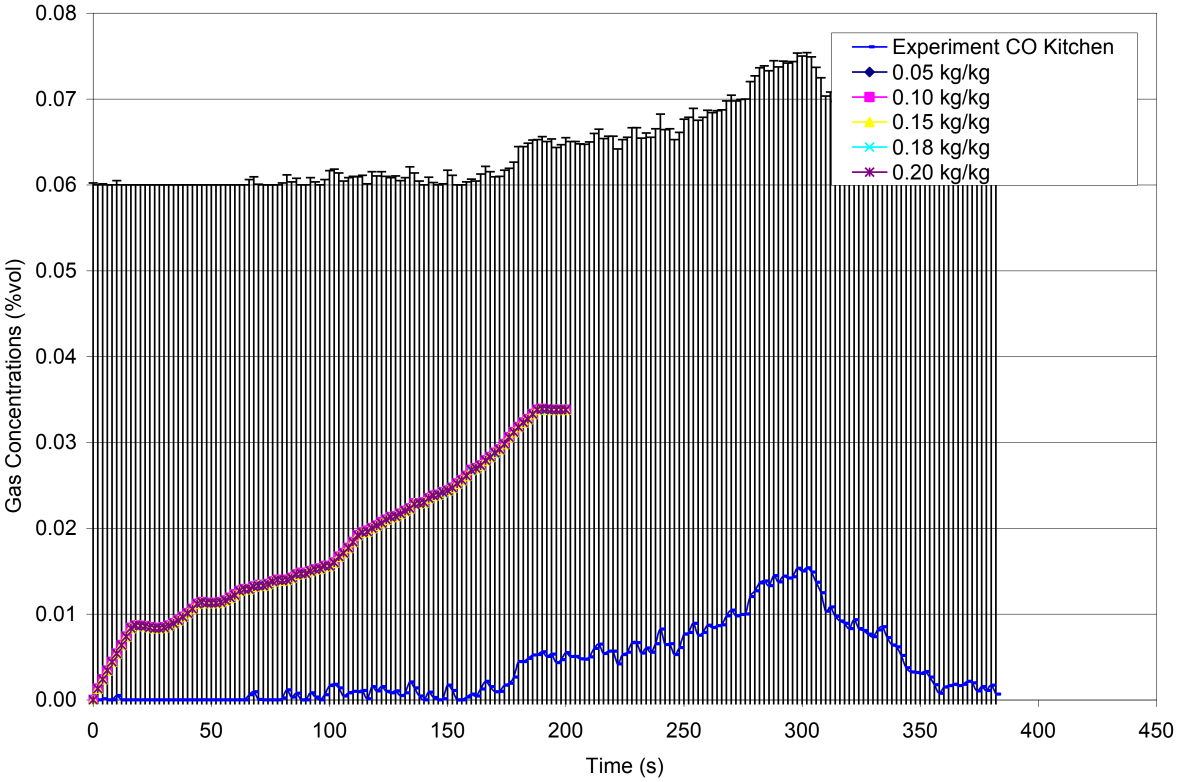

Gas Concentrations (%vol)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Bed#2
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)

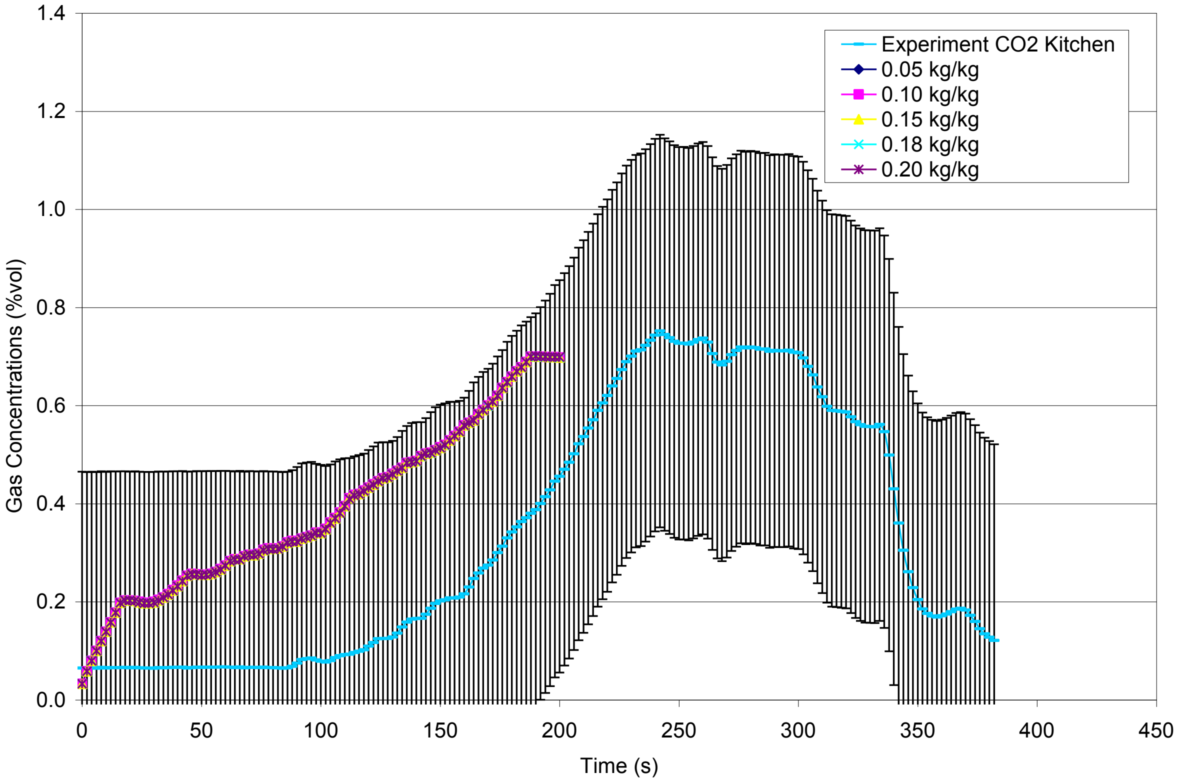


(c)

