Fire Protection Association

FIG UK – Fire Research into Practice

What’s FPA and RISCAuthority been up to this year?

- Toxicity of cladding systems
- Thatch Fires Update

10th October 2019

Dr Jim Glockling
Fire Protection Association

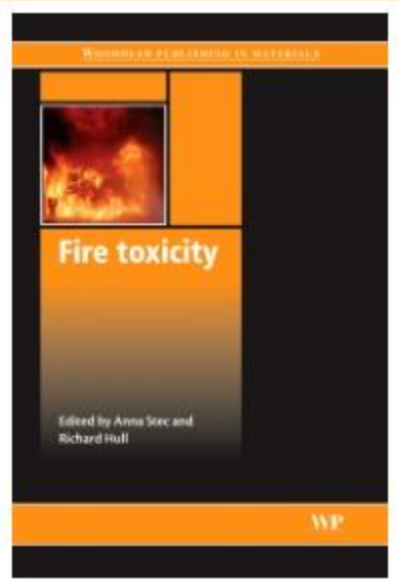
Cladding System Toxicity Study

A brief summary of progress and outstanding issues

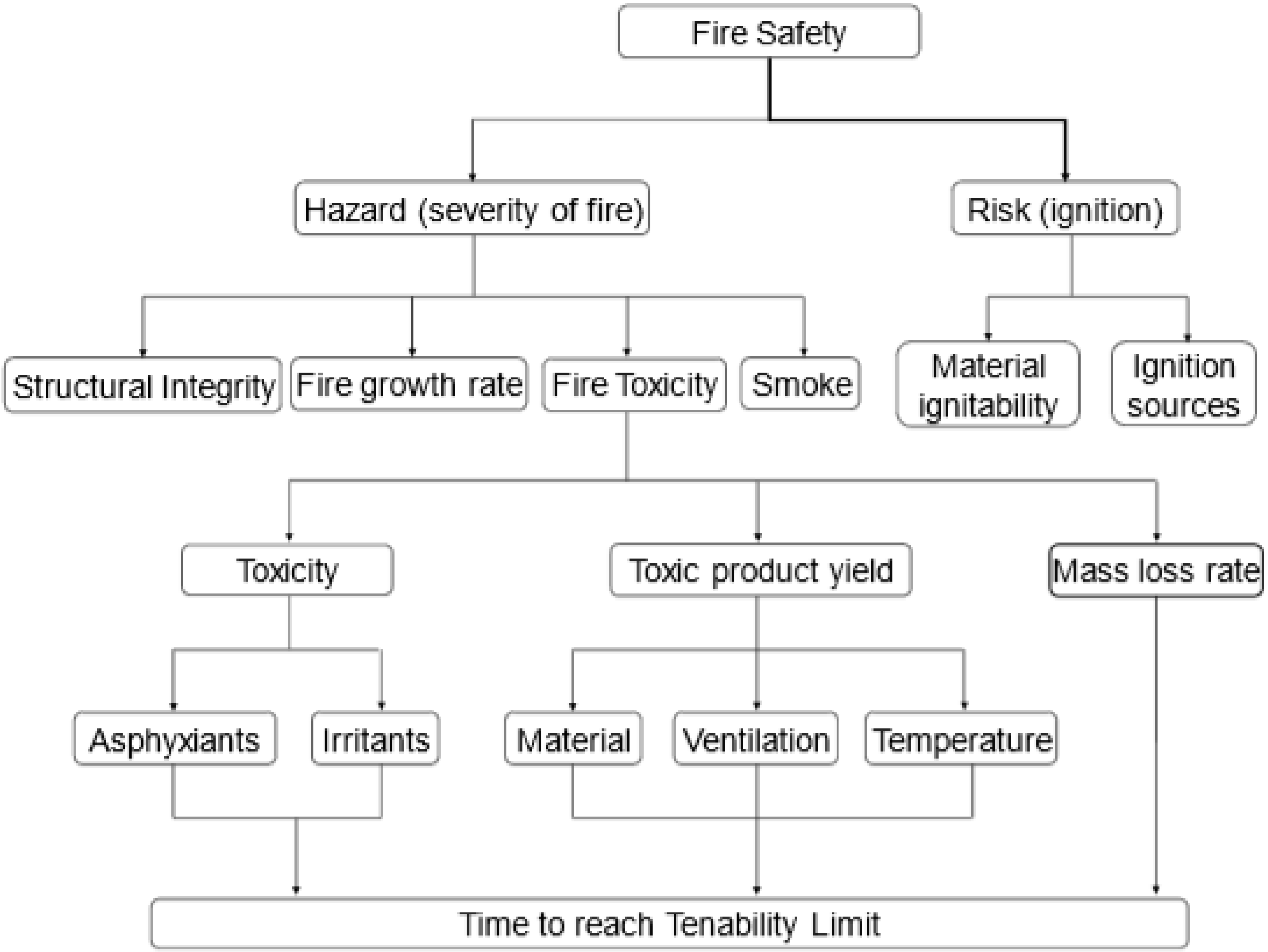
Fire Toxicity

Toxic fire effluents are responsible for the majority of fire deaths, and an increasingly large majority of fire injuries, driven by the widespread and increasing use of synthetic polymers.

Fire safety has focused on preventing ignition and reducing flame spread through reducing the rate of heat release, while neglecting the important issue of fire toxicity.



Anna Stec & Richard Hull – Lancaster UCLAN


Fire Safety
Hazard (severity of fire)
Risk (ignition)
Structural Integrity
Fire growth rate
Fire Toxicity
Smoke
Material ignitability
Ignition sources
Toxicity
Toxic product yield
Mass loss rate
Asphyxiants
Irritants
Material
Ventilation
Temperature
Time to reach Tenability Limit

Toxic threat

- Loss of visibility which may hinder escape
- Substances irritant to the eyes and lungs which may hinder escape (hydrochloric acid, formaldehyde, acrolein)
- Poisons that cause asphyxiation (preventing oxygen getting to the body) by:
  a) preferential combination with haemoglobin (carbon monoxide)
  b) by inhibiting cytochrome oxidase which prevents the use of oxygen by the body's cells (hydrogen cyanide)
- Gases that stimulate respiration thereby increasing the impact of other toxicants (carbon dioxide)
- Asphyxiation through reduced oxygen availability as it is consumed by the fire
- Substances that exhibit longer-term toxicity to humans (particulates, carcinogens, and endocrine disruptors)

Toxic sources

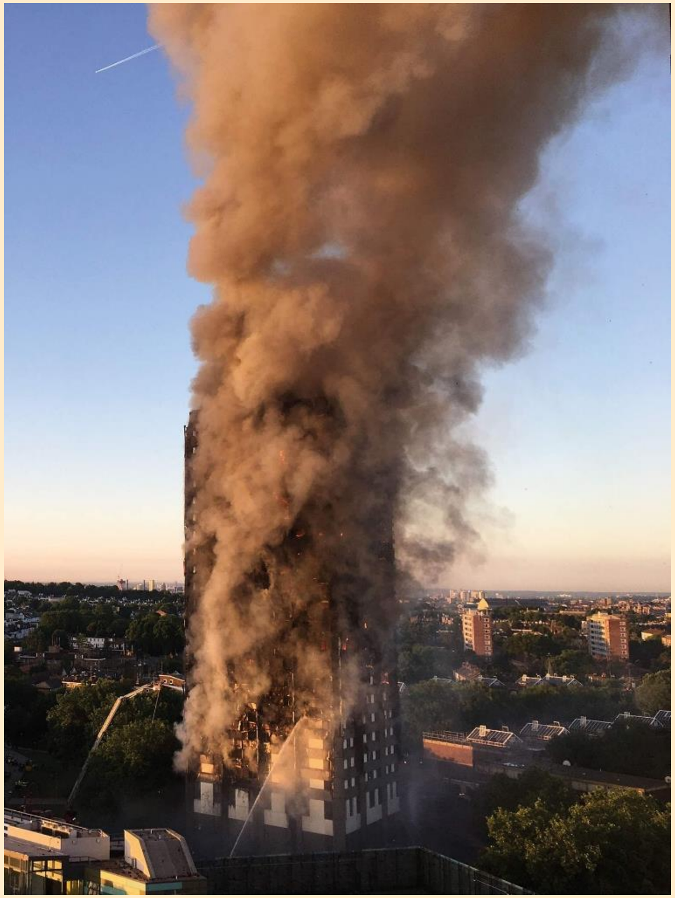
- Working assumption has always been that the sources of toxicity stem from the furnishings and contents of the occupied space

Toxic sources

- Do we still think this (still) is true?

- Do our regulations protect those inside a building well enough from building materials on fire outside it?

* Define 'Outside' & 'Inside' (Voids)



Potential for occupant toxic exposure from burning building products

- Point 1 – there is no toxicity limitation criteria for building materials
- Point 2 – there is no requirement to fire stop services penetrating the external envelop of the building (are ‘inside’, ‘outside’ and ‘voids’ actually one and the same thing)
- Point 3 – the impact of penetrations on cladding fire performance is not assessed
- Point 4 – Fire can spread faster in the cladding void than some reactive cavity barrier devices can operate
- Point 5 – It is vital to understand how toxic threat is adjusted by the burning scenario

Performance of Cavity Barriers

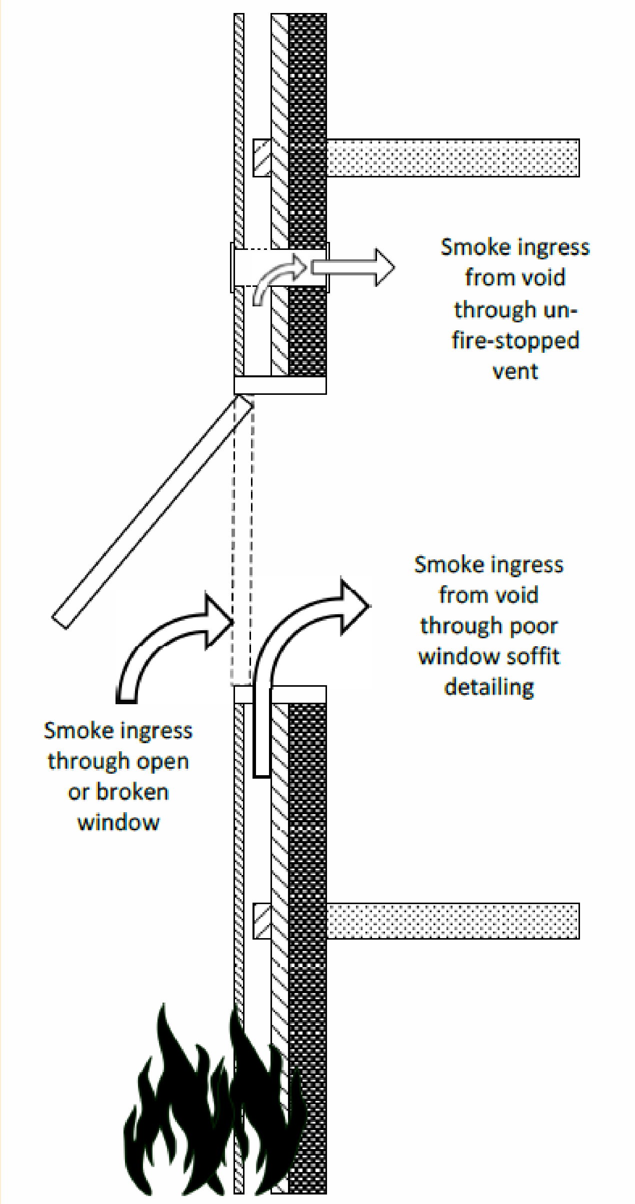
Capability of intumescent cavity barriers in vented rainscreen systems

