Historic England Building and Landscape Conservation

# Fires in Thatched Properties with Wood-Burning Stoves

Fire Protection Association (Dr James LD Glockling)

Discovery, Innovation and Science in the Historic Environment


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# Fires in Thatched Properties with Wood-Burning Stoves

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Front cover: Firefighters at a thatched cottage fire. Dorset Media Service/Alamy Stock Photo

## FOREWORD

Since the 1990s, the number of fires occurring in thatch roofed buildings has risen significantly. And in the past decade, more than 500 thatch roofed buildings in England have been damaged or even destroyed by fire. Evidence suggests there is a connection between the rising numbers of fires and the increasing popularity of wood-burning and multi-fuel stoves. In fact, studies have shown that these types of stoves are more likely to cause fires in thatch roofs than any other form of heating, including traditional open fires. But how and why this occurs has long been a subject of contention. One theory was that heat transferred by conduction through the chimney stack to the thatch was the cause of most fires. But in the late 2000s, forensic investigators noted that many fires could not be explained by this 'heat transfer' theory.

It was clear that more research was needed to understand better the threat posed by wood-burning and multi-fuel stoves to thatch roofs, and to find ways of reducing the risk of fire. In response, Historic England (Building Conservation and Research Team) and NFU Mutual Insurance commissioned the Fire Protection Association to carry out a two-year programme of research, including full-scale fire tests. This report describes the investigations carried out, presents the findings and recommends actions to mitigate risks.

## ACKNOWLEDGEMENTS

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## IMAGES

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# EXECUTIVE SUMMARY

Factors that might potentially contribute to the occurrence of fires in thatched roof buildings from the use of wood burning stoves are many, varied, and interrelated. The research described in this report establishes that wood burning and multi-fuel stoves represent a greater hazard in thatched roof buildings than open fires and as such are not a recommended form for heating. Where they are to be used the revised guidance as described in Appendix B should be followed. The principal findings of the work can be summarised as follows:

- The widely accepted idea that heat transfer by conduction (i.e.' Heat Transfer Theory') is the predominant mode of fire raising in thatched buildings is not supported by the test data.

- Confirmed forms of fire raising stem from the release of high energy embers from birds' nests built in the flue, and convective heat transfer through defective chimney brickwork.

- The emission of solid matter, some in the form of embers and sparks, is part of normal stove operation. Generally, sparks coming from the fire box are of low energy, but specific operations and fuels can change this.

- Flue-top devices termed 'spark arrestors' seem to have little or no impact on spark mitigation. In fact, they may encourage emitted sparks to remain in closer proximity to the thatch.

- Some stove designs are inherently safer than others.

- To minimise the risk of fire raising, it is important that users follow the correct operating procedures for their stove and understand the safe limits of its operation. A stove pipe thermometer is a highly effective means of monitoring the safety state of a stove.

In the light of the research findings, it is suggested that an 'ideal' stove system should incorporate the following features:

- A stove design that does not permit exclusive under-fuel venting, either by legitimate (vent control) or illegitimate means (opening ash pan door with fuel loading door closed). If a controlled under-fuel vent is provided to assist in lighting the stove, this should automatically reset to a safe operational setting without requiring human intervention.

- The adoption of a stove pipe temperature monitor in association with good occupant knowledge of how to read it and what it means to safe operation of the stove.

- Use of wide-bore flue liners, preferably of the rigid insulated variety, to reduce flue gas velocities and prevent convective heat transfer methods of fire raising.

- The provision of a mesh-top bird cage on the top of the stack or pot to prevent nesting and accumulation of combustible materials at the pot top.

- The maximum possible separation between pot top and thatch (Approved Document J recommends the minimum allowable).

- Stove, flue, pot and bird guard design that supports good access for camera inspection, sweeping, and cleaning.

- Stove designs that present a clear view of the fire (clean glass) without requiring overly high stove temperatures to be generated.

# 1 INTRODUCTION

This work, conducted at the Fire Protection Association's Research Laboratory, was jointly funded by Historic England and the National Farmers Union Mutual Insurance Society Limited. The objective of this study is to take a scientific, full-scale experimentally based, all-encompassing, 'fresh-eyes' review of fire in thatched buildings, investigating all 'possible' mechanisms without prior preference for any given mechanism being dominant over others. A wealth of anecdotal evidence exists for methods by which fires have started in thatched buildings and all of them have probably happened at some time, from the most unlikely and extra-ordinary, to the more understandable and obvious. However, fires in thatched houses, and buildings in general, are rare events so the starting point of such a study must be that:

- All methods are possible
- All methods are improbable
- Some methods will be more improbable than others
- Fires will have started by all methods (there is no definitive right or wrong)

This study is designed to ultimately assist the commissioning bodies and wider heritage community understand the key parameters that might both promote and mitigate the chances of fire in thatch so that more informed choices may be made in the allocation of effort and cost to reduce the fire risk.

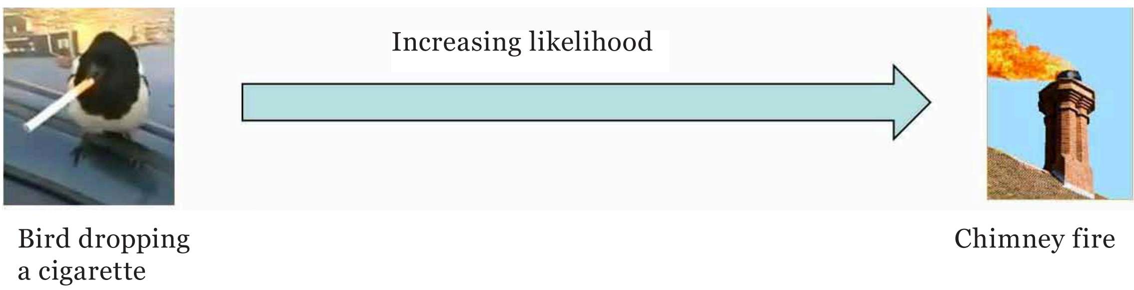



*Figure 1*

## 2 OVERVIEW AND SCOPE

This work is confined to fire-raising in thatched properties from the operation of wood burning stoves. It does not address fire ingress resulting from external fire sources or other internal ignition sources.

The programme of work sought to:

- Categorise potential fire-raising methods in wood burning stove (WBS) systems (Section 3).
- Numerically model chimney behaviours (Section 4).
- Categorise design and operational factors that might influence risk (Section 5).
- design and build full-scale rigs suitable for all experimental investigations (Section 6).
- Characterise WBS operational parameters (section 7).
- Study factors promoting ember transport out through the stack (Section 8).
- Investigate conductive heat transfer as a means for fire raising (Section 9).
- Investigate convective heat transfer as a means of fire raising (Section 10).
- Investigate 'near-pot-top' fires as a means of fire raising (Section 11).
- Consider stove design detail as a potential contributing risk factor (Section 12).
- Provide best practice guidance to thatch property owners (Section 13).
- Consider improving forensic data collection (Section 14).
- Give preliminary consideration to an ideal WBS installation (Section 15).

## 3 CATEGORISATION OF FIRE RAISING/HEAT TRANSFER MECHANISMS

For the purposes of this study the potential mechanisms for fire-raising in thatch have been considered and shall be categorised as follows.

### 3.1 Physical

Applies to the intermittent drop-off of hot/burning condensed material (tar) from the underside of a 'Chinese hat' rain guard, or spark arrestor assembly on to the thatch. Unlike a spark emanating from the chimney such deposits will be heavy with much higher energy densities. Contributing factors to tar build up might include inappropriate fuel selection, product design, poor maintenance or installation. Initiation might commence through poor stove management (high temperatures and high velocities).

*Figures 2-4. Physical mechanisms for fire-raising in thatch.*

## 3.2 Direct Spark Ignition

Applies to the emission of sparks, embers, and hot solid materials from the stack which then fall back onto the thatch with enough energy at given conditions to ignite the thatch. Contributing factors to emission might include fuel type, fuel disturbance and ventilation regime. Ignition propensity might be influenced by weather conditions, thatch condition, age, and type.

*Figures 5-7. Direct spark ignition of thatch.*

## 3.3 'Near pot' fires

Applies to conditions that lead to flaming and fire product emission at the stack which may ignite the thatch by radiation or dropping of flaming material. May work in association with physical mechanisms described above. Examples might include:

- Chimney fire (ignition of soot/tar lining)
- Birds nest/blockage fire

*Figures 8-11. 'Near pot' fires in thatch.*

## 3.4 Convection

In this instance applies to the transfer of heat associated with the movement of a hot flue gases to the thatch which it will heat and possibly ignite. Convective heat transfer depends upon there being a pathway for gases to flow and as such, in the case of this study, it specifically refers to circumstances where the brickwork, mortar, and or lining is imperfect, thereby allowing the thatch to be heated directly by the fire gases, or gases heated on the other side of a perfect liner. The 'desire' of gases to flow through any given path depends very much on the pressure regimes of the system and as such restrictions and blockages, built up over time (i.e. annulus of sweeping residue), or instantaneously (bird nest), may be important factors for consideration. Examples of different convective regimes are given below.

### Convection Scenario 1

Unlined chimney. Escape of hot gases/embers through defective masonry or mortar joints in chimney at thatch interface leading to ignition of thatch.