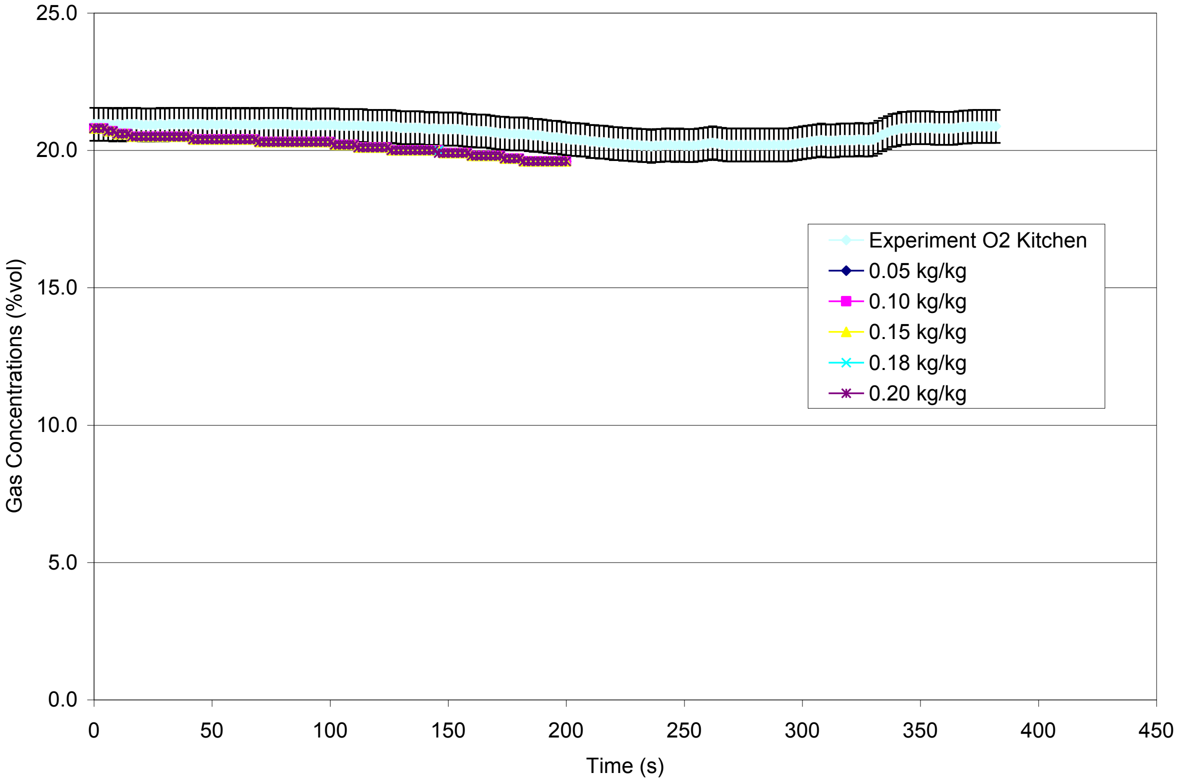
Figure 58. An example of results for a location near to the seat of the fire. Experiment and BRANZFIRE upper layer results for Bedroom #2 volume percentage for (a) carbon monoxide, (b) carbon dioxide and (c) oxygen



(a)



(b)



(c)

Figure 59. Experiment and BRANZFIRE upper layer results for Kitchen volume percentage for (a) carbon monoxide, (b) carbon dioxide and (c) oxygen

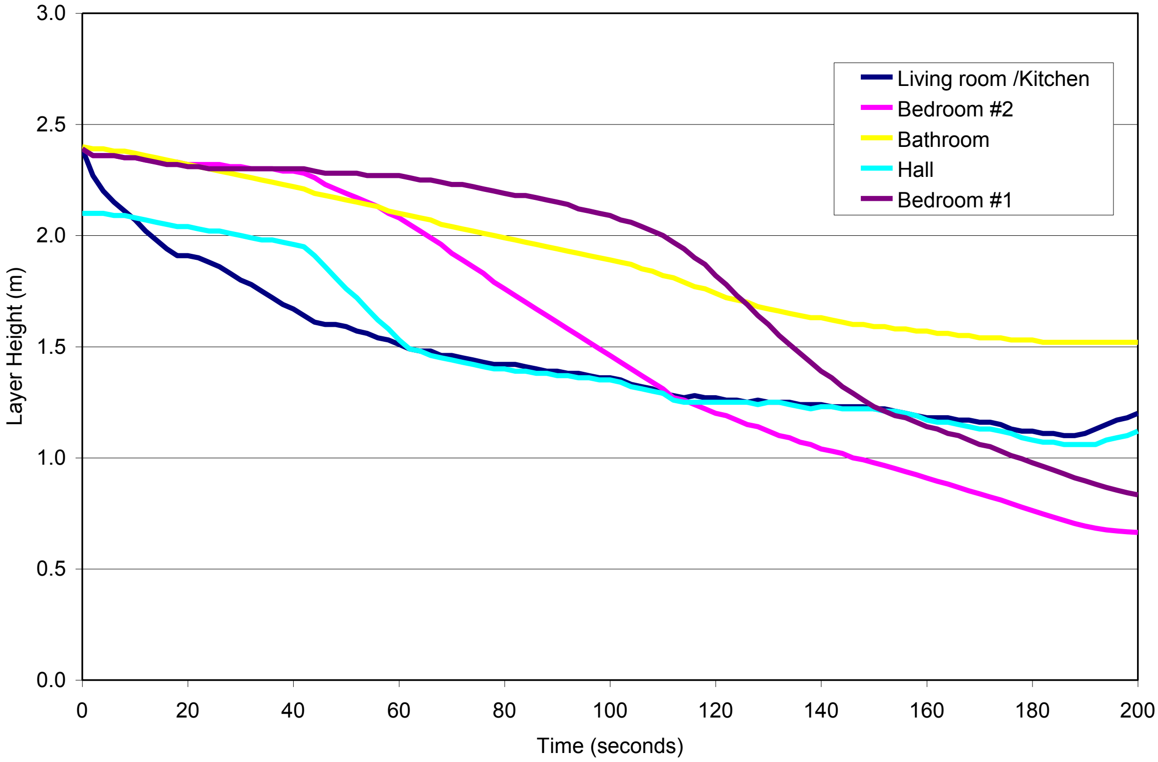
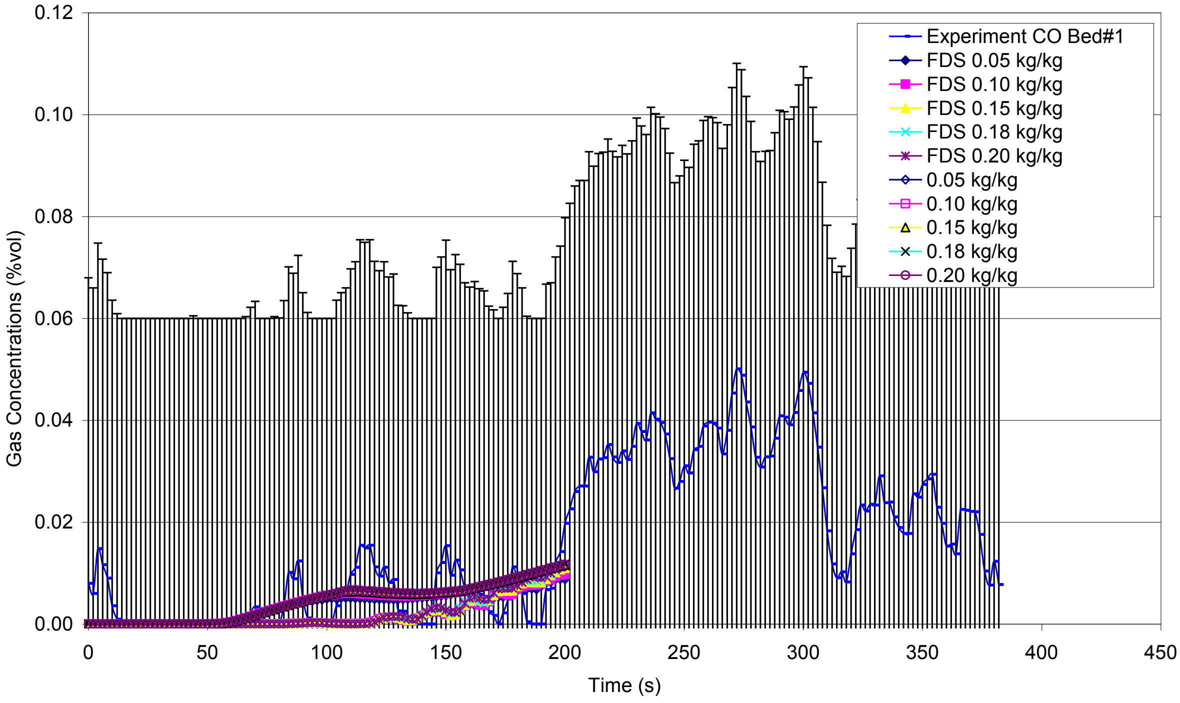