Summary

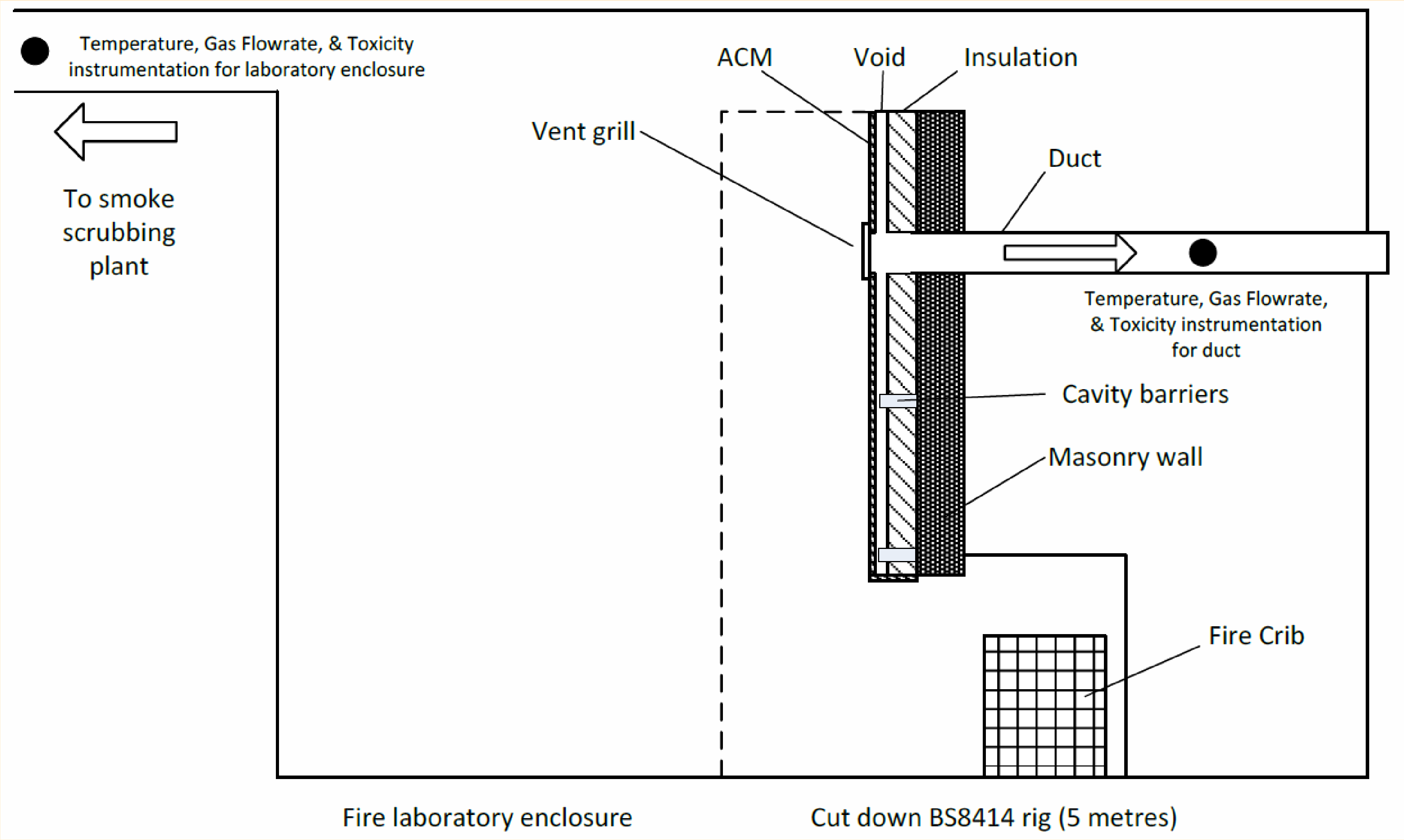
Cladding System Toxicity: it has been demonstrated that

- fire may enter the cladding void via ‘soft spots’
- in some material configurations cavity barriers may not prevent spread
- that there is potential for the communication of gases, smoke and fire to all occupied spaces that connect to the cladding void via i.e. vents

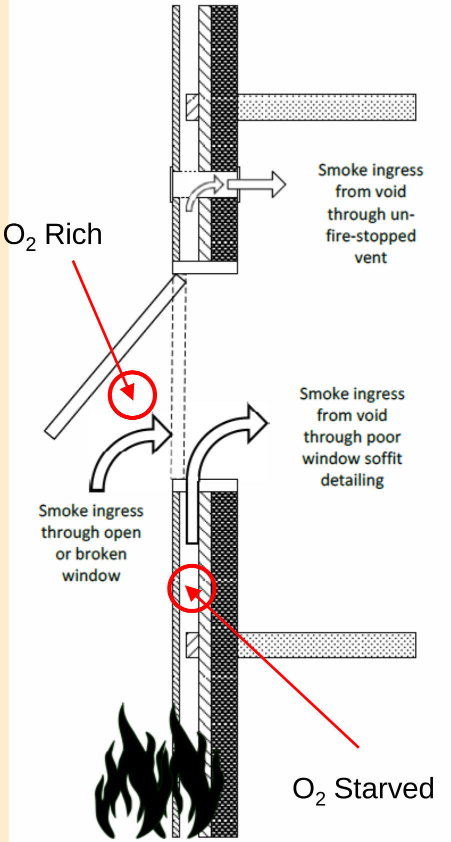
… so is their potential for occupant harm?

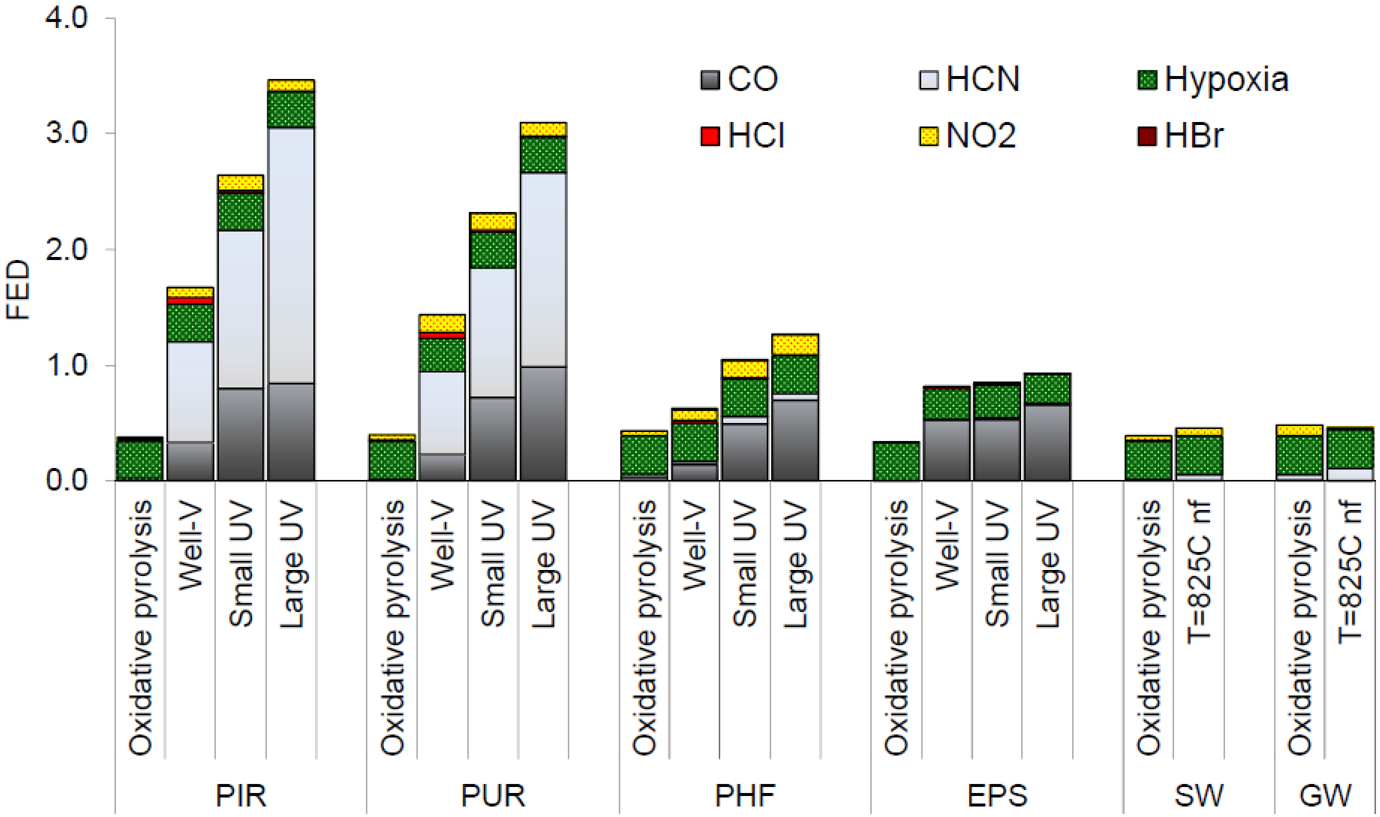


Smoke ingress from void through un-fire-stopped vent
Smoke ingress from void through poor window soffit detailing
Smoke ingress through open or broken window



Temperature, Gas Flowrate, & Toxicity instrumentation for laboratory enclosure
To smoke scrubbing plant
ACM
Void
Insulation
Vent grill
Duct
Temperature, Gas Flowrate, & Toxicity instrumentation for duct
Cavity barriers
Masonry wall
Fire Crib
Fire laboratory enclosure
Cut down BS8414 rig (5 metres)





Ref: Stec & Hull

Figure 3 - Stone wool insulated system with A2 ACM panels

Figure 4 - PIR insulated system with A2 ACM panels

Figure 5 - Phenolic insulated system with A2 ACM panels

Figure 6 - PIR insulated system with PE ACM panels (note test had to be stopped early, after 12 minutes)

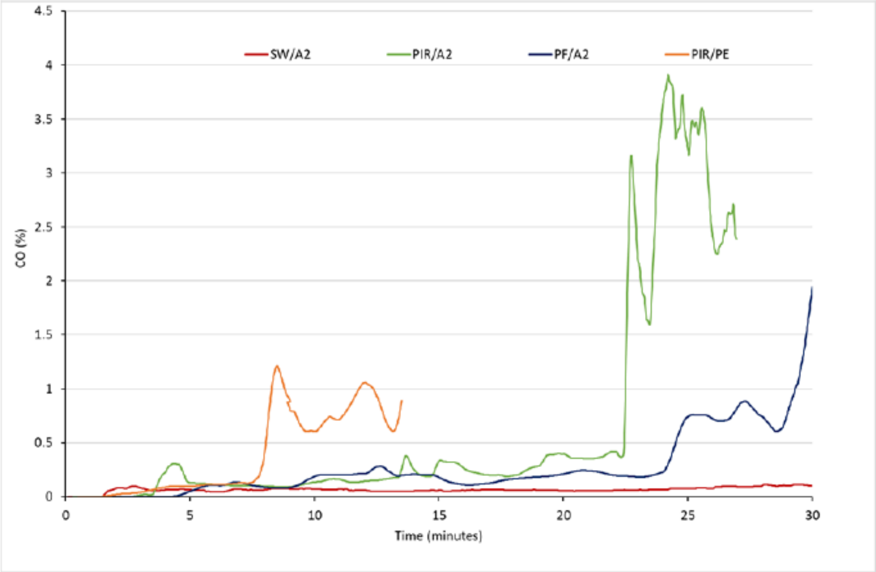


Figure 12 – Carbon Monoxide concentrations measured in cladding system vent

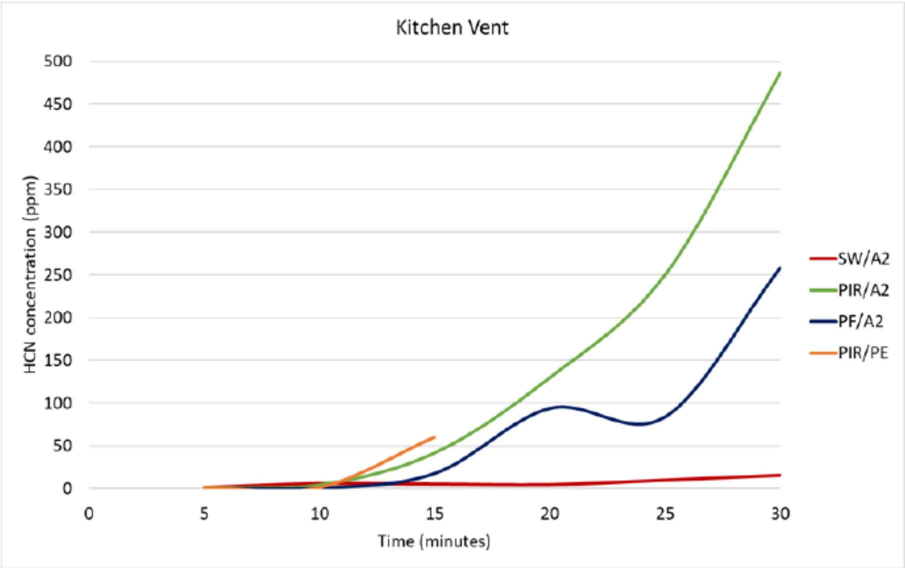


Figure 14 – Hydrogen Cyanide concentrations measured in cladding system vent

FED analysis of gases in 50m³ room connected to cladding void via a 100mm diameter vent:

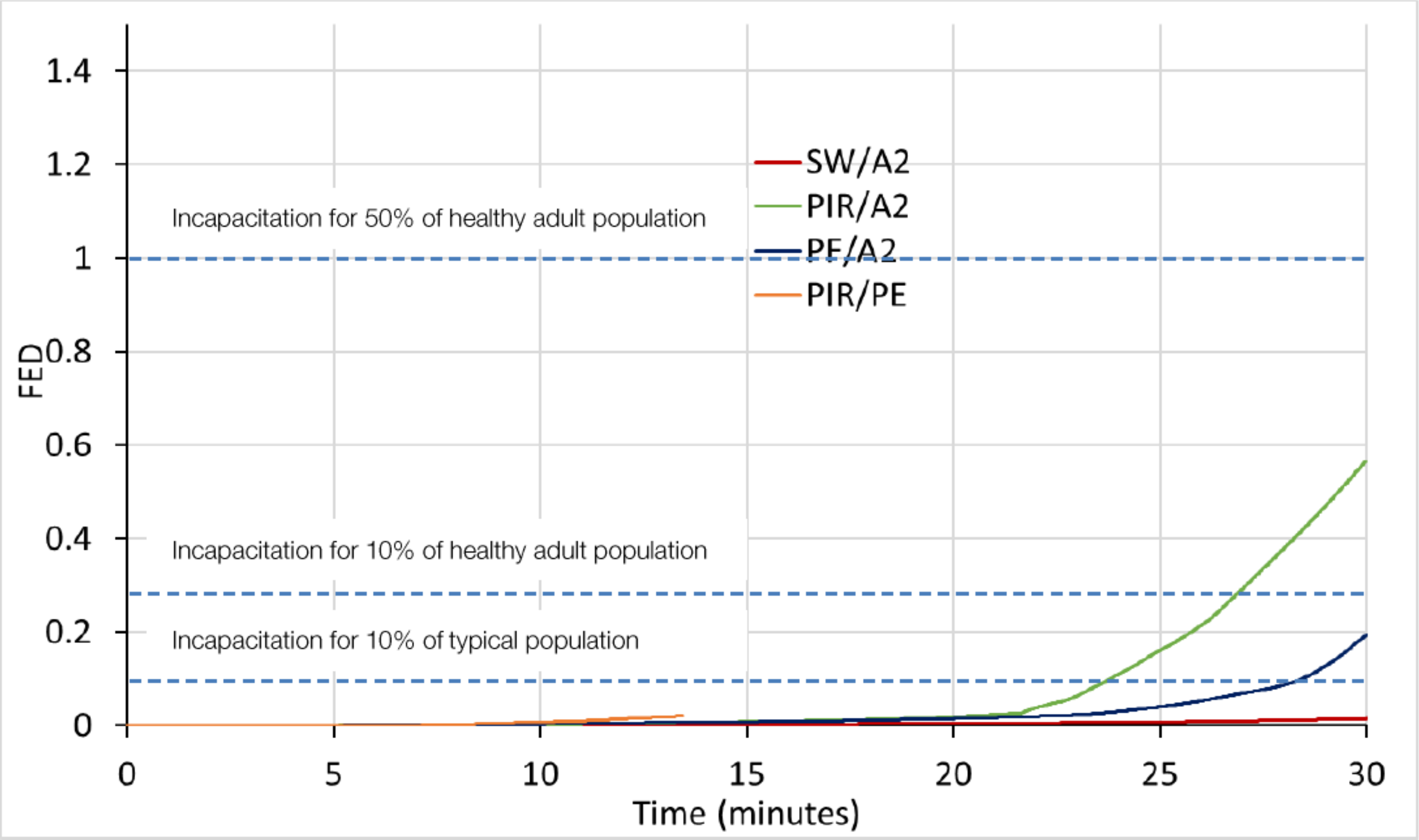


Figure 16 – Total FED for incapacitation for gases entering a 50m³ room from cladding through 100mm vent (The curve for PIR/PE is shown until the wood crib was extinguished at 12 minutes)

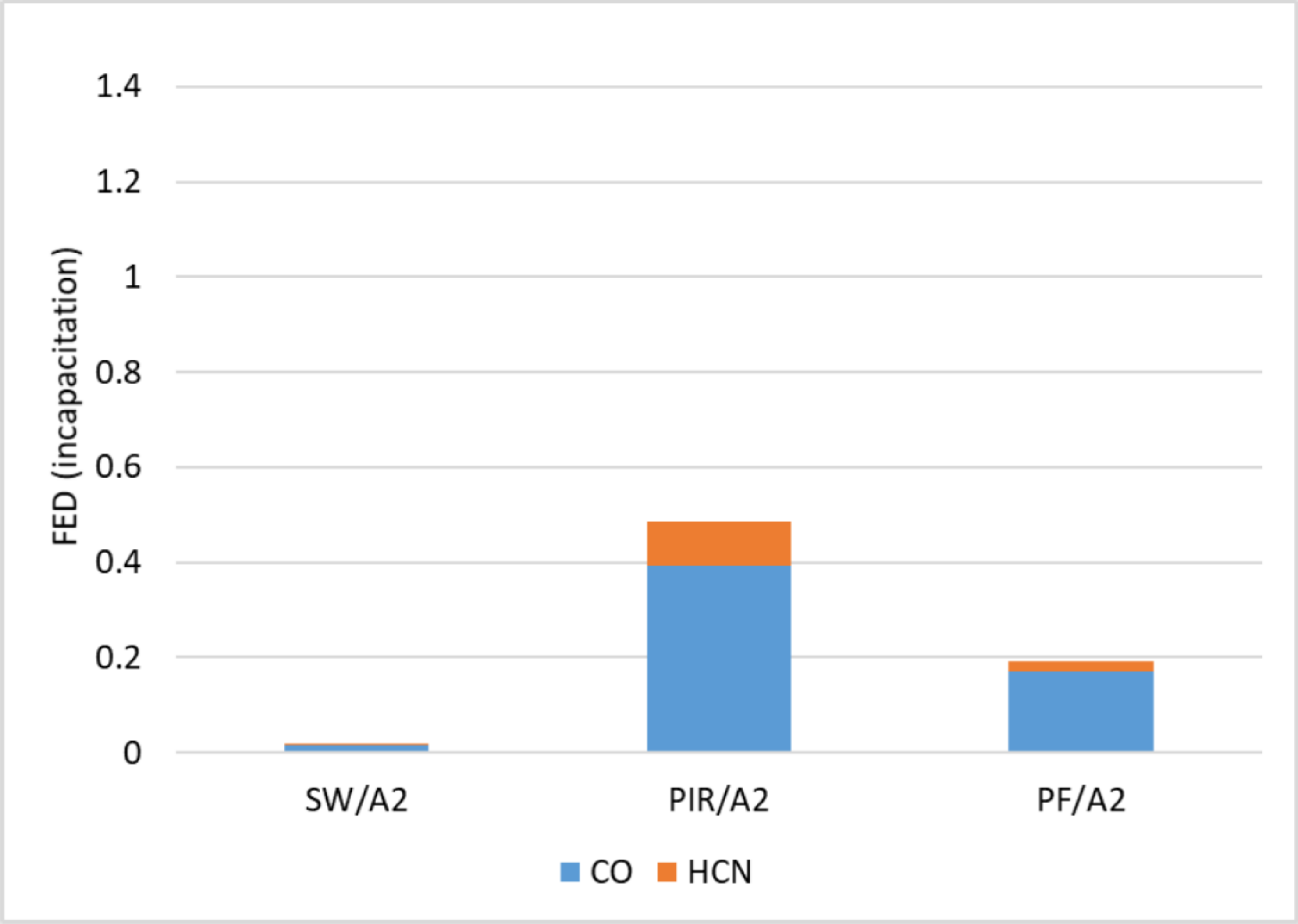


Figure 17 – Contribution of CO and HCN to incapacitation at 30 minutes for gases entering a 50m^3 room from cladding through 100mm vent

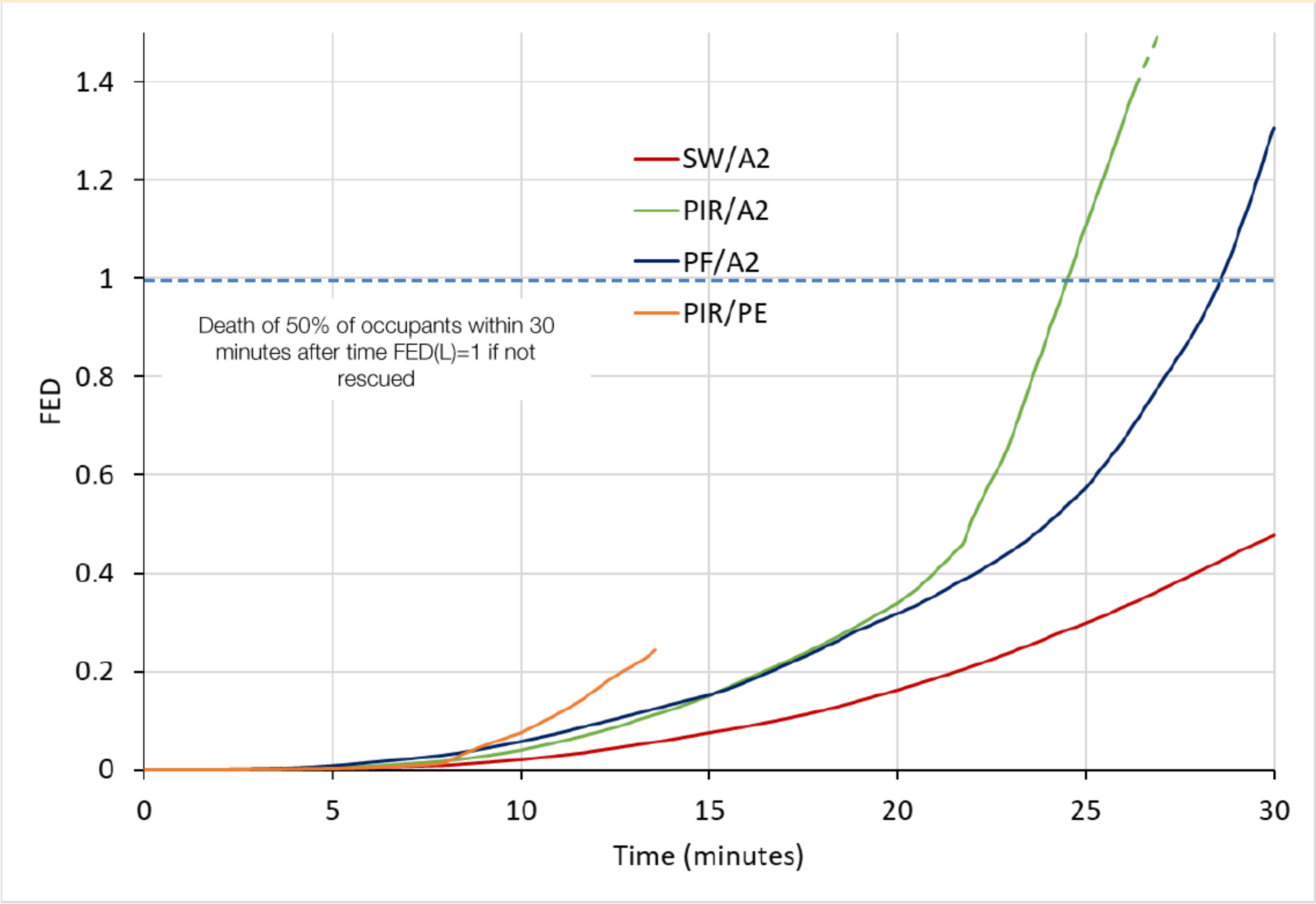


Figure 18 – Total FED for lethality for gases entering a $50m^3$ room from cladding through 100mm vent (The curve for PIR/PE is shown until the wood crib was extinguished at 12 minutes)