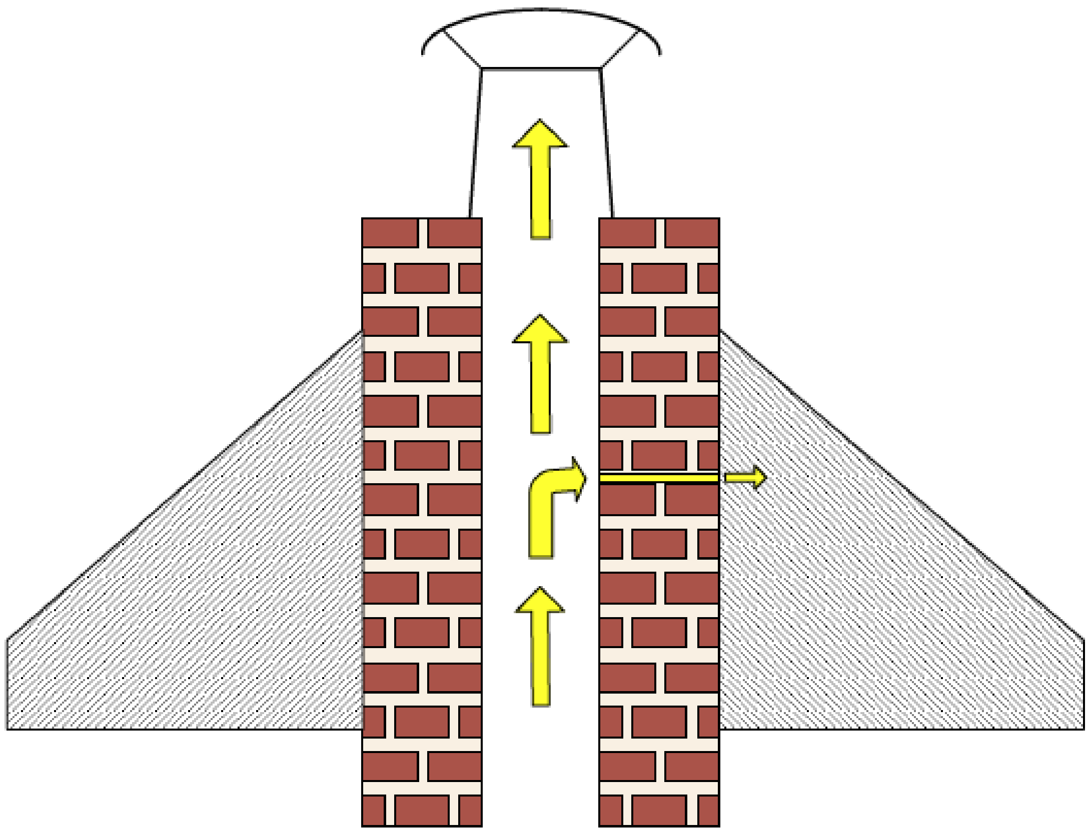


*Figure 12*

## Convection Scenario 2

Unlined chimney with restriction that may act to force more hot gases into the thatch through defective masonry or mortar joints and brickwork

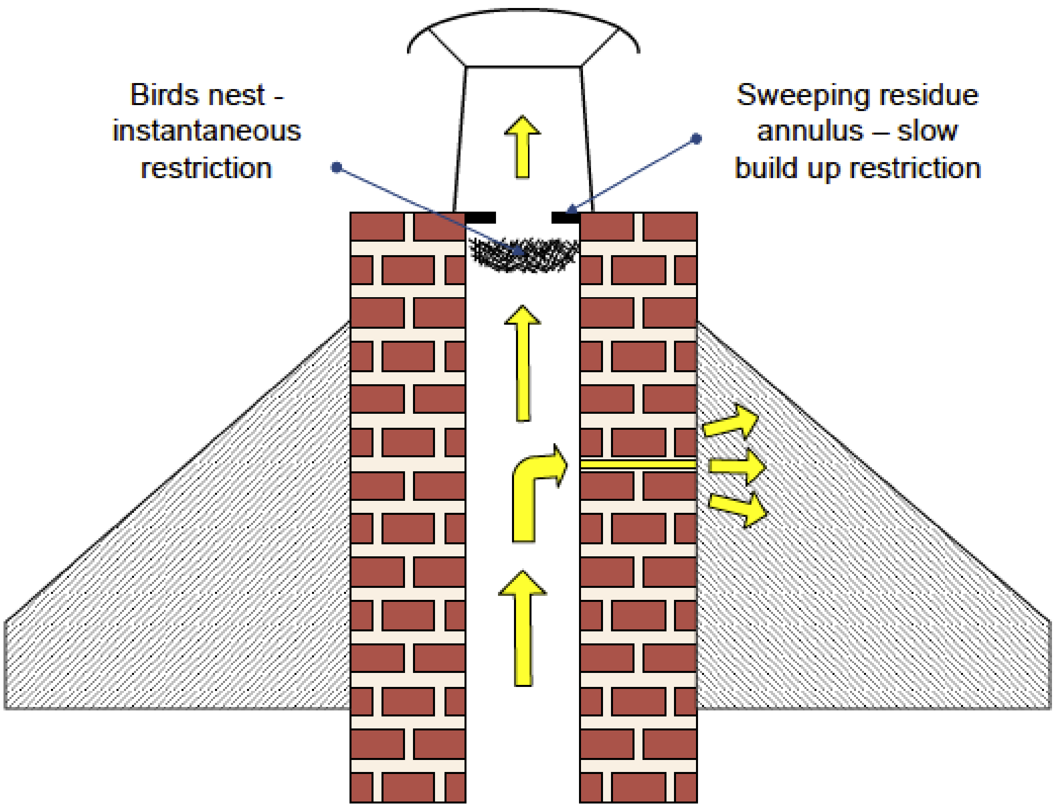



*Figure 13*

## Convection Scenario 3

Perfectly lined (uninsulated) chimney. Escape of secondary heated gases (air around liner rather than combustion gases) through defective masonry or mortar joints in chimney at thatch interface leading to thatch ignition.

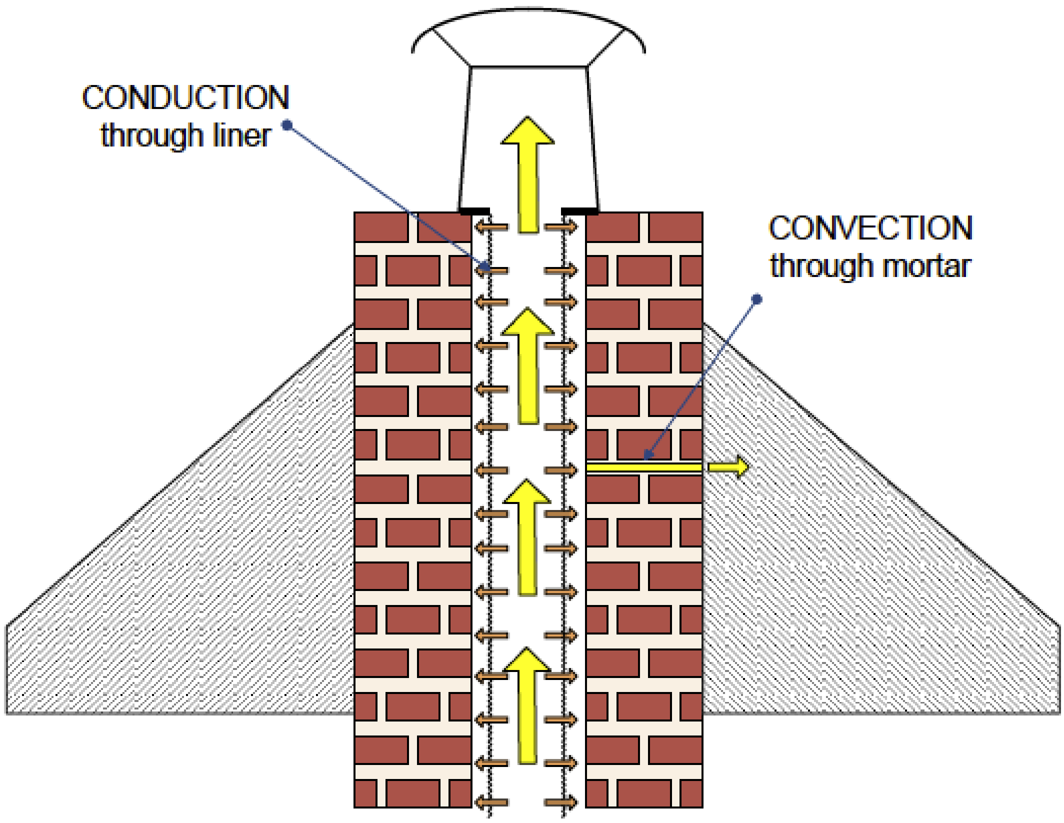



*Figure 14*

## Convection Scenario 4

Broken liner. Escape of hot gases/embers through failed liner and defective masonry or mortar joints in chimney at thatch interface leading to ignition of thatch.

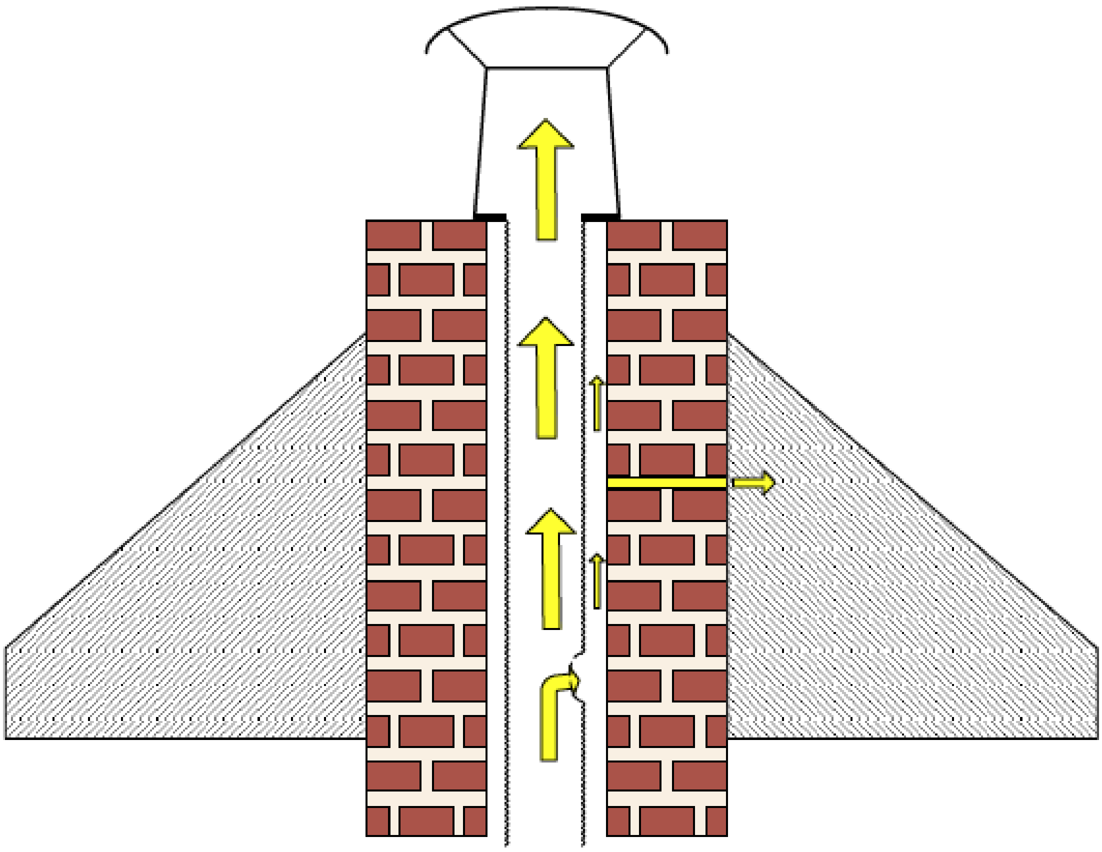


*Figure 15*

## 3.5 Conduction

Conduction refers to a mode of heat transfer that takes place through solid materials. In the case of this study it refers to circumstances where brickwork and mortar in the chimney are free from defects and conduction is the only way of directly heating the thatch. The rate at which heat is transported depends upon the physical properties of the solid and how the structure is made. Brick and stone are relatively poor conductors of heat, and will be slow to absorb heat, and slow to lose it. Good conductors, such as most metals will heat up and cool down quickly. Examples of the different conductive regimes considered here are given below.