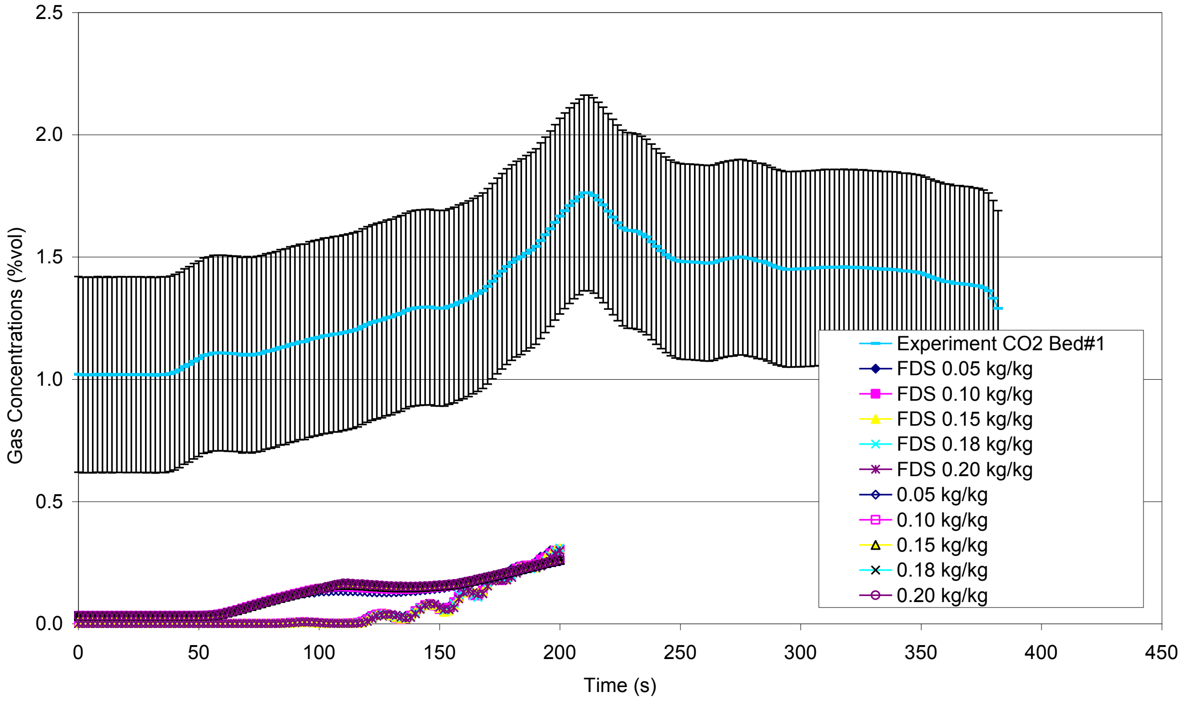
Figure 60. Example of the heights of the interface between upper and lower layers for each of the rooms (0.05 kg/kg soot yield)

APPENDIX D COMPARISON OF FDS AND BRANZFIRE RESULTS

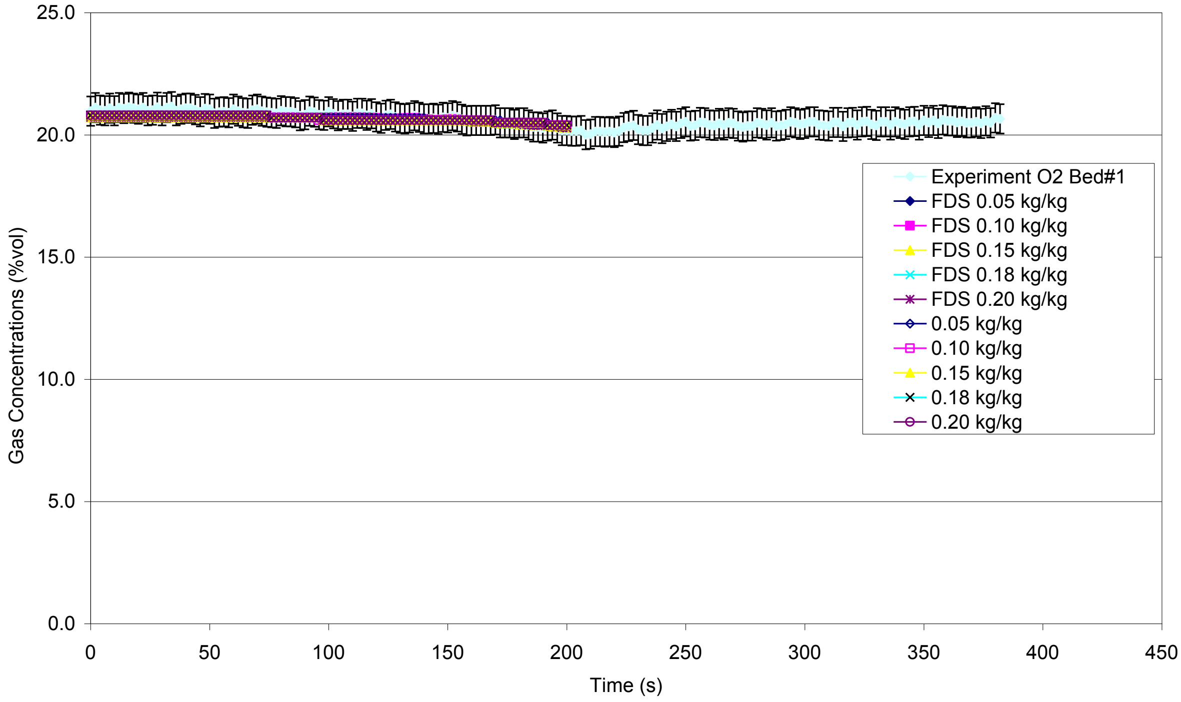
Similar to the previous section, in this section the results indicated as “0.05 kg/kg”, “0.10 kg/kg”, “0.15 kg/kg”, “0.18 kg/kg” and “0.20 kg/kg” denote BRANZFIRE results corresponding to the soot yield values. In the case of model values for both FDS and BRANZFIRE, no variation is expected for the gas concentrations, since only the soot yield value has been changed for each of the model results. Instead the results are included to show consistency between for each model approach.