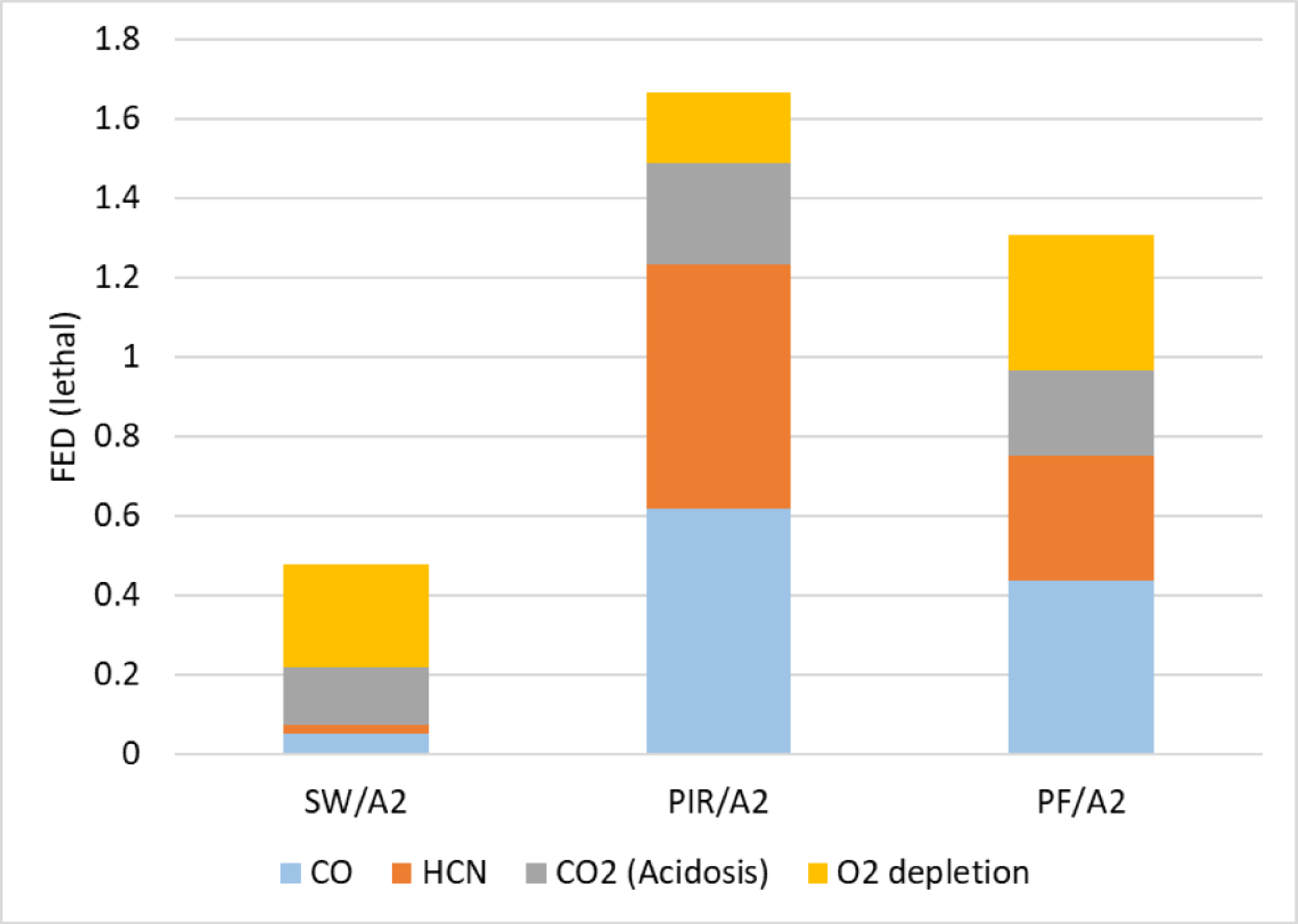
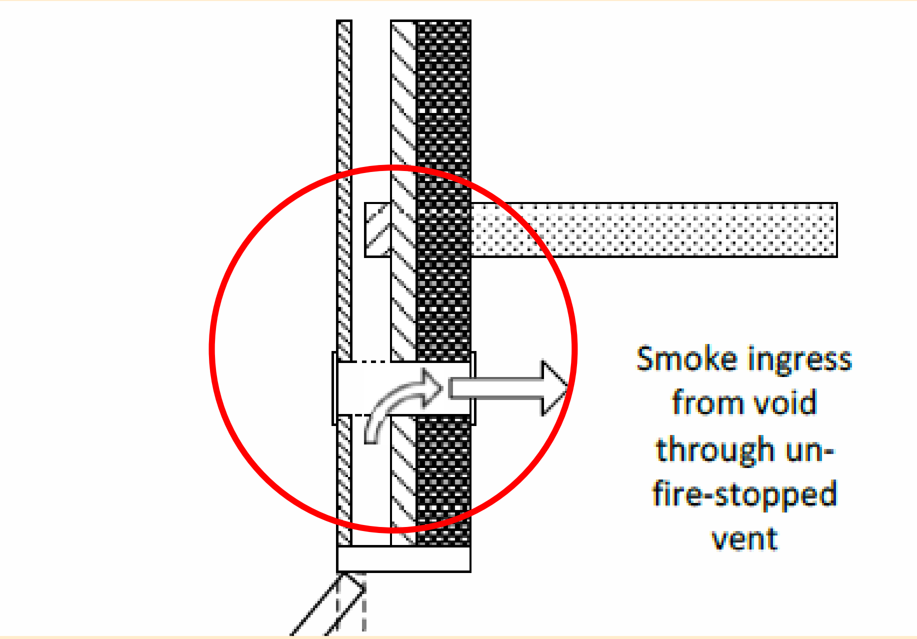


Figure 19 - Contribution of CO, HCN, CO_2 and O_2 to lethality at 30 minutes

For a 50m^3 room, connected to the rain-screen void via a 100mm vent, the results suggest that for some material combinations (ones with higher combustible content) incapacitation can occur in around 10 minutes after the fire breaks into the location of the cladding system containing the vent (at around 7, 22, and 29 minutes for PIR/PE, PIR/A2, and PF/A2, respectively), and, if they cannot escape before becoming unconscious, that death may follow within 30 minutes if they are not rescued.



Fire Protection Association

Historic England

Historic England : Research into fires from Wood Burning Stoves in thatched buildings – Continued …..

A ‘fresh-eyes’ look at thatch ignition funded by Historic England and NFU Mutual

Starting point – fire raising in thatch

- All methods are possible
- All methods are improbable
- Some methods might be more improbable than others
- Fires will have started by all methods (everyone is right!)
- but we need to know what’s ‘prevalent’ so we can focus effort

Bird dropping a lit cigarette

Increasing likelihood →

Chimney fire

Near Pot Top Fires – Birds nest

- Birds nests can appear in a day
- That day may be the day before sweeping, or the day after sweeping
- A mechanism by which high energy material already has advantages over gravity and proximity to the thatch to cause trouble.

Mechanism

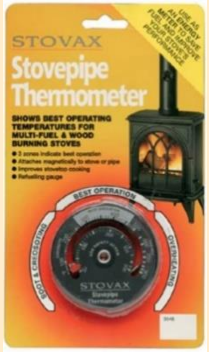
1. Bird build’s nest
2. Cold spell – WBS lit
3. Volatiles driven off from nest material
4. Hot but low oxygen flue gas -> Charcoal
5. After 20-40 minutes the now brittle nest collapses into uprising gas stream
6. On exiting chimney and meeting oxygen the light but high energy hot charcoal spontaneously burns
7. The charcoal embers are heavy enough, and energetic enough to travel downwards remaining viable ignition sources for long distances

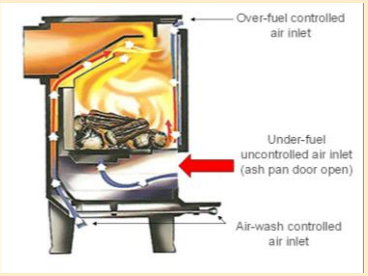
Birds Nest Test

Continuation programme

Having established:

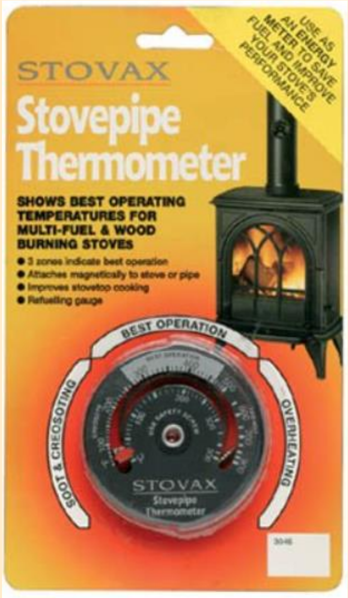
1. the benefit of stove temperature sensors – which one should be recommended / distributed to reduce thatch fire losses?
2. that some stove designs might be safer than others – how can this be quantified?
3. that specific circumstances can lead to spark ejection of an endangering type – what are the capabilities of thatch FP treatments to prevent ignition?





Stove Sensors

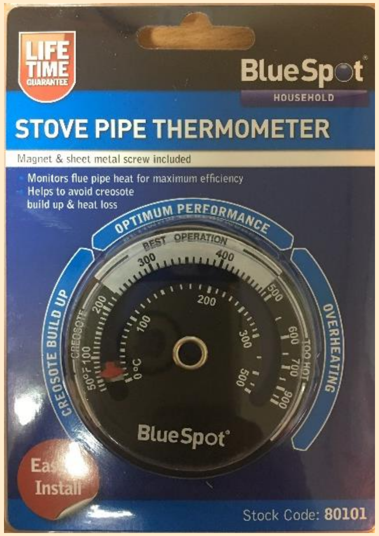
- Seek to inform whether the stove is being operated ‘safely’
- ‘Unsafe lower limit’ – too cool – tar formation in flue
- ‘Unsafe upper limit’ – too hot – spark lift / high heat
- ‘Safe limit’ – gases leave at minimal temperature that avoids tar condensation



Technical challenge

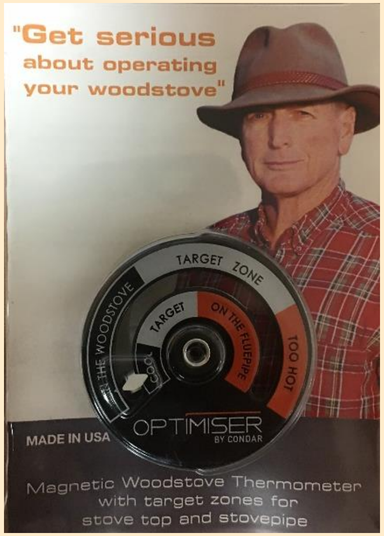
- A measurement made on the stove or stove pipe is attempting to describe the conditions at height in the flue
- This probably needs more information to do accurately than this simple device can deliver
- What is the ‘optimal’ flue temperature ($T_{stove\ pipe} = T_{flue}$)?