### Conduction Scenario 1

Unlined chimney. Conduction of combustion gas heat through brickwork at thatch interface leading to ignition of the thatch.

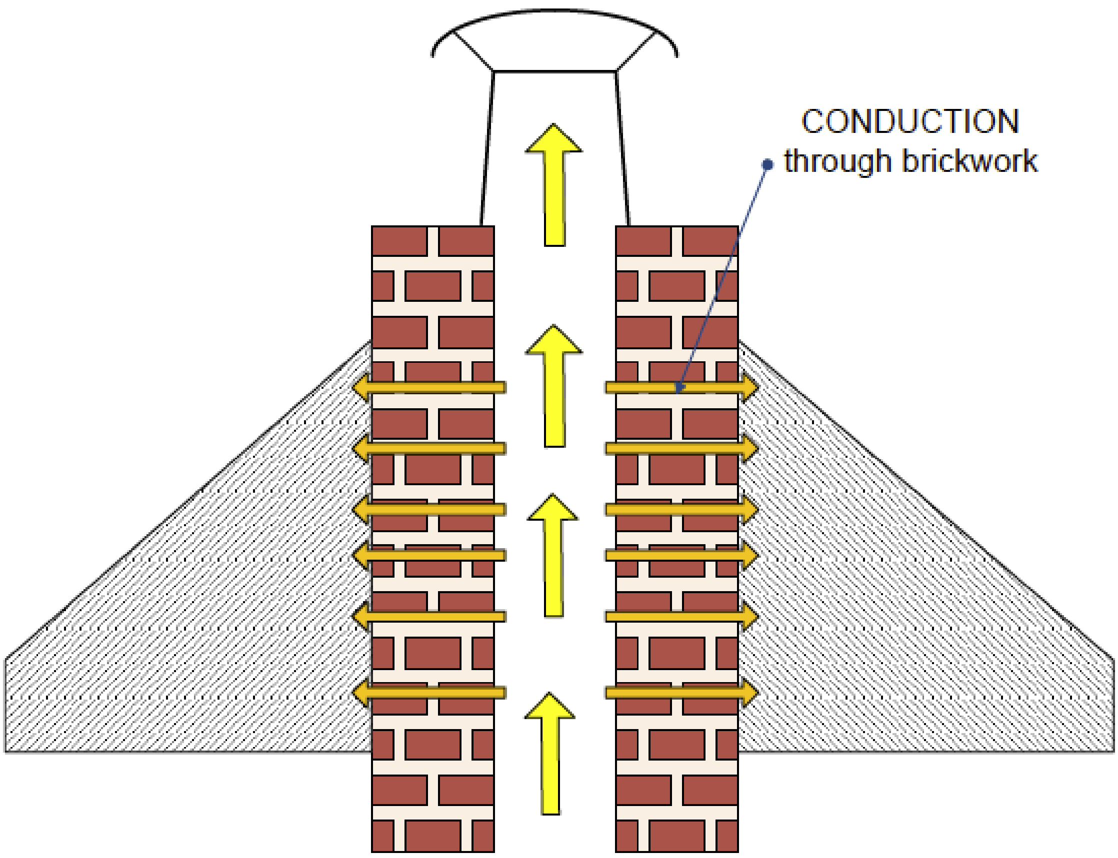



*Figure 16*

### Conduction Scenario 2

Perfectly lined (uninsulated) chimney. Conduction through brickwork of hot secondary gases (air around flue rather than combustion gases) at thatch interface leading to ignition of the thatch.

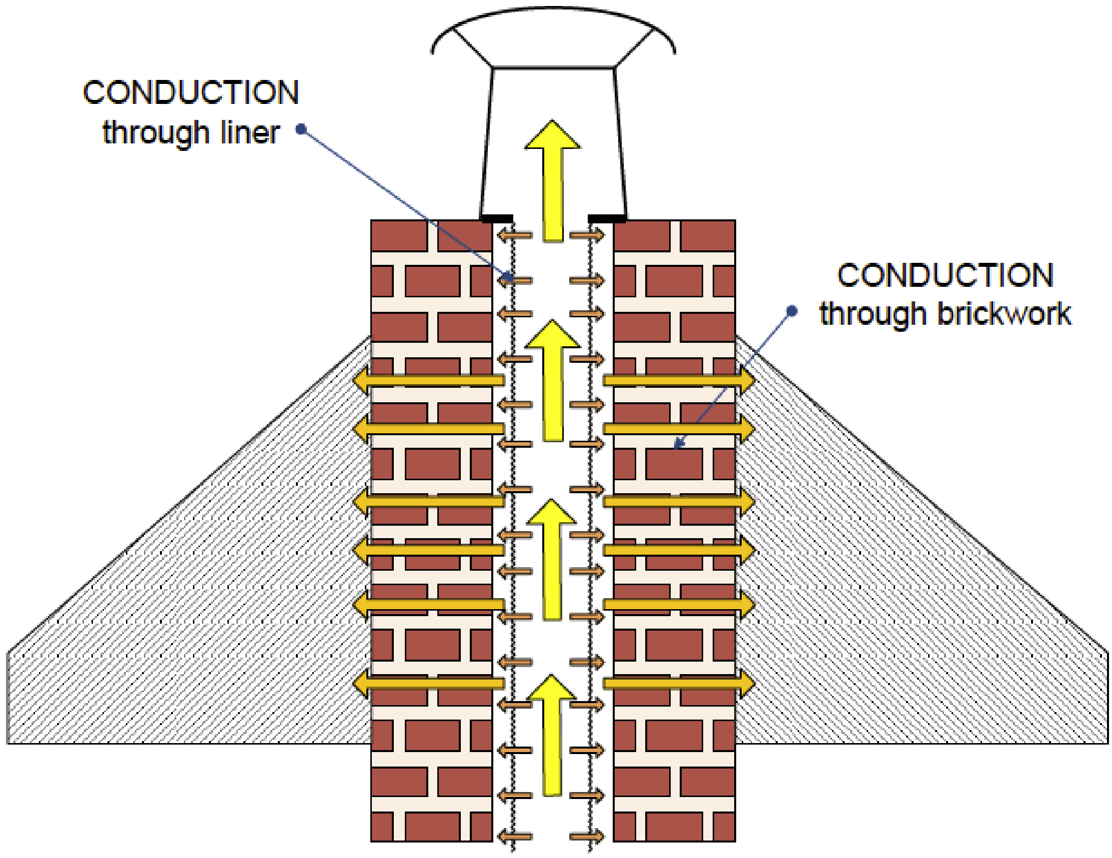



*Figure 17*

### Other Conduction scenarios

- Insulated vs. non-insulated liners.
- Liner touching the brickwork.
- Broken liner (performance assumed to be somewhere between 'perfectly lined' and 'unlined').

# 4 BASIC CHIMNEY DESIGN: NUMERICAL MODELLING

Chimney design plays an important role in the effective and safe removal of the toxic by-products of combustion and un-extracted heat. Is it not uncommon for chimneys with a 'poor draw' to be lengthened to make them perform better and this is easily described through the use of simple physical equations to calculate the pressure difference between the fire and the chimney pot that ultimately determines the velocity of gas movement from one location to the other. The key parameters in this determination are:

- Fire temperature
- Outside air temperature
- Chimney height
- Chimney cross sectional area

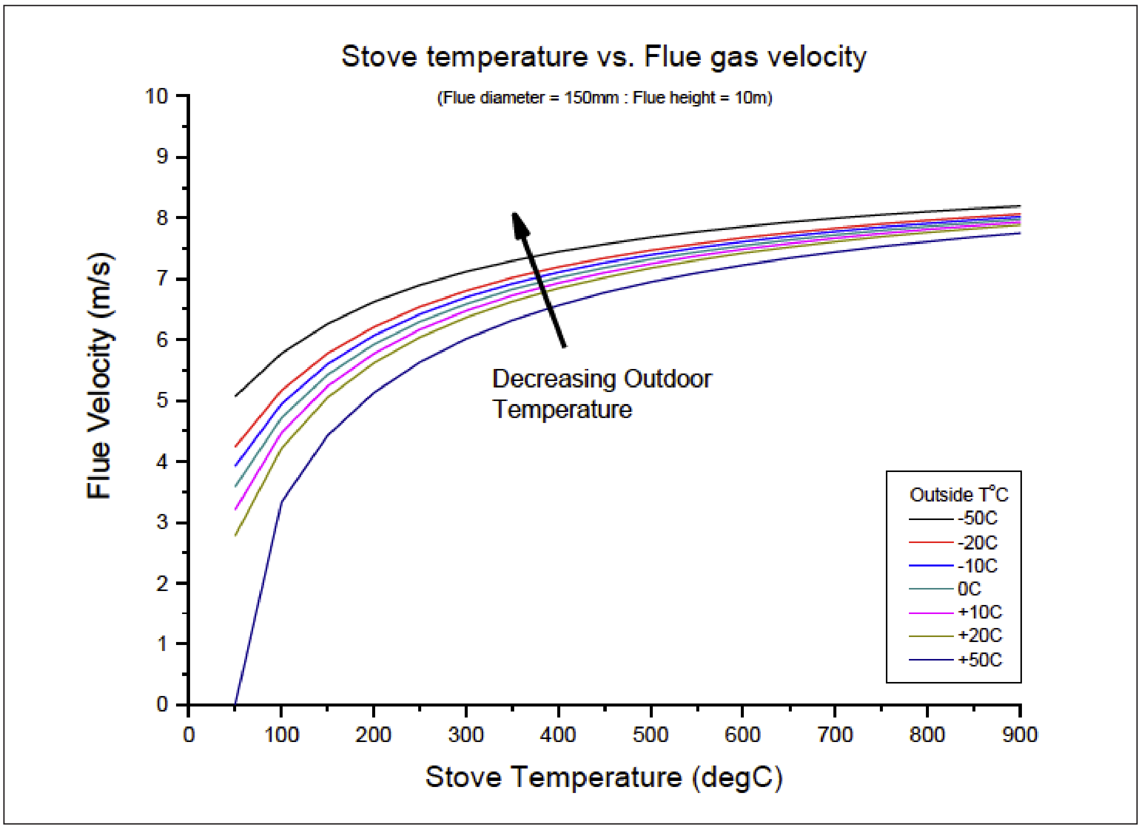
Flue velocities are observed to increase with decreasing outside air temperature, although the function is relatively weak, and increases strongly with increasing chimney height. The determination of gas velocity (or gas flowrate) is an important consideration for this study as it can impact:

- **Spark lift potential**
  Higher velocities may carry larger, higher energy-containing sparks out of the chimney.

- **Chimney lining temperatures**
  For any given fire temperature, higher gas flowrates will act to reduce gas temperatures.

- **Physical impact**
  High velocities may dislodge soot and tar which might be an instigating factor in chimney soot fires and physical 'tar drop' fires.

Aside from these parameters many other design, management and installation factors may contribute greatly to determining the risks associated with wood burning stove/open fire use. These are discussed in more detail in Section 5.



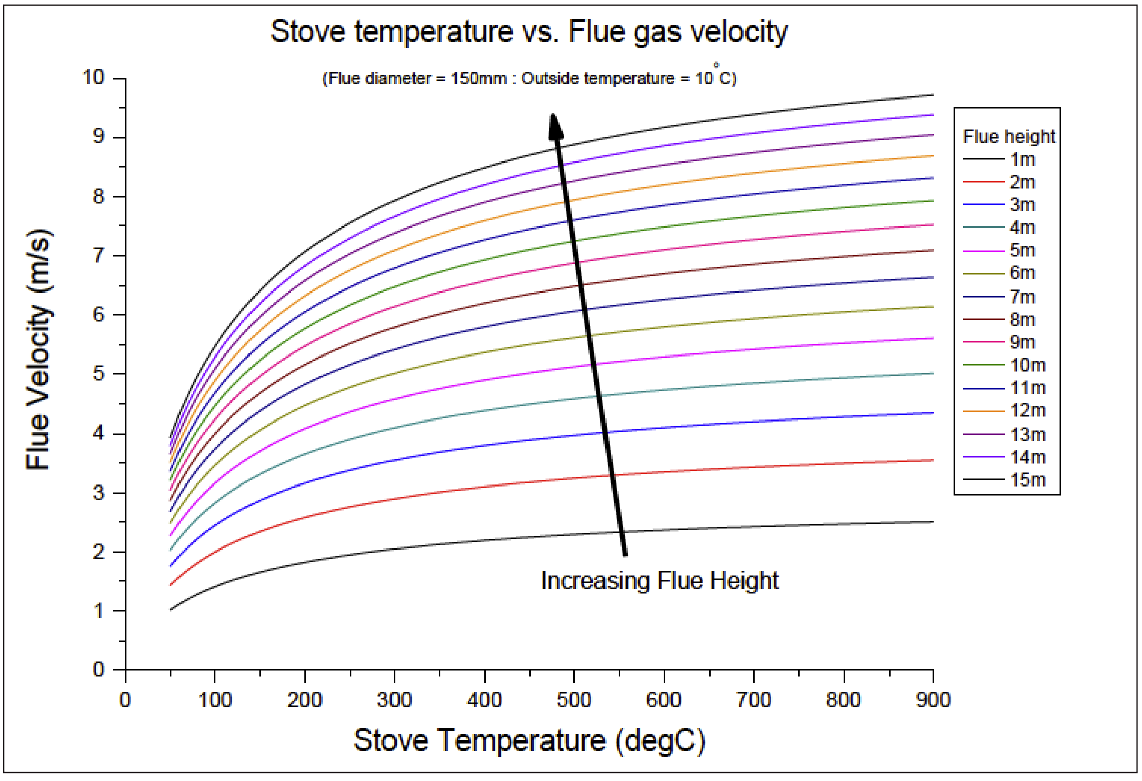




*Figure 18. Correlation between stove temperature and flue gas velocity for a range of outside temperatures.*
*Figure 19. Correlation between stove temperature and flue gas velocity for a range of flue heights.*

# 5 CATEGORISATION OF POTENTIAL CONTRIBUTING FACTORS TO FIRE RAISING IN THATCH

This section describes in more detail factors considered potentially important to this study. These are addressed in terms of:

- installation and design factors
- operational factors
- temporal factors

## 5.1 Installation and Design Factors

### 5.1.1 Stove Design

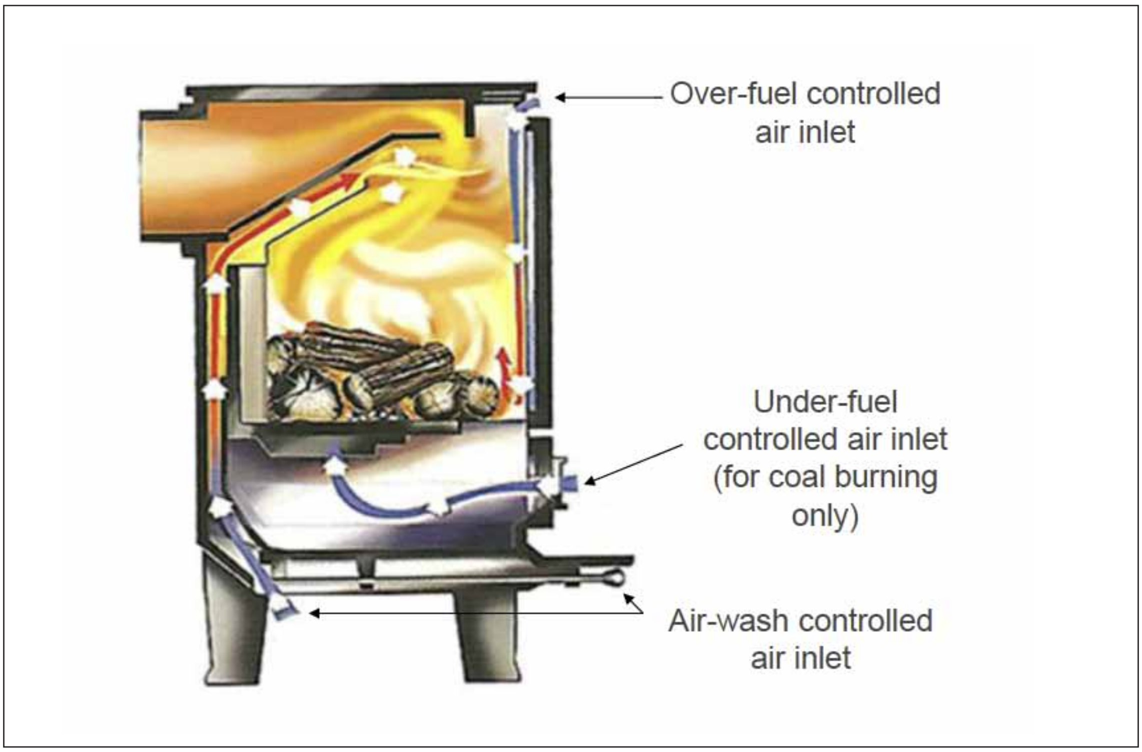
The important stove design parameters for this study are considered to be:

- stove kW heat output (physical size of the stove for the space requiring heating)
- fuel capability (wood only or multi-fuel)
- means of introducing air (via air vents, and doors)

It is not uncommon for stoves to be oversized for their application especially where small rooms with large inglenook fireplaces exist and the fitting of a small, yet correctly sized stove would look out of place. Stoves are often offered in 2 forms, wood burning or multi-fuel. Multi-fuel stoves enable the additional use of coal and are characterised by the addition of an ‘ash pan’ assembly and ‘under-fuel’ ventilation control. It is normal for wood to burn on a bed of its own ashes, whilst coal burning requires the ash to fall away through a grate otherwise the fire suffocates (ash quantities with coal can be very much higher than wood). The addition of an ash pan can provide an ‘inappropriate’ means of intense and aggressive ventilation of the fire by admitting large quantities of air under the fuel load (much like a blacksmith’s forge) if the ash pan door is not interlocked in some way with the fuel loading door. The same intense ventilation does not occur if the fuel loading door is left open because (a) the air is drawn over the fuel rather than through it, and (b) large quantities of cool air from the room are drawn in which go up the chimney acting to cool the gases much as would be the case for an open fire.

Intended ventilation systems for stoves usually include provision for ‘over-fuel’ air addition via a dial or slider in the door, and ‘air-wash’ provision intended to keep the glass in the door free of soot. Under-fuel venting of some wood-burning stoves is possible but recommended only for ignition purposes.

Whilst stoves are supplied with operating instructions this study must consider abusive use so that worst case scenarios can be tested.