(a)

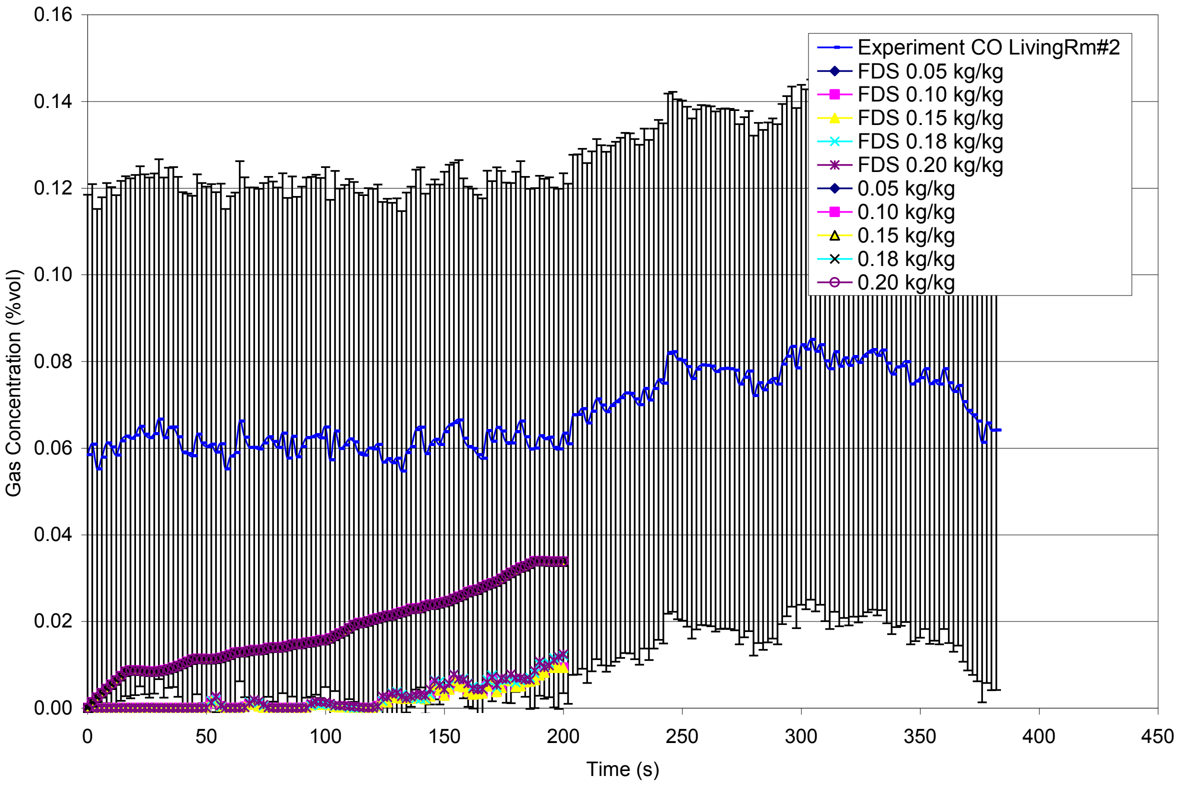


(b)

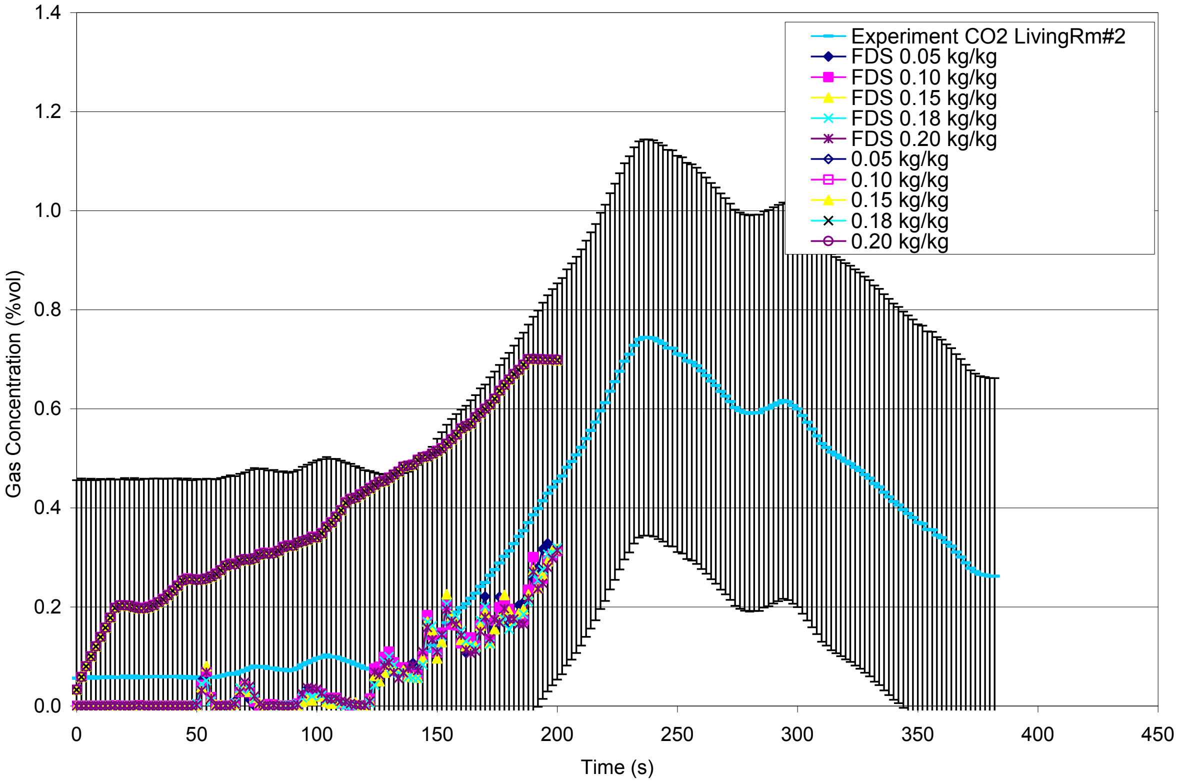


(c)