Stove sensors - Variations



Mounting Location:

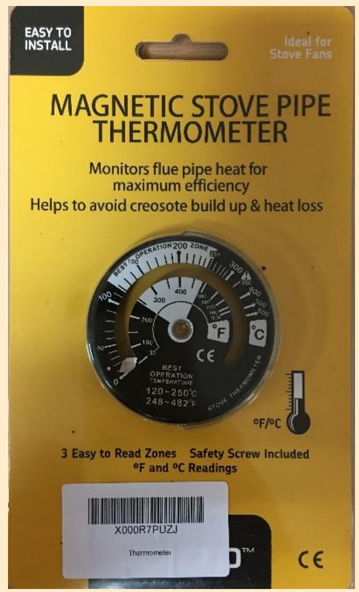
- Mount on Stove pipe
- Mount on Stove collar
- Mount on Stove
- Mount on Either

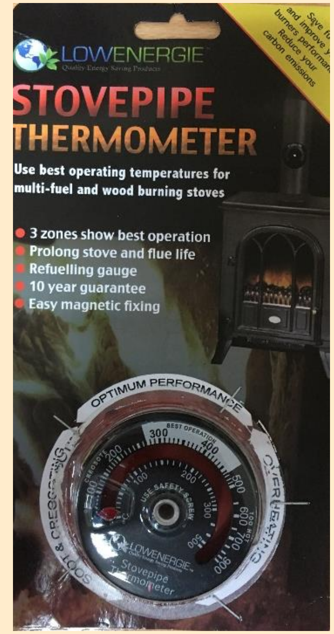


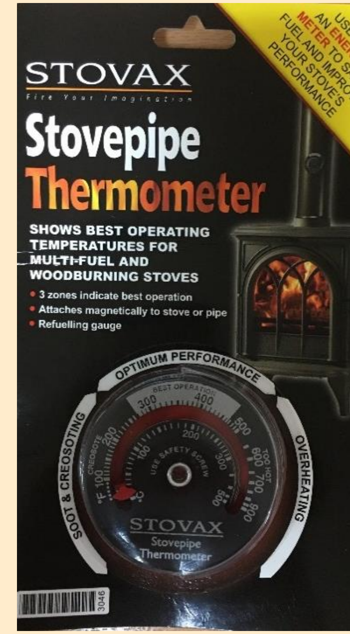
Scale:

- Temperature – Single
- Temperature – Double (Stove pipe mount / Stove Mount)
- Colour (Too cool, Optimum, Too Hot)

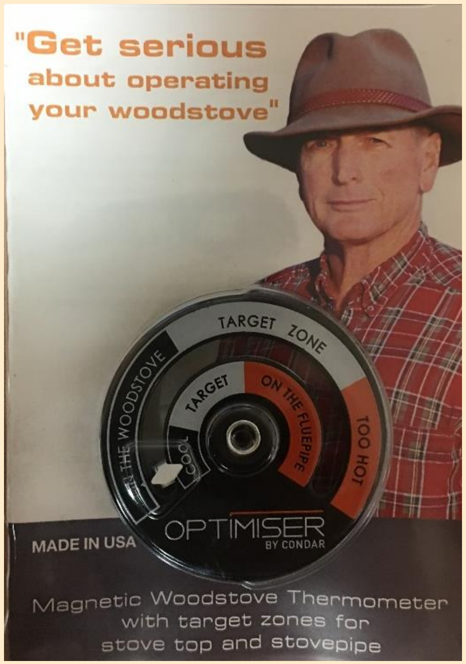
Stove Sensors Tested – Stove Pipe

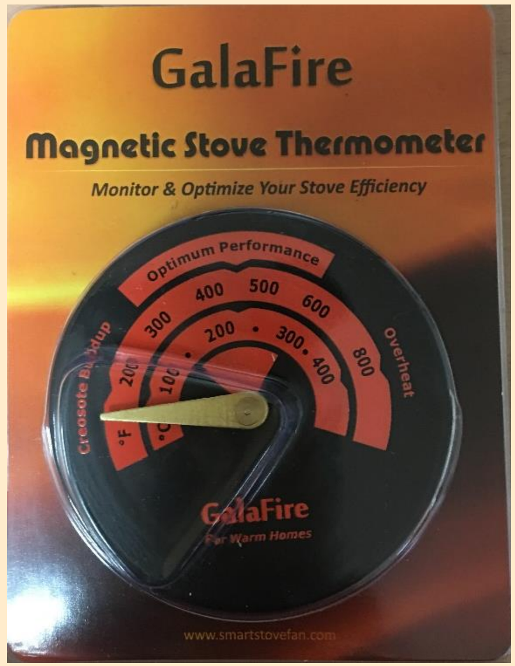


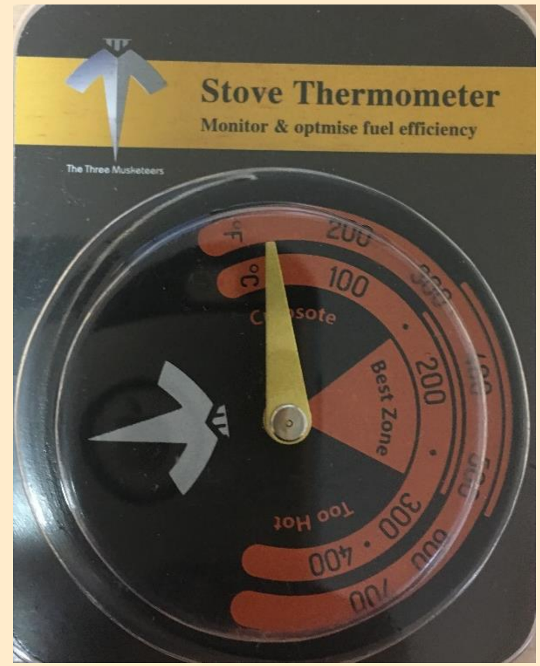




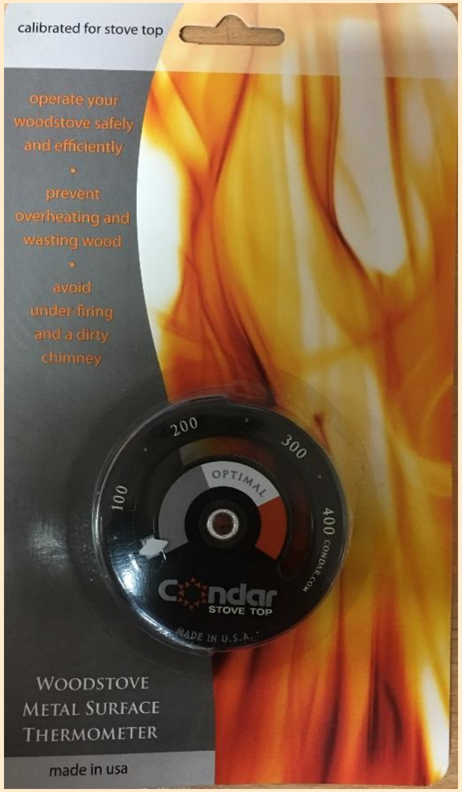
Stove Sensors Tested – Dual







Stove Sensors Tested – Stove Top



Stove Sensors – Test Method

Using the highly instrumented FPA stoves:

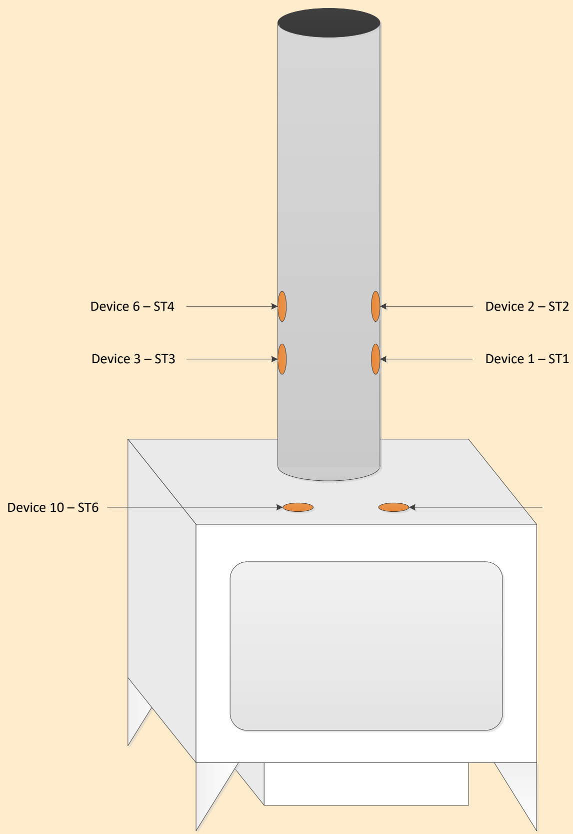
- Simultaneous comparison of Sensor readings
- Comparison of reading ($T^{o}C$ and Too cool / Optimum / Too Hot)
- Actual flue temperatures

Analyse for:

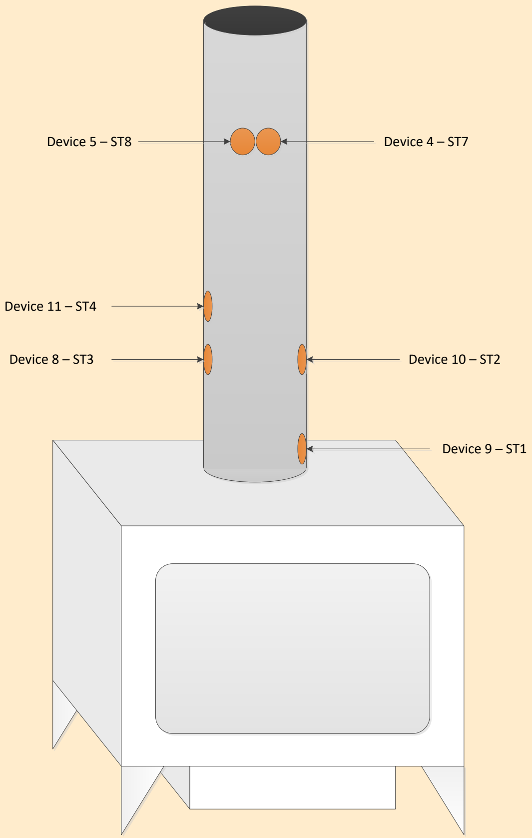
- $T^{o}C$ accuracy
- Comparison between unit
- Relevance to flue temperatures

Stove Sensors – Equipment

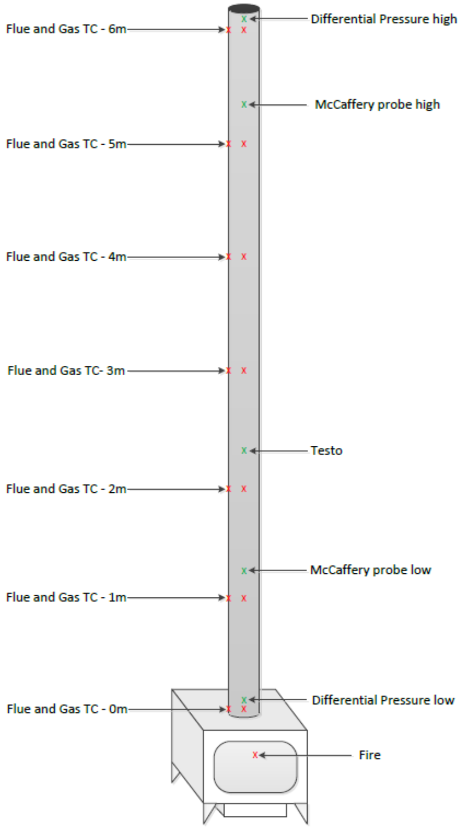
Test 2 & 3
(Device and TC locations)



Test 4 & 5
(Device and TC locations)