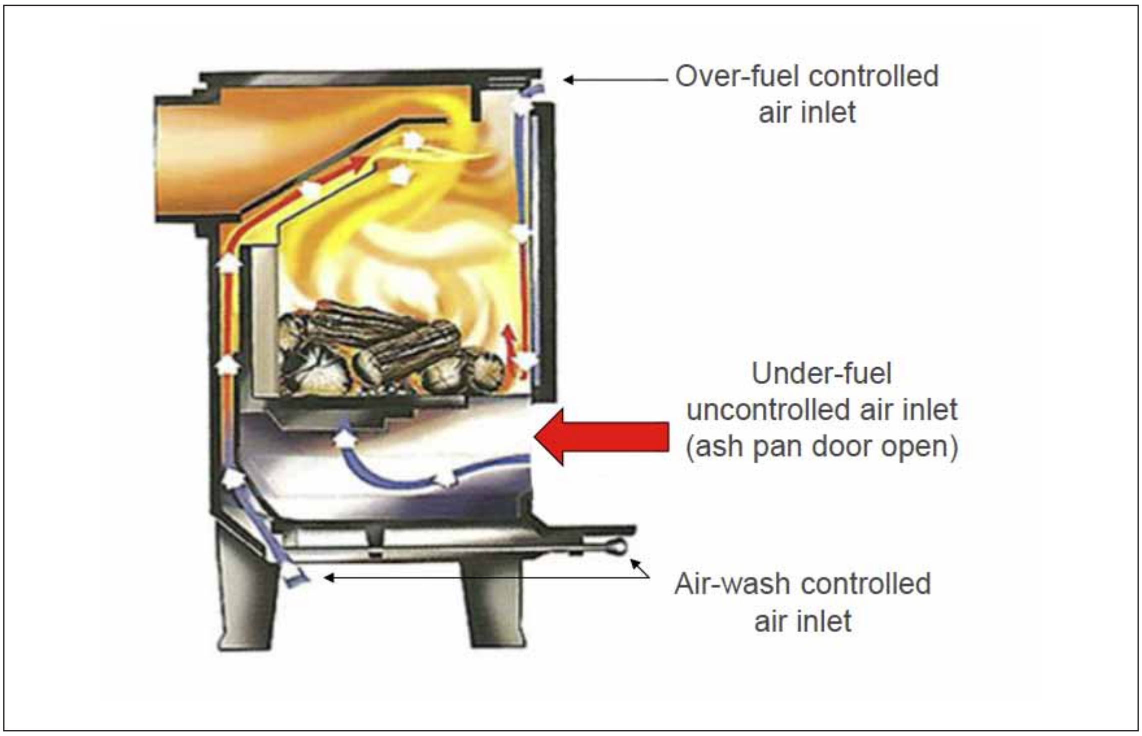




*Figure 20. Ventilation of a multi-fuel stove using supplied controls.*
*Figure 21. Ventilation of a multi-fuel stove using the ash-pan door.*

*Figure 22. Example of a wood / log burning stove with no ash-pan.*

*Figure 23. Example of multi-fuel stove with single door providing access for fuel loading and ash-pan removal.*

*Figure 24. Example of multi-fuel stove with separate doors for providing fuel loading and ash-pan removal.*

### 5.1.2 Chimney Interior Design

In addition to the chimney design factors already discussed in Section 4, the nature of the flue lining is a potentially important aspect.. Commonly encountered installations might include:

- unlined (brickwork or stone only or rendered surface)
- flexible uninsulated stainless-steel liner within the brick chimney
- rigid twin-wall insulated stainless steel liner within brick chimney
- solid cement, lyca or clay type liners
- cranked, kinked or stepped stacks, some with multiple feeds on several floor levels

These chimney design elements will influence the:

- temperature of the flue gases
- velocity of the flue gases (capability to lift sparks)
- temperature of the non-flue gases between liner and brickwork (conductive/convective heat transfer)
- propensity for direct liner/flue contact (conductive heat transfer)
- temperature of the brickwork (conductive heat transfer)
- ability of flue gases to challenge faulty brickwork (convective heat transfer)


*Figure 25. Brick chimney.*
*Figure 26. Flexible lined chimney.*
*Figure 27. Twin wall rigid insulated chimney liner.*

### 5.1.3 Chimney external design

Standards exist within Building Regulations and the 'Dorset Model' for the distance between chimney top and thatch surface. But unlike other roof covering methods (Approved Document J), the height of thatch may change greatly over time as it is redressed without removal of older layers. Pot-top to thatch surface distance will be a critical factor that has the potential to greatly influence the likelihood of fire-raising by:

- Spark and ember transport
  It would be expected that spark and embers of lower energy content and shorter lifespan would have a greater chance of leading to fire where the distance is shorter.

- Radiative ignition from a near pot fire or flames from a chimney fire
  Again, shorter distances would be expected to initiate fires from smaller pot-top and chimney fires.

Chimney height is commonly adjusted with thatch height by the addition of extra-long pots.

*Figure 28. Thatched property with very small pot top to thatch clearance.*
*Figure 29. Long-pot used to increase thatch to pot top clearance.*

## 5.2 Operational Factors

Whilst the installation requirements for fires and stoves seek, as far as is practicable, to ensure safety in use and minimisation of fire risks, all of these measures may be overridden by inappropriate use. All stoves come with comprehensive guidance to ensure efficient and safe use and remaining areas should be covered by common sense. This section discusses potential issues arising from:

- fuels
- ignition methods
- refuelling methods

### 5.2.1 Fuels

Fuels include all substances burned within the stove or on the fire. They comprise ignition materials, the staple fuel source, and ad hoc materials (disposal). All guidance on staple fuel is coherent and consistent with a preference for well-seasoned hardwoods and will not be dwelt upon here. Unseasoned woods, and woods with high resin content can lead to excessive tar production which will coat surfaces and may lead to chimney fires and tar build up on chimney top devices. Other ad-hoc fuels known to lead to burning material escaping from the chimney include waste paper (such as bank statements and Christmas wrapping paper) which may exit in full flame.

### 5.2.2. Ignition method

Relevant ignition factors include:

- fuels used
- ventilation regime
- monitoring period

Sundry substances are used for igniting stoves and open fires including newspaper, card, firelighters, and soft wood stick kindling. Each combination, in association with the ventilation regime adopted, will get the fire going to a point of being self-sustaining with varying degrees of rapidness. Seldom, in a stove, is the ventilation regime adopted for ignition appropriate for 'normal' operation once the fire is established. To this end the monitoring period during and following ignition is critical to the safe operation of the stove as the ventilation will need to be manually reduced (by adjusting a vent or closing a door).

During the ignition process several simultaneous events are taking place:

- Increasing quantities of fuel are being encouraged to burn.
- The stove heats up to re-radiate heat to the fire to enable it to self-sustain.
- The chimney heats up so that there is sufficient air drawn into the stove/fire to self-sustain the fire and prevent smoke blow-back.

### 5.2.3 Refuelling method

Critical factors at the time of refuelling include:

- **How low the fire has been allowed to burn at the time of refuelling**
  This will impact upon the friability and energy content of the remaining material (affecting the likelihood of spark lift and emission), and the need to re-ventilate.
- **The mechanism used to re-ventilate the fire when necessary**
  Aggressive under-fuel ventilation via the ash-pan door might increase gas velocities enhancing spark lift. Fore-ventilation necessitates monitoring and later manual adjustment of the stove's settings.
- **What material was burning previously**
  At the time of first refuel, it is likely that the remaining fuel will have components of ignition/kindling materials which might have very different 'lifting' properties to the staple fuel when disturbed or ventilated.

The most important elements amongst these are the recognition that at the time of refuelling, the contents of the firebox might be lightweight, will be disturbed by the action of refuelling and re-venting, and may require monitoring for a period of time afterwards.

## 5.3 Temporal Factors to Consider

Aside from considering the fixed installation and operational elements, other factors may radically alter the system's performance, even when the fixed installation and operational aspects remain constant.. These are discussed below in accordance with the timescales they are likely to occur on.

### 5.3.1 Slow changes

Slow, progressive changes that can happen within a stove/open fire heating system are as follows:

*Figure 30. Tarred up chimney liner.*

- **Soot build-up in the chimney which might lead to a chimney fire**
  The restriction of cross section might also act to encourage the user to more aggressively ventilate their fire over time as the draw gradually reduces with deposition. Soot build up may be prevalent where sweeping regimes are not followed or inappropriate fuels are burned.

*Figure 31. Chimney sweeping annulus.*

- **Soot sweeping annulus build-up if repeated sweeping fails to clean to the very top of the chimney**
  This will act to reduce the draw of the chimney and encourage the user to gradually increase ventilation over time. It may contribute to a 'near-pot' fire or force hot gases out of damaged chimney brickwork and into the thatch by restricting gas from exiting at the top. Sweeping annuli often form where there are concerns about dislodging cappings and bird guards during cleaning.


*Figure 32. Split chimney liner.*

- **Corrosion/splitting of the liner will allow fire gases to escape into the cavity between liner and brickwork**
  This might raise brick temperatures and if the brickwork/mortar is imperfect might allow hot fire gases to gain direct access to the thatch. Corrosion may be accelerated through the adoption of poor quality materials and inappropriate fuel supply, or be due to wear and tear associated with its age.

*Figure 33. Imperfect mortar in brickwork.*

*Figure 34. Thatch by imperfect chimney brickwork.*

*Figure 35. Tarred up chimney bird guard.*

*Figure 36. Liner found to be in contact with chimney brickwork.*

- **Deterioration of render, mortar and brickwork**
  This might enable fire gases, or secondary heated gases if lined, to gain direct access to the thatch material. The impact on the thatch will be to heat it and deposit fire products which might result in fire.

- **Aging of thatch layer next to chimney**
  The fire properties of thatch may change by merit of:
  - Time – natural aging and drying
  - Repeated heat-up/cool-down cycling if located next to chimney brickwork
  - Contamination through deposition of fire products if located by imperfect chimney brickwork.

  Over time the risk of ignition may slowly increase up to the point where previously normal operation of the stove or open fire may lead to ignition of the thatch.

- **Tar build up on arrestors, bird guards and rain guards**
  Fire combustion gases are made up of many components. Some remain as gases after exiting the chimney, but others on cooling will condense as either liquids or solids in the air or on cold surfaces. Over time these deposits can build up to a point where they themselves may catch fire and detach. At the very least they may restrict flow of gases from the chimney and facilitate other modes of fire raising. The ability to clean such deposits is often a function of the chimneys position on the roof.

- **Liner slump/slippage**
  Liners should ideally not touch the internal brick surface of the chimney since the benefit of an insulating air partition is lost at this location and brick temperatures will be expected to be higher. This might act to transfer more heat into the thatch layer by conductive modes. Most flexible liners, being supplied coiled, will make contact with the stack at several points particularly in narrow and angled chimneys where spacers cannot be used.