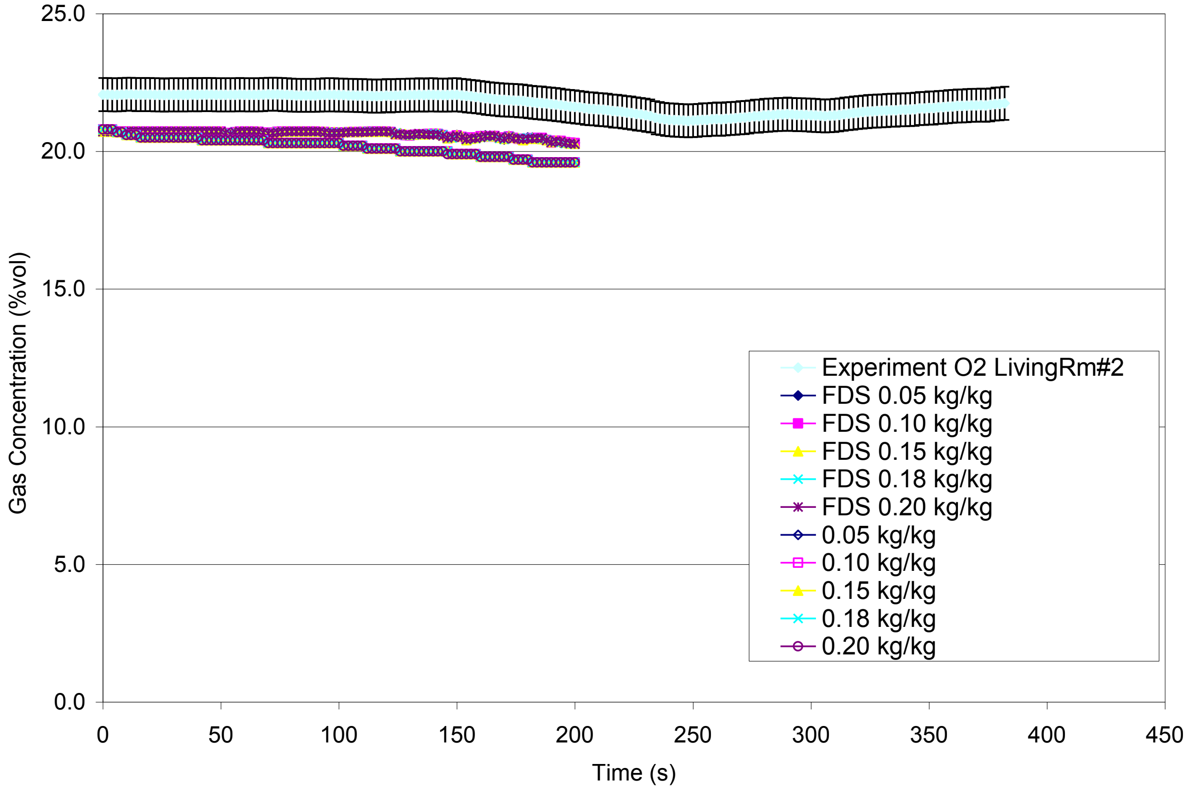
Figure 61. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #1 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages


0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Gas Concentration (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO LivingRm#2
FDS 0.05 kg/kg
FDS 0.10 kg/kg
FDS 0.15 kg/kg
FDS 0.18 kg/kg
FDS 0.20 kg/kg
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(a)

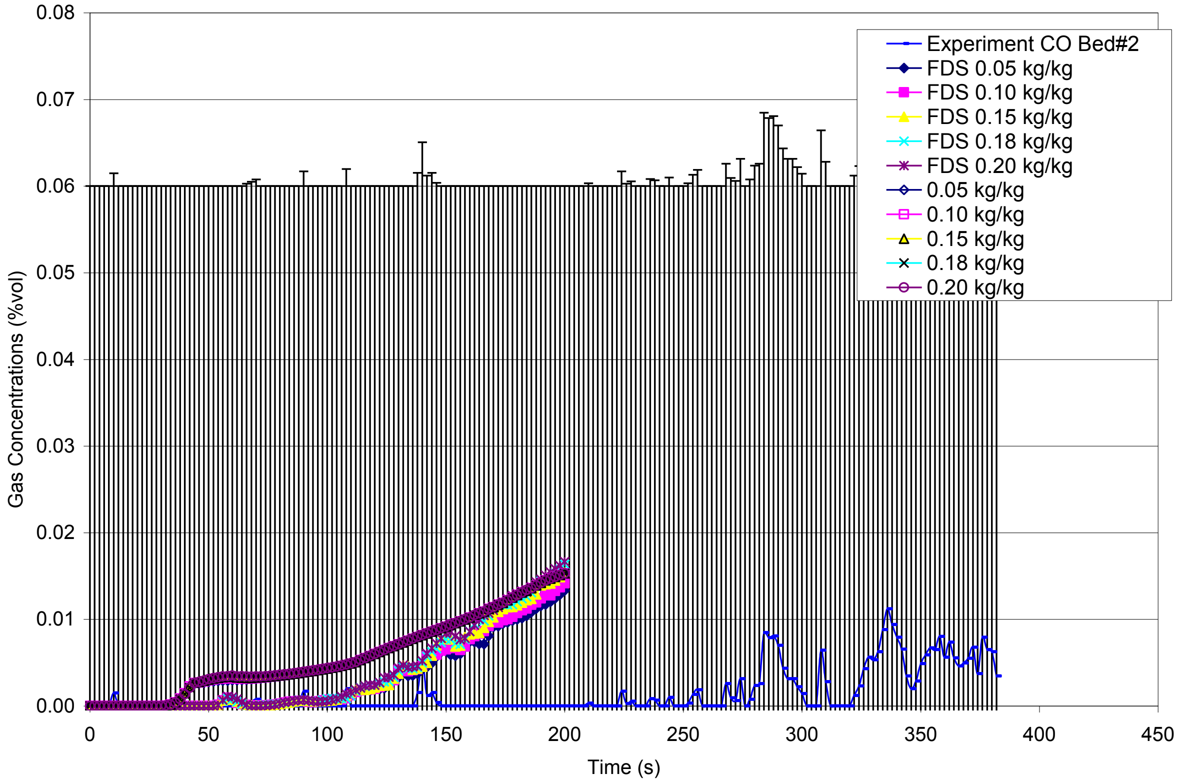

1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Gas Concentration (%vol)
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 LivingRm#2
FDS 0.05 kg/kg
FDS 0.10 kg/kg
FDS 0.15 kg/kg
FDS 0.18 kg/kg
FDS 0.20 kg/kg
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)