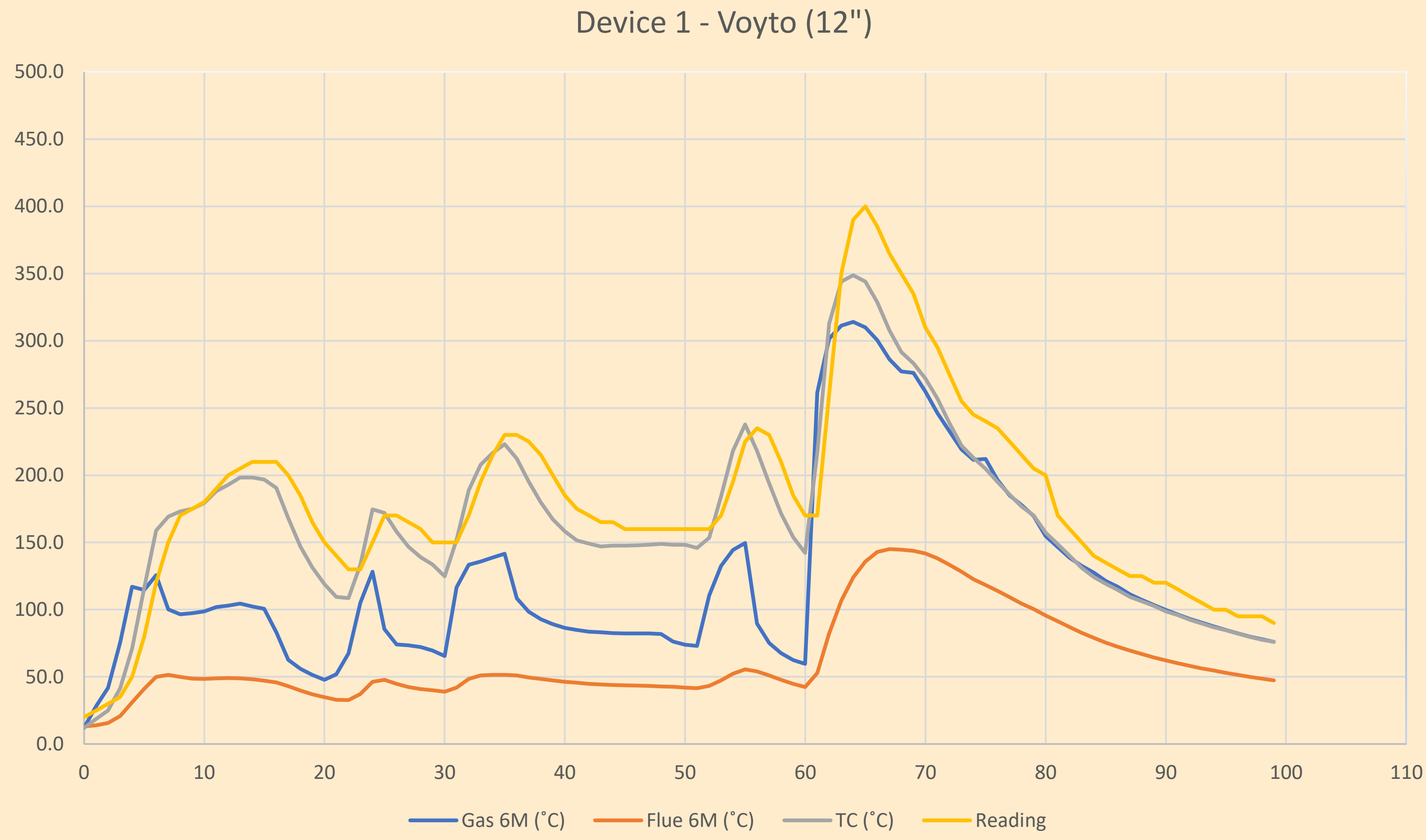


Instrumentation
types and locations

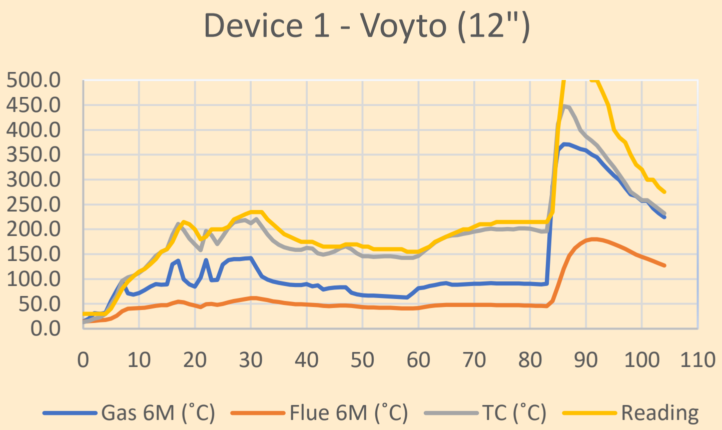


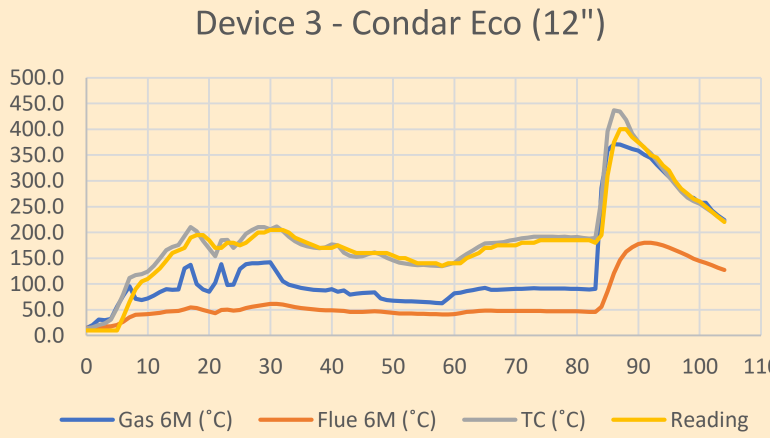
Stove Sensors – Video Recording

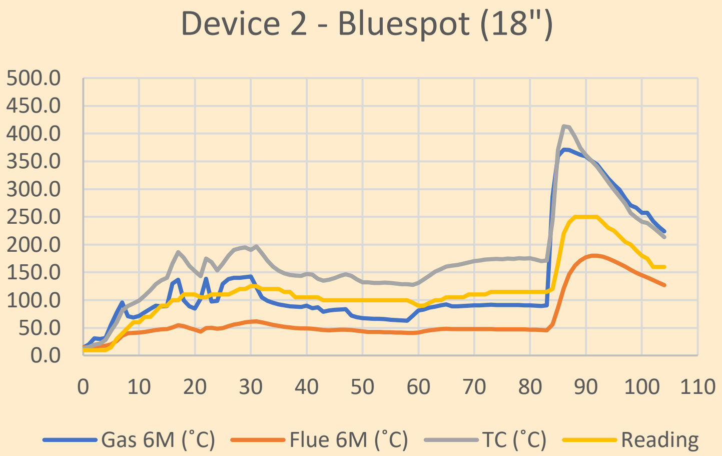
Stove Sensors – Sensor & T/C measurements

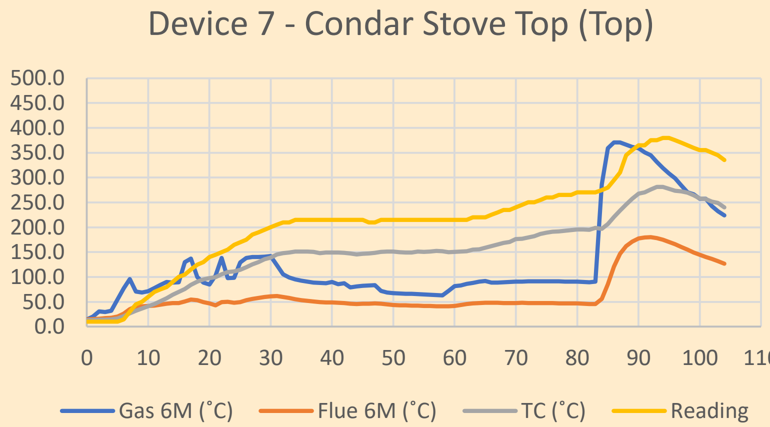


Stove Sensors – Sensor & T/C measurements









Stove Sensors – Range measurement

Test 2				Device 1		Device 2		Device 3		Device 6		Device 7		Device 10	
Video start time @ 1516				Voyto (Flue pipe 12")		Bluespot (Flue pipe 18")		Condar Eco (Flue pipe 12")		GalaFire (Flue pipe 18")		Condar Stove Top (Stove top)		Condar Optimiser (Stove top)	
Best Operation Zone				120-250		120-250		110-250		150-280		200-350		Zones	
Time (m)	Fire (˚C)	Gas 6M (˚C)	Flue 6M (˚C)	TC (˚C)	Reading	TC (˚C)	Reading	TC (˚C)	Reading	TC (˚C)	Reading	TC (˚C)	Reading	TC (˚C)	Reading
0	13.3	12.1	13.0	12.0	20	12.0	10	12.1	10	12.0	50	11.6	10	11.6	Cool
1	151.4	28.2	14.1	18.8	25	17.7	10	17.7	10	16.9	50	11.9	10	11.9	Cool
2	214.3	41.8	15.7	24.9	30	23.2	10	24.2	10	22.3	50	12.2	10	12.3	Cool
3	266.8	75.7	20.9	41.6	35	37.3	15	39.0	15	35.2	50	13.1	10	13.8	Cool
4	315.9	116.9	31.0	70.8	50	63.1	25	66.9	20	58.0	55	14.7	10	17.1	Cool
5	738.4	114.6	41.1	116.1	80	100.1	45	122.4	55	104.9	85	19.9	10	24.8	Cool
6	745.4	125.7	50.0	158.9	120	137.1	60	167.2	100	143.7	105	28.1	20	35.1	Cool
7	539.4	100.3	51.4	169.2	150	146.8	85	183.2	145	158.1	115	37.1	30	46.3	Cool
8	620.0	96.6	49.9	173.0	170	150.2	100	187.7	165	162.1	130	45.5	50	57.2	Cool
9	633.2	97.4	48.8	175.0	175	152.5	100	190.4	175	165.2	145	53.3	70	67.7	Cool
10	609.9	98.7	48.4	179.4	180	156.7	100	190.5	180	165.8	145	61.2	90	76.5	Cool
58	379.7	67.7	47.8	171.7	210	157.6	125	173.1	190	157.0	165	160.2	225	154.6	Target
59	365.2	62.6	44.9	153.8	185	142.4	115	155.2	175	142.4	150	158.9	225	152.8	Target
60	464.2	59.7	42.4	142.2	170	132.1	105	143.3	165	132.8	145	156.2	220	150.1	Target
61	827.3	261.4	52.9	216.5	170	194.9	100	196.9	160	180.3	145	155.5	220	150.6	Target
62	850.6	301.5	82.4	312.7	260	283.0	135	287.1	210	260.4	185	162.5	225	157.6	Target
63	833.0	311.3	106.6	344.1	350	315.1	165	323.3	270	293.5	210	171.9	235	168.2	Target
64	792.3	314.1	123.9	348.8	390	320.9	175	330.3	300	302.0	230	182.6	250	178.6	Target
65	806.5	309.9	135.7	344.1	400	318.3	180	325.6	315	300.1	245	190.0	265	187.6	Target
66	754.4	300.5	142.9	328.7	385	304.7	180	317.4	320	293.1	245	197.7	275	196.2	Target
67	666.8	286.2	145.1	307.9	365	286.7	180	299.3	310	277.6	240	202.0	280	201.6	Target
68	615.3	277.1	144.5	291.7	350	272.1	180	280.7	295	261.7	235	204.9	280	203.6	Target
69	592.1	276.1	143.7	283.2	335	263.9	180	271.4	280	252.0	230	205.6	285	202.8	Target
70	596.4	262.4	141.9	272.1	310	252.8	175	259.4	265	242.4	220	206.5	285	201.9	Target
71	592.9	246.1	138.2	256.9	295	238.8	175	246.7	255	230.8	215	207.2	285	202.0	Target
72	564.4	232.7	133.4	238.9	275	222.2	155	230.1	235	216.4	205	205.3	285	198.1	Target
73	517.4	219.1	128.1	222.0	255	206.9	145	211.9	210	200.3	190	204.5	285	195.7	Target
74	445.4	211.4	122.6	212.9	245	198.2	140	204.1	205	191.6	190	201.4	280	195.0	Target
75	443.8	212.2	118.3	204.7	240	190.8	140	201.3	200	187.1	185	198.4	275	192.2	Target
76	418.2	196.6	114.0	195.1	235	181.8	135	193.3	195	179.6	180	194.1	265	189.0	Target
77	329.3	184.8	109.3	185.5	225	173.2	130	180.8	185	169.0	170	189.4	265	183.8	Target