### 5.3.2 Rapid changes

Rapid changes, acting singly or in combination, can occur and increase the risk of fire raising when a stove/open fire is newly lit. These include:

- Weather
  Certain weather patterns are suspected of raising fire risks in thatched properties. In particular, long dry warm spells followed by an abrupt dry cold night causing users to light their stoves possibly after long periods of no use. Local wind conditions at the point where an ember lands may also be a key factor in differentiating a near-miss from a fire.

- Animal hibernation and bird nesting times
  In the course of a day, animal and bird activity can both block a formerly healthy chimney and introduce significant quantities of combustible material directly into the hot gas stream. Certain birds that nest late in the season may introduce combustible/blocking nesting material into the stack after the traditional period of sweeping in preparation for winter stove use.

- Damage to liner by sweeping
  Following overaggressive sweeping, or sweeping of a weak and corroded liner, previously contained fire gases may be able to leak into the liner/chimney void which may then, subject to the state of the brickwork, heat the thatch by convective means.

- Seasonal fuels
  Christmas day wrapping paper burned on the fire may pose an immediate risk not normally present, as previously discussed

- New thatch
  A re-thatched house with reduced pot top to thatch clearance may immediately have a higher risk profile than pre-rethatch times.

- Wood supply
  A change in wood supply to use recycled soft wood products (burning pallets) or unseasoned wood, especially late on in the winter season when quality supplies have dried up, could lead to a modified risk profile starting on the day of use. New fuel types on the market, including compressed straw logs, may have a bearing on risk profiles in the future.

## 5.4 Fires Occurring in 'Clusters'

In the UK, it is not uncommon for fires in thatched properties to occur in 'clusters' or many on the same day. Of the items listed in Section 5 the most likely competing factors are changes which have happened over the spring and summer months, such as nest building, in association with a lack of pre-season sweeping and a sudden change to cold weather. Jackdaws, common chimney residents, build their nests any time between April and August and may even go on into September.

Table 1. Common birds and nesting seasons

| Species | Nesting start | Incubation period (days) | Fledge (days) |
|---|---|---|---|
| Jackdaw | April | 17–18 | 28–32 |
| Rook | March–April | 16–20 | 30–36 |
| Carrion Crow | April | 17–18 | 28–32 |
| Raven | February | 20 | 35–40 |

Discovery of an active bird's nest in a chimney is highly problematic as they are protected by law: prevention is a much preferred approach.

The *Wildlife & Countryside Act 1981* states it is an offence to intentionally:

- kill, injure or take any wild bird
- take, damage or destroy the nest of any wild bird while that nest is in use or being built
- take or destroy an egg of any wild bird

# 6 EXPERIMENTAL RIG DETAILS

For the purposes of this investigation two rigs were constructed at full scale based around a stove of the multi-fuel type with separate ash-pan door configuration. The rigs were designed to elicit fundamental performance parameters appropriate to each element of this study.

## 6.1 Operational Basics and Ember Transport Rig (OBETR)

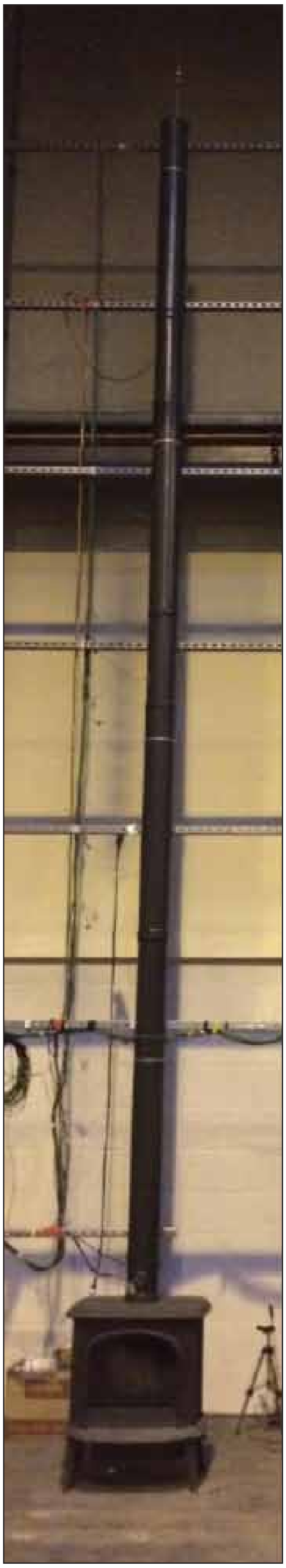
The OBETR was constructed based around the Stovax Huntingdon 40 multi-fuel stove rated at 12kW output. The stove is characterised by a separate ash-pan door with ventilation by over-fuel air wash and bottom vent. The chimney was constructed entirely of mild steel stove pipe which, for this study was convenient for the mounting of sensors. Stove pipe is normally only used for the short section between the stove top on the flue liner situated above the fireplace's register plate.

The OBETR is intensely instrumented to describe every aspect of its operation. The requirement was to be able to establish cause and effect scenarios and understand completely the changes that were taking place within the heating system together with magnitude measurements.

Instrumentation details are as follows:

- Temperature
    - Fire box
    - Flue gas at 1 metre intervals stove to top
    - Flue wall at 1 metre intervals
    - Plume temperature of exiting gases (3 at 0.5 metre intervals)
- Flue differential pressure (between fire box and top of chimney
- Gas velocity at low and high positions in flue
- Gas species
    - Oxygen
    - Carbon dioxide
    - Carbon monoxide
- Simultaneous video observation
    - Stove front and vent controls
    - Chimney top

All information could be captured at a sampling rate of one reading per second.



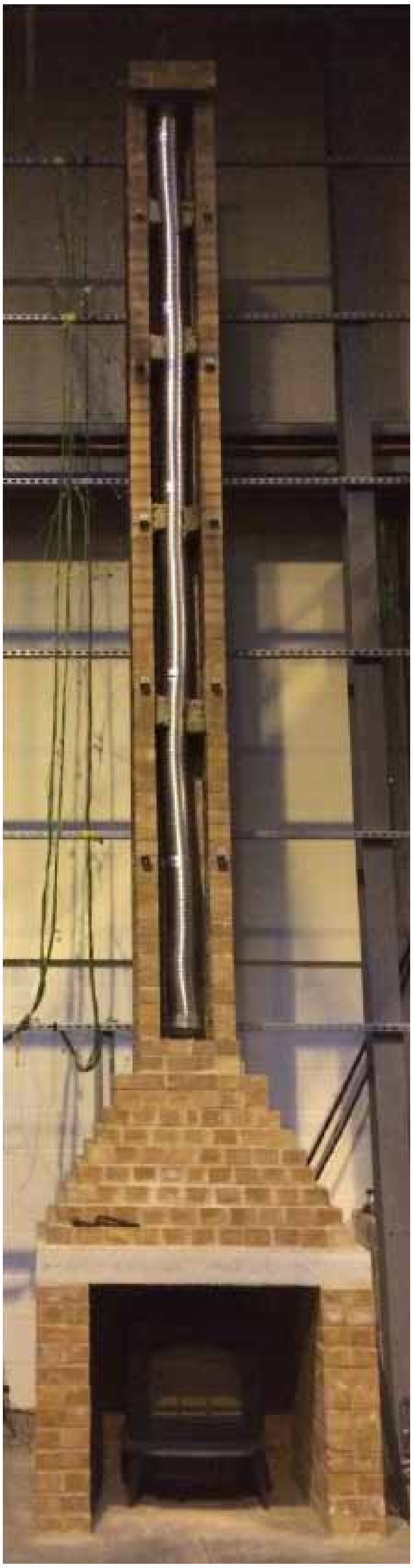


*Figure 37 (left). The Operational Basics and Ember Transport Rig.*
*Figure 38 (right). Convection and Conduction Mode Test Rig.*

## 6.2 Convection and Conduction Mode Test Rig (CCMTR)

The CCMTR was again based around the Stovax Huntingdon 40 multi-fuel stove rated at 12kW output but this time the chimney detailing was changed to allow detailed examination of the influences of liners in brick chimneys. The fireplace was additionally constructed to enable future examination of 'open fire' scenarios.

To be representative of heritage installations the bricks used were handmade, and for ease of installation of liners and instrumentation the chimney was made to be 3-sided with the front face accepting an insulating board or glass panels for sealing and observation. The rig is capable of being operated unlined, and with both flexible and rigid twin wall liners. Thick layers of insulation around the top portion of the chimney were used to simulate the presence of thatch (not shown in this picture).

Again the CCMTR is intensely instrumented to describe every aspect of its operation.

Common to the OBETR instrumentation details are as follows:

- Temperature
    - Fire box
    - Flue gas at 1 metre intervals stove to top
    - Flue wall at 1 metre intervals
    - Plume temperature of exiting gases (3 at 0.5 metre intervals)
- Flue differential pressure (between fire box and top of chimney
- Gas velocity at low and high positions in flue
- Gas species
    - Oxygen
    - Carbon dioxide
    - Carbon monoxide
- Simultaneous video observation
    - Stove front and vent controls
    - Chimney top

But additional instrumentation is provided for:

- Temperature in liner/flue gap at thatch level
- Temperature on inner brick surface at thatch level
- Temperature inside brick at thatch level
- Temperature 'in faulty mortar gap' (convection) at thatch level
- Temperature on external brick surface at thatch level

# 7 CHARACTERISATION OF WOOD BURNING STOVE (WBS) OPERATIONAL PARAMETERS

All tests carried for this phase of the work used very standard ignition fuels of newspaper, firelighters, and kindling with a stock fuel of well-seasoned hardwood logs. Example data is given for a 4 hour long test which mimics normal daily use aside from the fact that at times of ignition and refuelling ventilation is aggressively undertaken using the ash-pan door which would obviously be contrary to the manufacturer's instructions. Table 2 describes the key events during the 4 hour test.