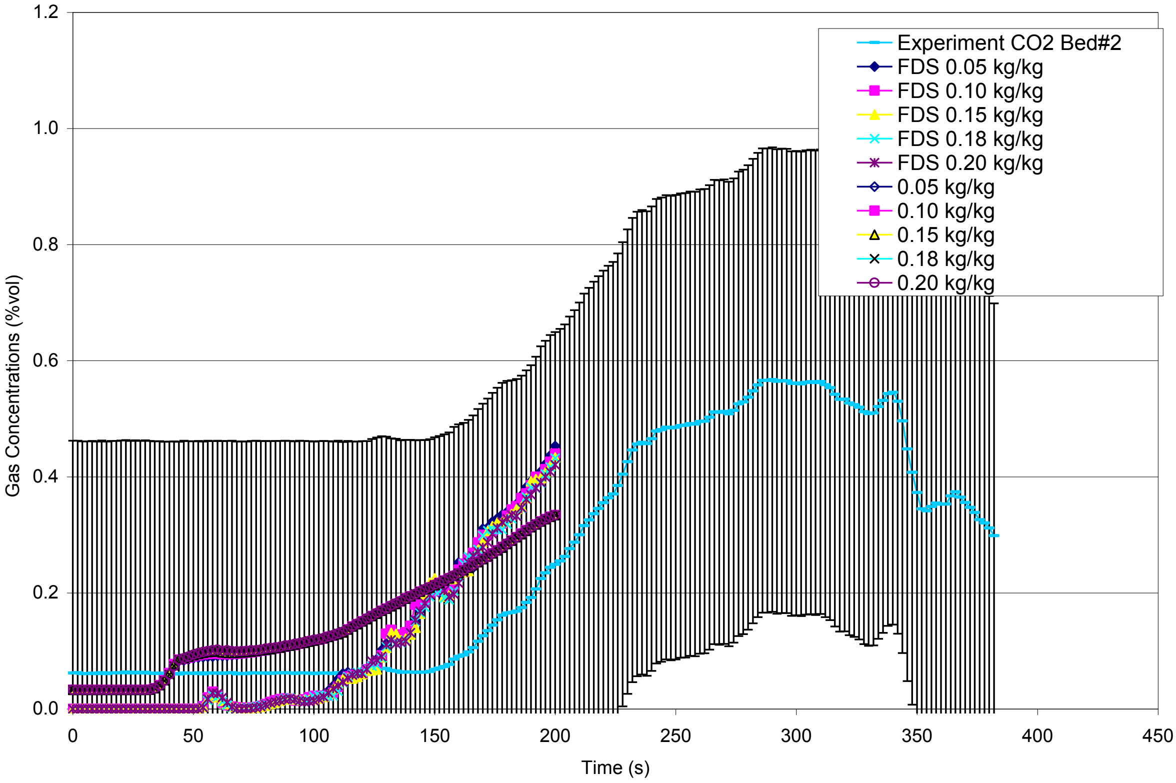


(c)

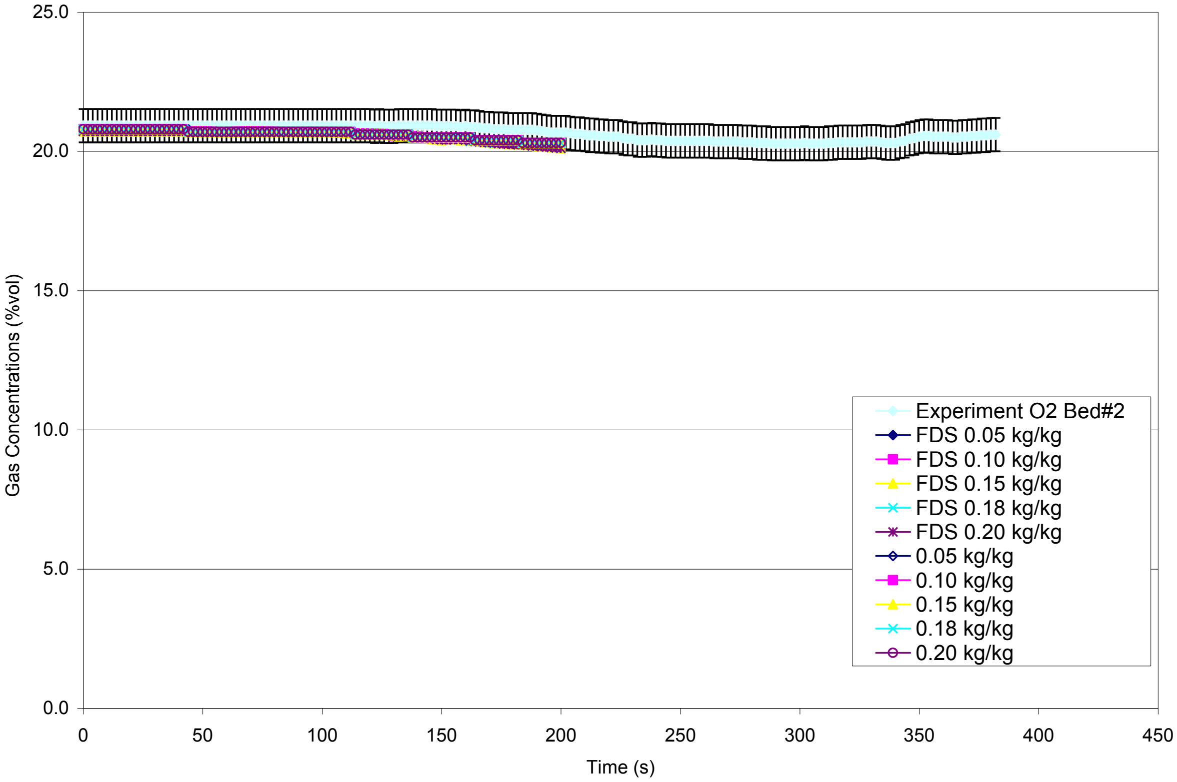
Figure 62. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Living Room #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



(a)