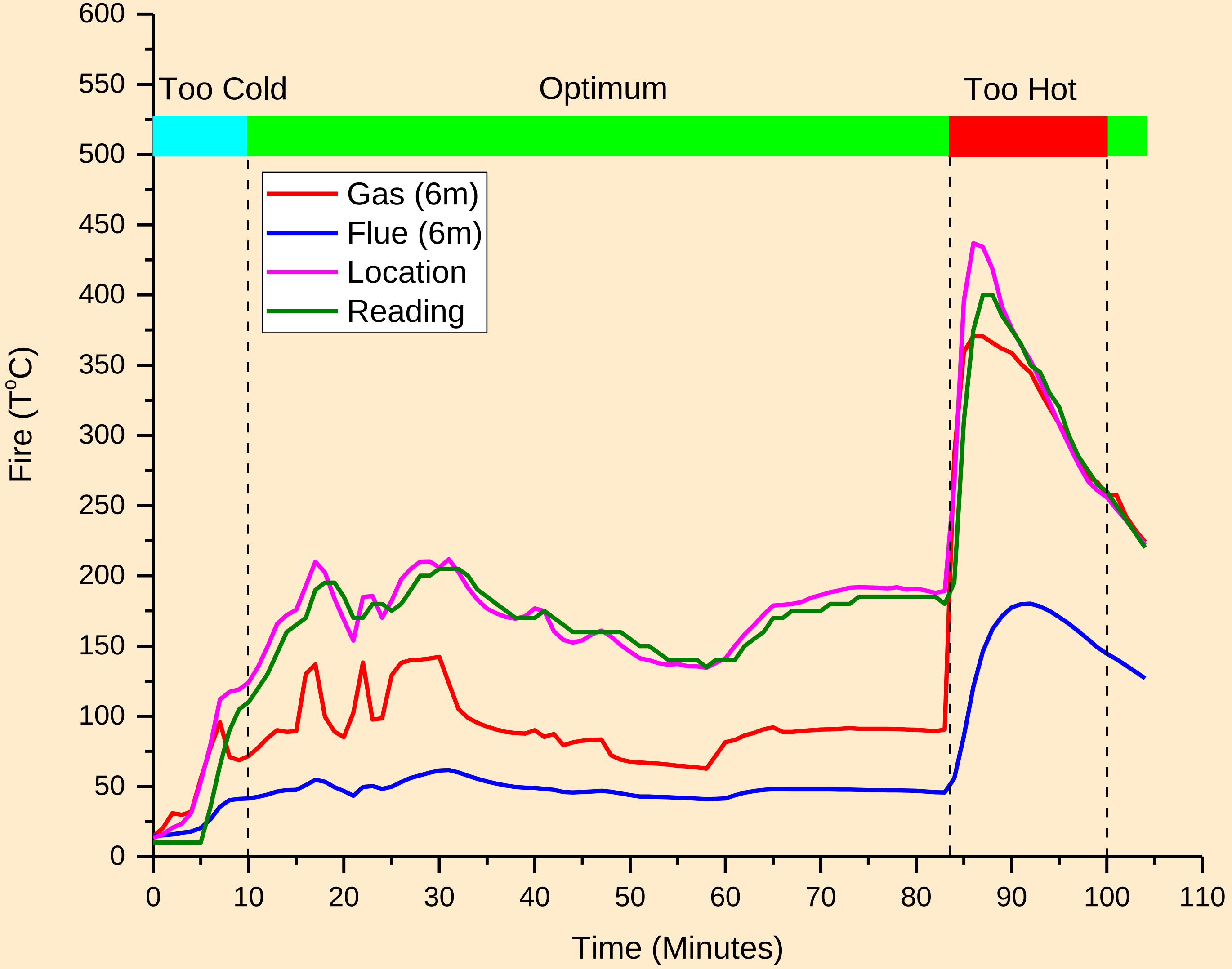
Stove Sensors - Analysis

What causes Tar Build Up within a flue?

The smoke from wood fires and stoves will contain a full range of hydrocarbons dissolved in it. As the smoke cools within the flue, it will start to deposit these hydrocarbons on the surface of the flue. This process starts with the heavier oils, such as tar, and moves onto creosotes and even paraffin as you progress up the flue. Once deposited onto the surface of the flue, this tar build up, is very hard to remove without causing further damage to the flue. All of these hydrocarbons are highly flammable and are the main cause of chimney fires.

50 degrees C is the dew point of the condensates in the flue gases and tar and impurities in the flue gases will condensate on surfaces in the flue and chimney.

Performance of Condar ECO



Stove Sensors – Summary

- Stove Sensors seek to describe the safety of conditions at a distance far away from where they are actually making measurement.
- For our 6m chimney this seemed to work well for many devices
- They may not read correctly for:
  - longer and more complex chimneys
  - where the chimney is not lined
  - where the chimney has a large cross sectional area
- Poor performance was indicated by:
  - Inaccurate temperature measurement
  - Poor speed of response
  - Zone marking that did not seem to represent the threat of our chimney system
- Stove Pipe mounted devices had a much better reaction time.

Stove Design – ‘Abusability’

- Identified as a critical potential issue in respect of risk to thatched properties
- Greatest risk perceived from stoves that allowed exclusive under-fuel venting either:
  - deliberately (in accordance with operating manual)
  - illegally (not in accordance with operating manual)
- Three potential modes of operation:
  - Fuel loading door only open (above fuel)
  - Interlocked doors (above and below fuel)
  - Ash pan door only (below fuel)

Stove Design – 'Abusability'

Example of a wood / log burning stove with no ash-pan

Example of multi-fuel stove with single door providing access for fuel loading and ash-pan removal

Example of multi-fuel stove with separate doors for providing fuel loading and ash-pan removal

Stove Design – ‘Abusability’

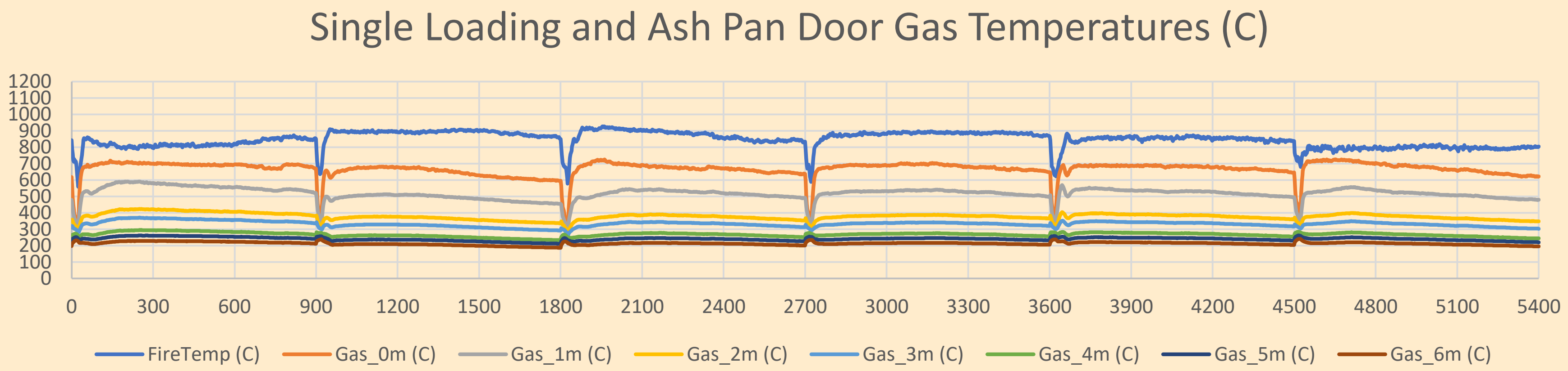
Method:

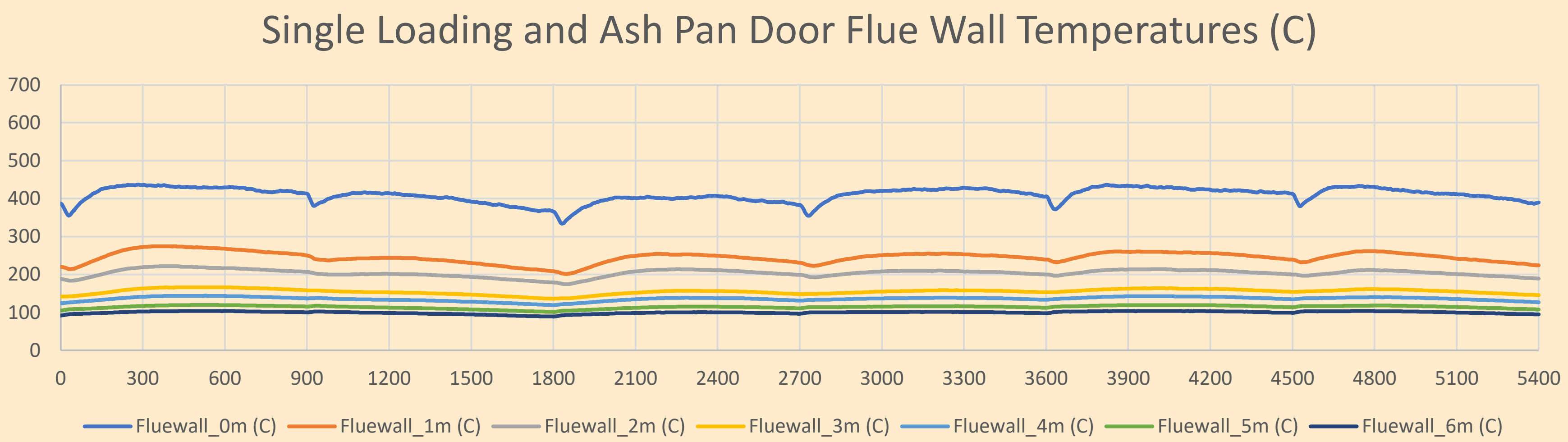
- Attempt to run stoves as hot as possible with the only limitation being door configuration

Analysis

- Gas temperatures – fuel / spark lift potential
- Flue wall temperature – chimney fire potential