Table 2. Key events during 4-hour test

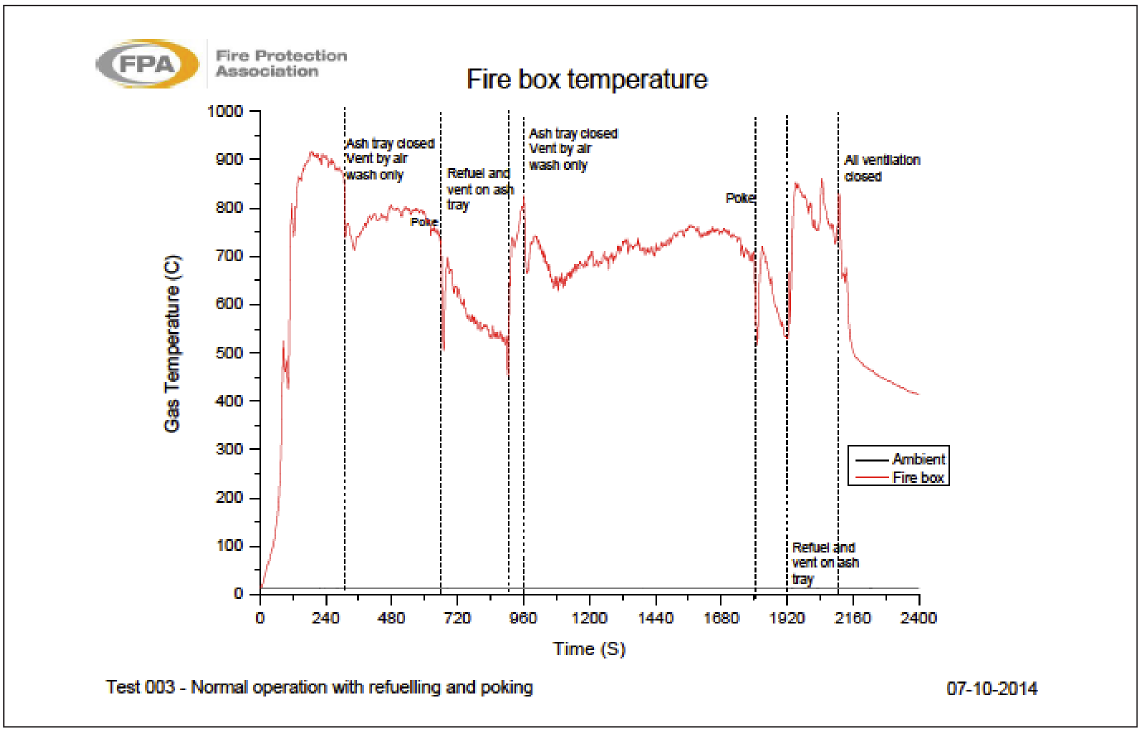
| Time | Action |
|---|---|
| 0 | Ignition of kindling material. Initial ventilation by ash-pan door being open, and air wash set to full |
| 300 | Ash-try door closed |
| 660 | Fuel loading door opened, contents poked, and door re-closed |
| 900 | Stove restocked with logs and ventilated by opening of ash-pan door |
| 960 | Ash-pan door closed |
| 1800 | Fuel loading door opened, contents poked, and door re-closed |
| 1920 | Stove restocked with logs and ventilated by opening of ash-pan door |
| 2100 | All ventilation shut down and stove left to suffocate and cool |

## 7.1 Thermal performance

Figure 39 to Figure 42 plot the temperature measured within the fire box, in the flue, on the exterior surface of the flue and at the exit of the chimney.

### Analysis points of note

- During aggressive ventilation fire box temperatures may reach around 900°C.
- During quiescent periods fire box temperatures of between 500°C and 800°C are more normal.
- Temperature rise on ventilation is almost instantaneous within the fire box and flue.
- At the top of the stove above the fire box, temperatures are around 200°C lower than the fire box.
- Over the 6 metre length of flue pipe temperatures drop typically by 300°C (50°C per metre).
- At thatch height (1 metre below the chimney top) flue gas temperature range from 200°C to 325°C.
- Opening the fuel loading door of the stove to gain access to poke the fire immediately drops the temperature within the firebox and stove as fresh cool air is drawn in over the fuel and up the flue. An inversion is noted at 3 metres above which the already low temperatures momentarily increase.
- External stove pipe temperatures are measured to be just in excess of 50% of the main stream internal gas temperature with a maximum value measured of 350°C.
- At thatch height (1 metre below the chimney top) external flue temperatures are measured to be between 75°C and 125°C.
- The rate of change of temperature measured on the external flue surface is greatly damped in comparison to the internal flue gas and firebox temperatures.



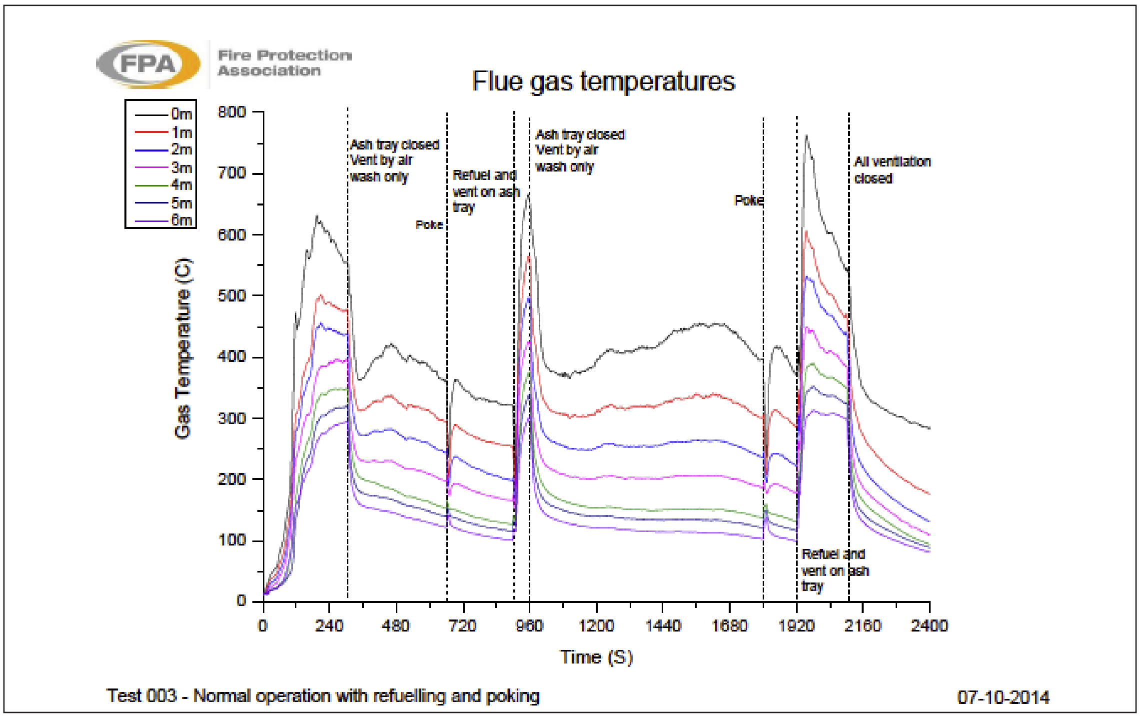
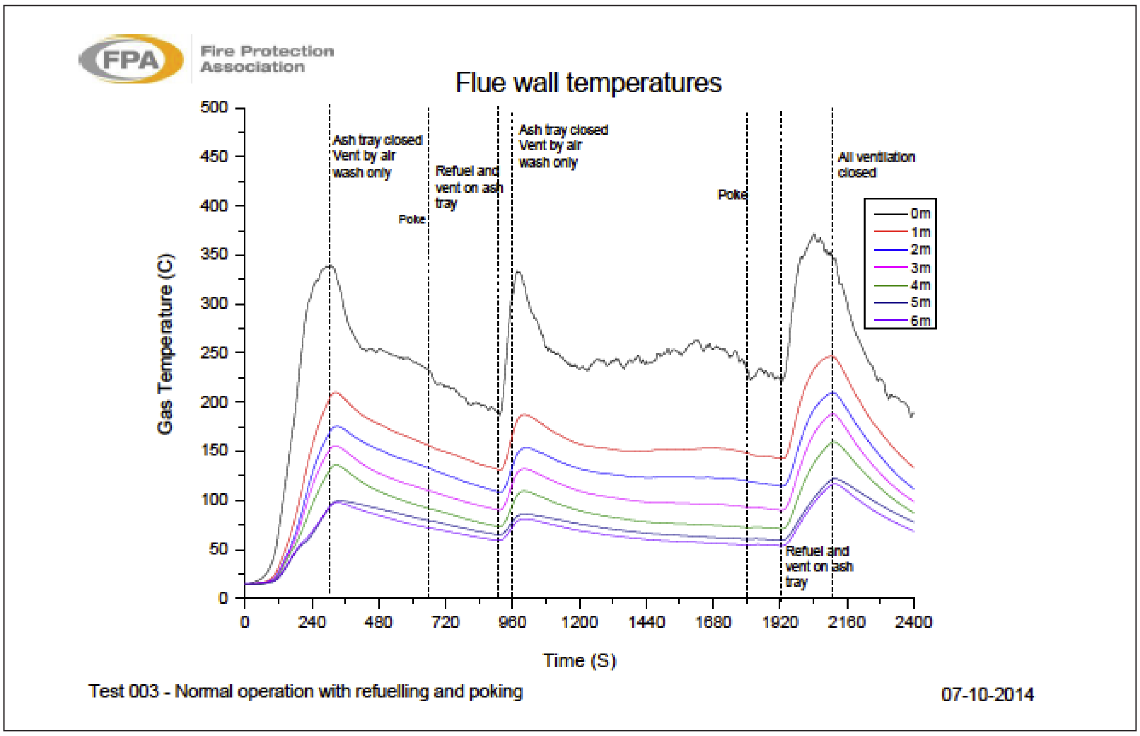




*Figure 39. Fire box temperatures during normal 4 hour stove use.*
*Figure 40. Flue gas temperatures during normal 4 hour stove use.*