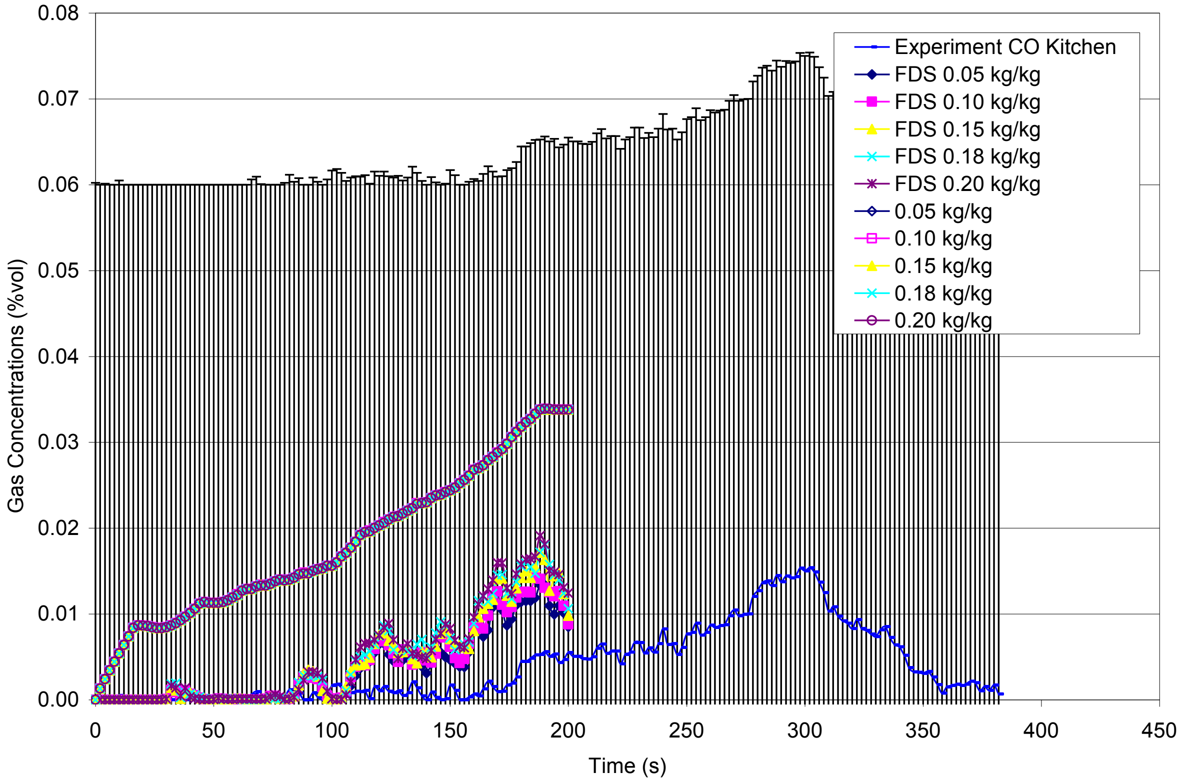


(b)



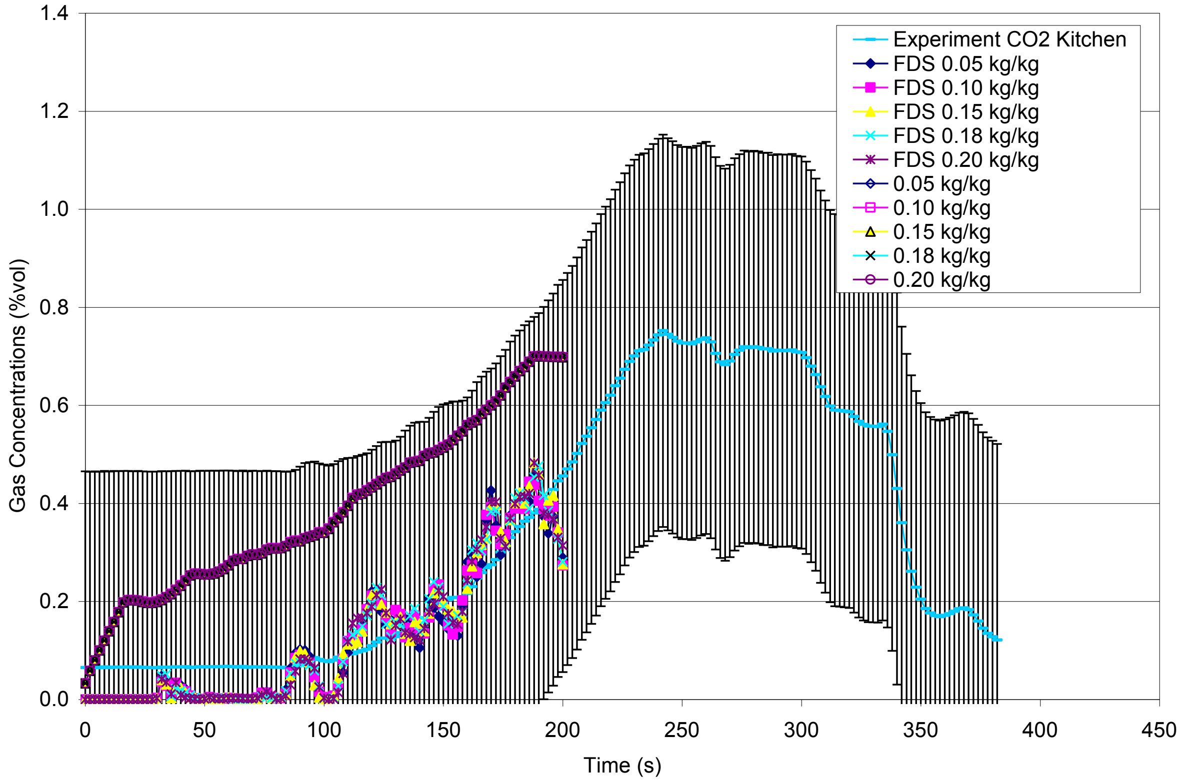
(c)

Figure 63. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Bedroom #2 (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages



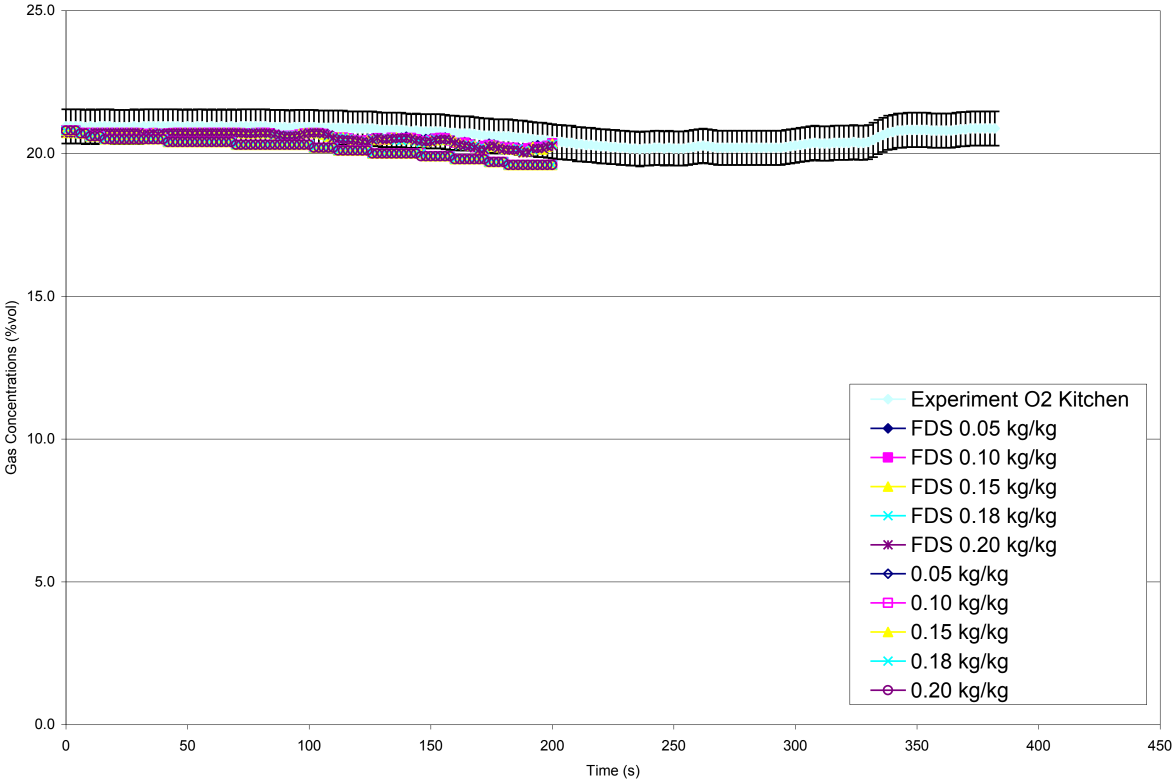
Gas Concentrations (%vol)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO Kitchen
FDS 0.05 kg/kg
FDS 0.10 kg/kg
FDS 0.15 kg/kg
FDS 0.18 kg/kg
FDS 0.20 kg/kg
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

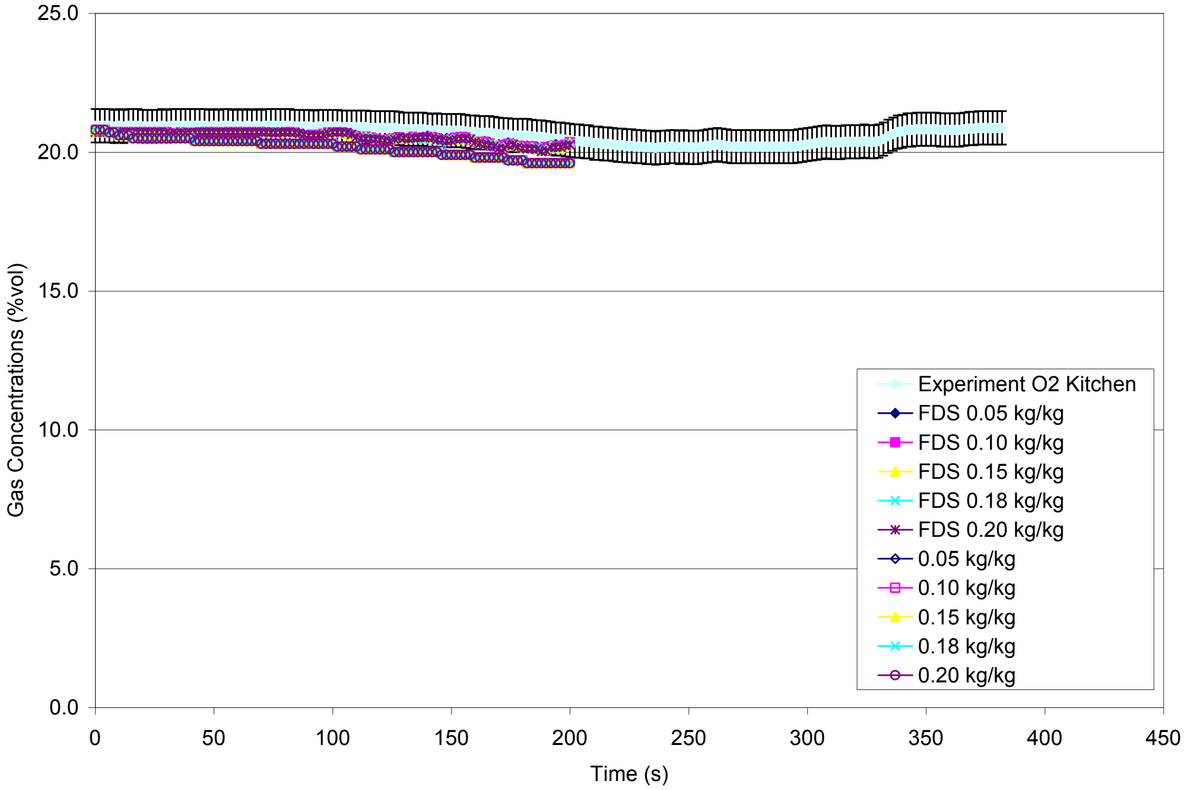
(a)



Gas Concentrations (%vol)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
400
450
Time (s)
Experiment CO2 Kitchen
FDS 0.05 kg/kg
FDS 0.10 kg/kg
FDS 0.15 kg/kg
FDS 0.18 kg/kg
FDS 0.20 kg/kg
0.05 kg/kg
0.10 kg/kg
0.15 kg/kg
0.18 kg/kg
0.20 kg/kg

(b)





(c)

Figure 64. Experiment and model results, using FDS with 62.5, 100, 150 & 300 mm grid spacing and a soot yield value of 0.10 kg/kg, for Kitchen (a) carbon monoxide, (b) carbon dioxide and (c) oxygen volume percentages

APPENDIX E ADDITIONAL EXPERIMENT AND MODEL SCENARIO INFORMATION

The 'a' and 'b' of each smoke detector type presented in Table 16 relate to the listed detectors used in the experiments (NIST Test FR 4061, Peacock et al 2002). Results of the comparison of the experiment and model results for the smoke detectors are not included in this report.

Table 16. Summary of smoke detector inputs

Smoke Detector Type	Sensitivity (%/m)
Ionization 1a	2.93
b	5.33
Ionization 2 a	2.63
b	5.93
Photoelectric a	2.46
b	11.06