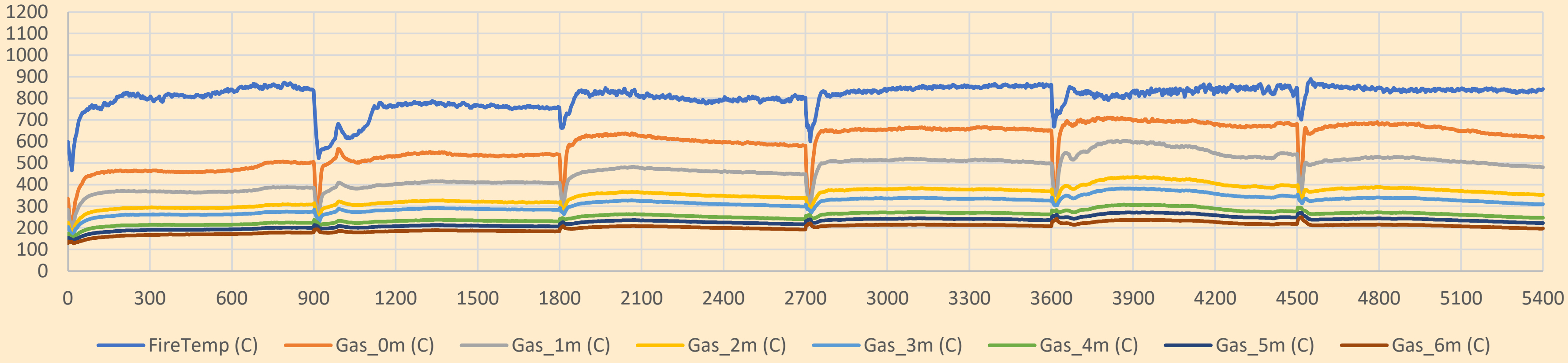
Stove Design – Loading door



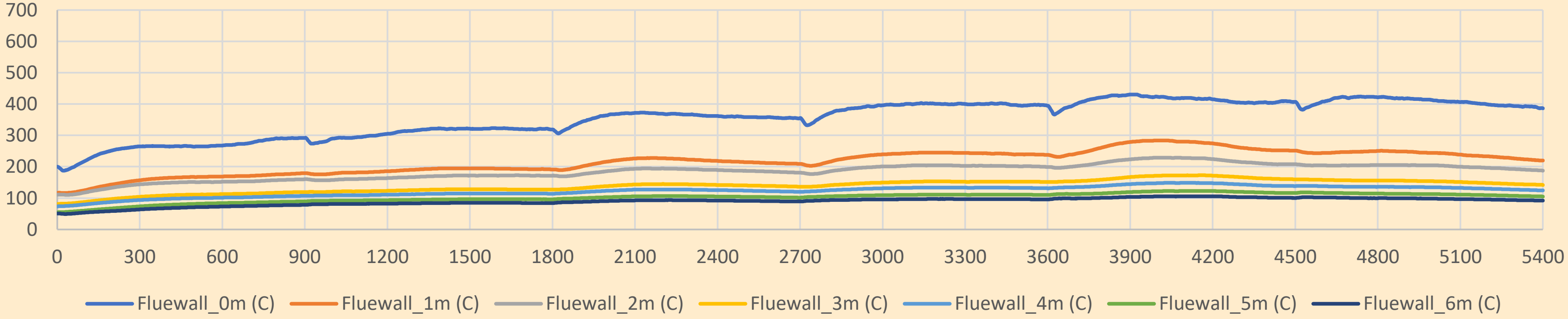


Stove Design – Interlocked door

Interlocked Loading and Ash Pan Door Gas Temperatures (C)

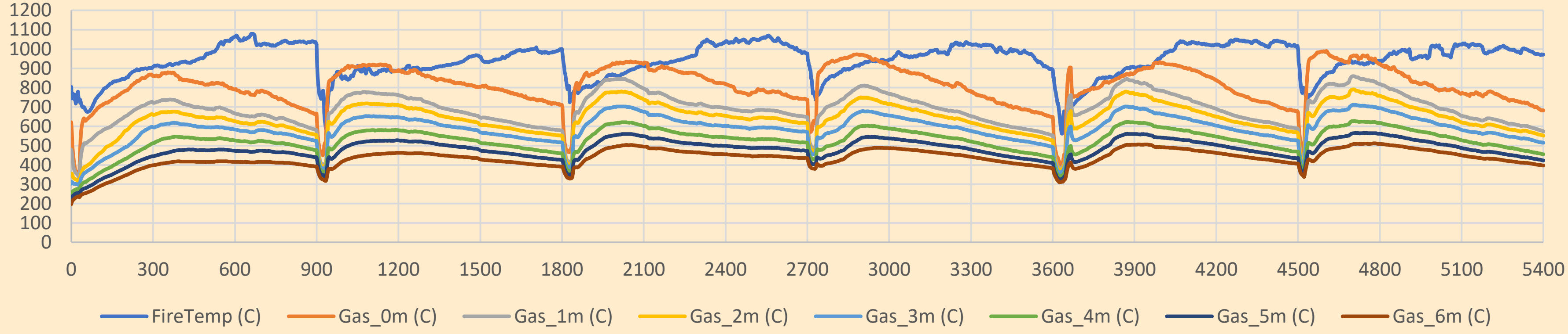


Interlocked Loading and Ash Pan Door Flue Wall Temperatures (C)

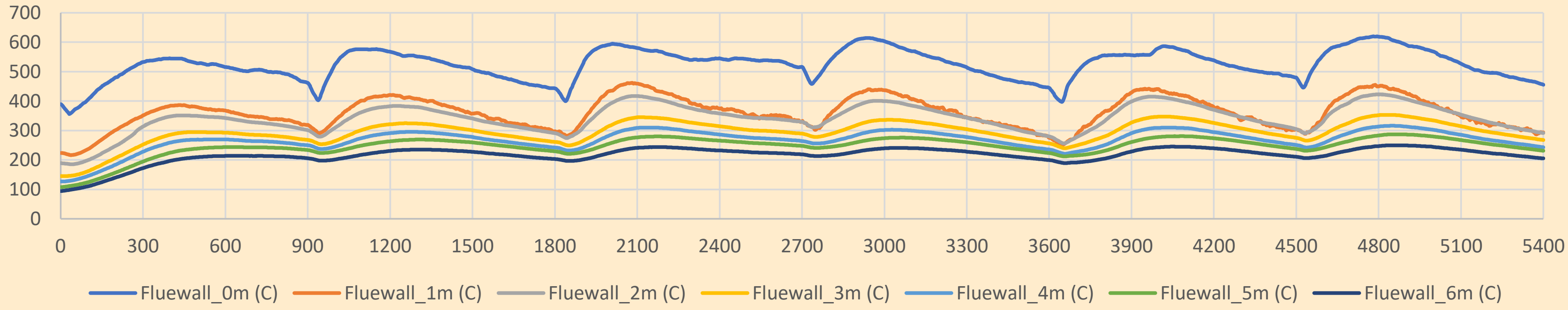


Stove Design – Ashpan Venting

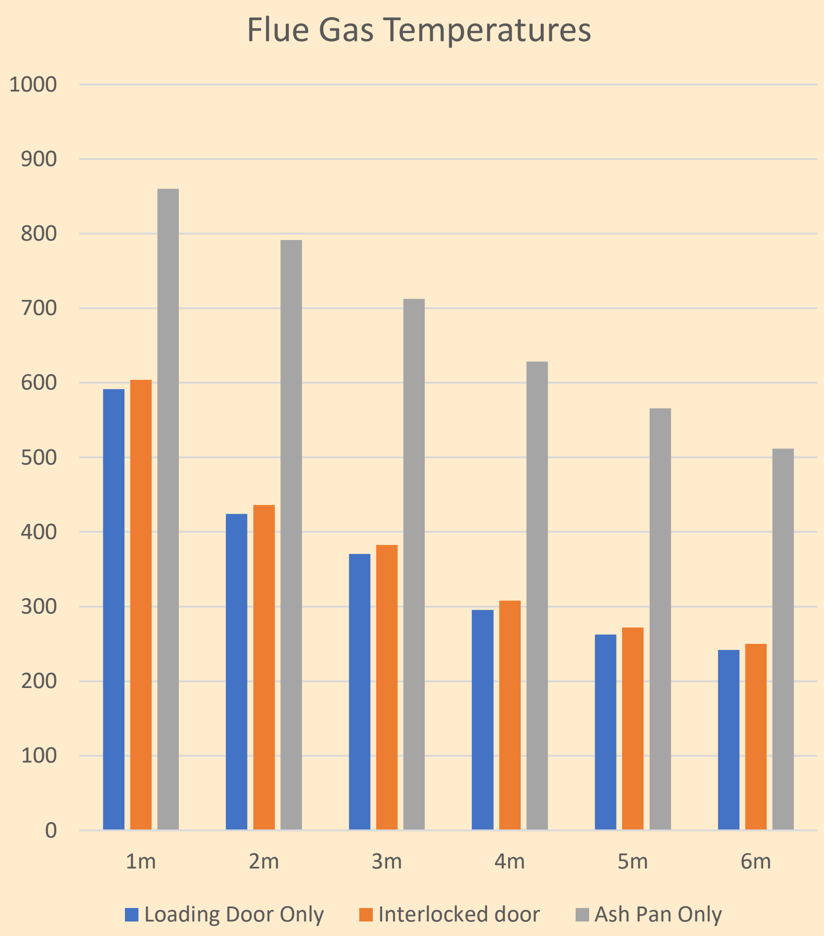
Independent Loading Door and Ash Pan Door Gas Temperatures (C)

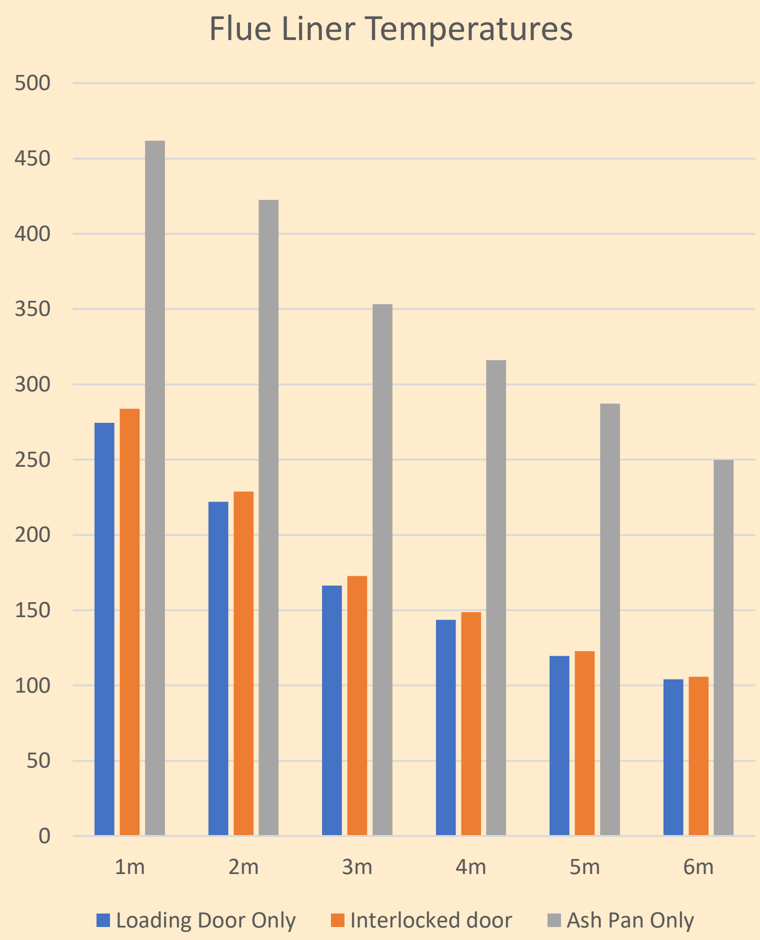


Independent Loading Door and Ash Pan Door Flue Wall Temperatures (C)



Stove Design – Analysis





Stove Design – Conclusions

Designs that allow (intentionally or illegally) the exclusive under-fuel ventilation of the stove can result in:

- Gas temperatures over x2 that achievable by other designs
- Flue liner temperatures over x2 that achievable by other designs

Accepted ignition temperature of chimney creosote is 230^{o}C

Stoves allowing under-fuel ventilation regime have shown:

- T_{gas} = 500 ^{o}C
- $T_{flue\ wall}$ = 250 ^{o}C

at the top of the flue where tar formation will be prevalent and higher temperatures at all location below (only 230 ^{o}C & 100 ^{o}C respectively for other ventilation methods.

Thatch protection

Method:

- Create a number of test rigs
- Create ‘ember generation rig’
- Treat and monitor performance over a period of time
- Determine capability over untreated thatch of same age

Thatch protection – Test rigs

Thatch protection – Ember generator

Simulates creation of 'bird's nest' proven scenario

- Heats nesting material in oxygen deprived environment
- Allows for fan pressurisation to simulate spark ejection from longer flue

Thatch Protection - Treatment

Thank you

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