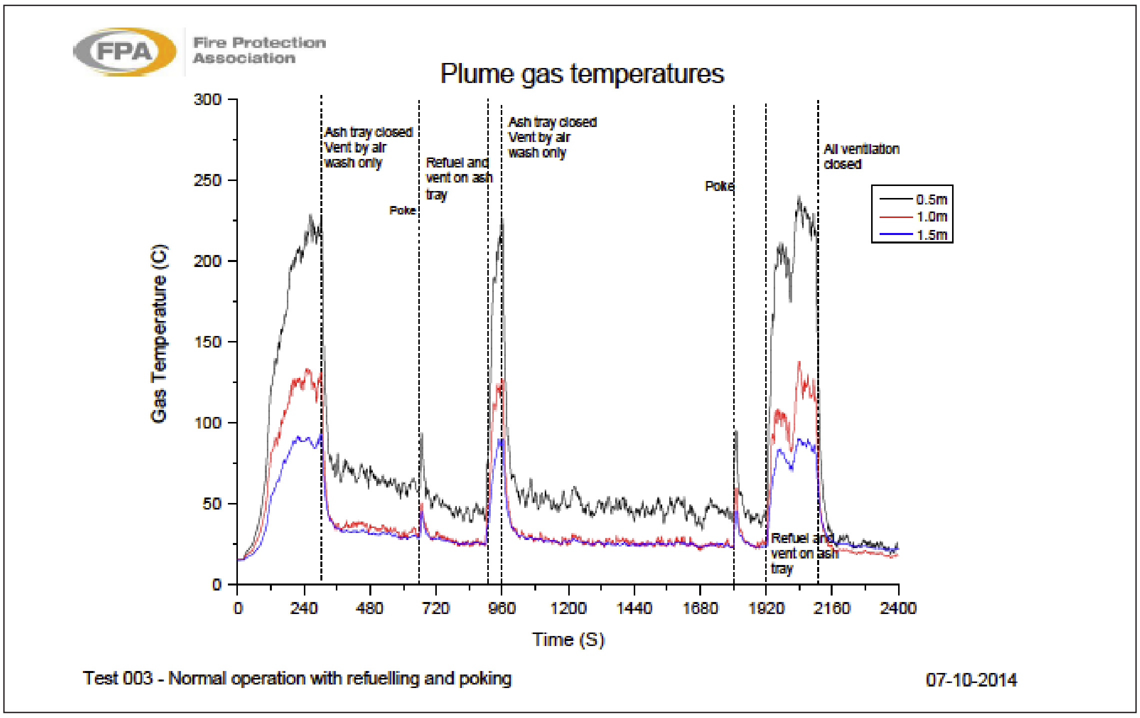




*Figure 41. Flue wall temperatures during normal 4 hour stove use.*
*Figure 42. Chimney plume gas temperature during normal 4 hour stove use.*

## 7.2 Velocity and Pressure Study

Figure 43 shows the measured gas velocities within the flue and should be read in association with the thermal data previously shown.

### Analysis points of note

- During aggressive ventilation at the time of ignition velocity increase is rapid yet steady and flattens out at the point where temperatures in the firebox stabilise.
- On closing the ash-pan door the reduction in gas flow is immediate.
- Once heated up (following ignition), and additional ventilation of the stove by fuel loading door or ash-pan door immediately causes an instantaneous increase in gas velocities.

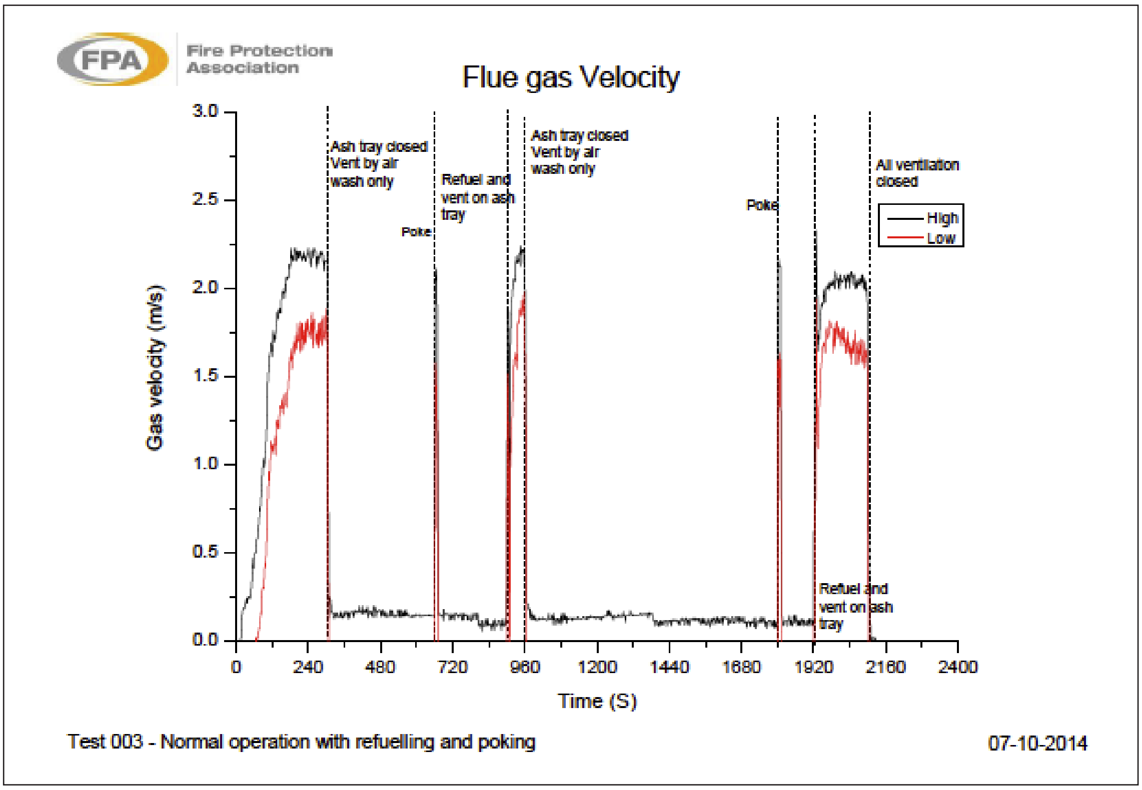



*Figure 43. Flue gas velocities during normal 4 hour stove use.*

## 7.3 Gas species study

Figure 44 and Figure 45 plot the gas concentrations within the flue during the 4 hours of the test. These graphs should be read in association with the thermal and velocity data previously supplied. General points of note in respect of understanding the relevance of gaseous measurements:

### Oxygen

- During combustion oxygen is consumed by fire.
- A low or lowering oxygen value may result when the fire is consuming more than the ventilation arrangement will allow. Fire appears darker and soot accumulation on the door glass occurs.
- A high or rising oxygen value may result when the fire is demanding less, perhaps as the fuel runs out, or the ventilation arrangement is adjusted to deliver more to the fire.

### Carbon Dioxide and Carbon Monoxide

- Carbon dioxide and Carbon monoxide are generated by the fire.
- High concentrations of Carbon Dioxide in association with low concentrations of Carbon Monoxide are a sign of highly efficient combustion.
- High concentrations of Carbon Monoxide, usually in association with low concentrations of oxygen, are a sign of incomplete, inefficient combustion which might also be characterised by the increased production of soot and tar (smoke).

### Analysis points of note

- Fuel is observed to burn most efficiently during times of aggressive ventilation and is characterised by:
    - high carbon dioxide concentrations
    - low carbon monoxide concentrations
    - high velocities
    - high temperatures
    - reduced soot deposits

- Fuel is observed to burn less efficiently during quiescent phases when the oxygen supply is control limited and is characterised by:
  - Low oxygen concentrations
  - Lower Carbon dioxide concentrations
  - High Carbon monoxide concentration
  - Low gas velocities
  - Low gas temperatures
  - Increased soot deposits

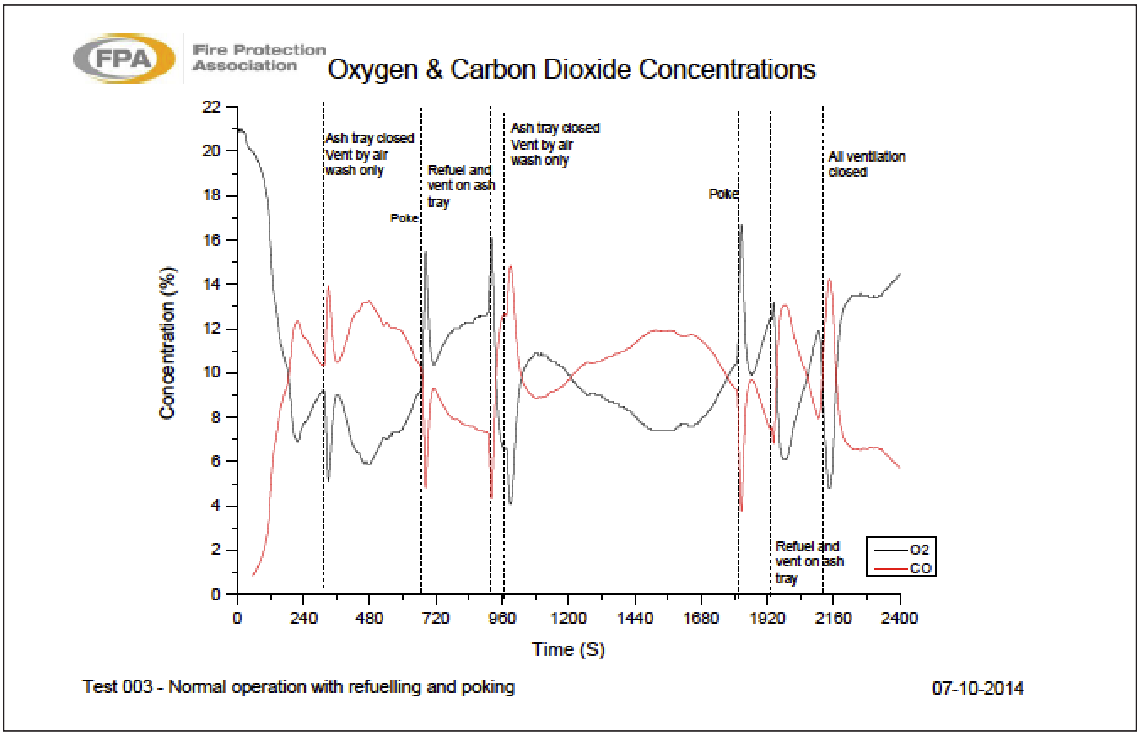



*Figure 44. Oxygen and Carbon dioxide concentrations during normal 4-hour stove use.*

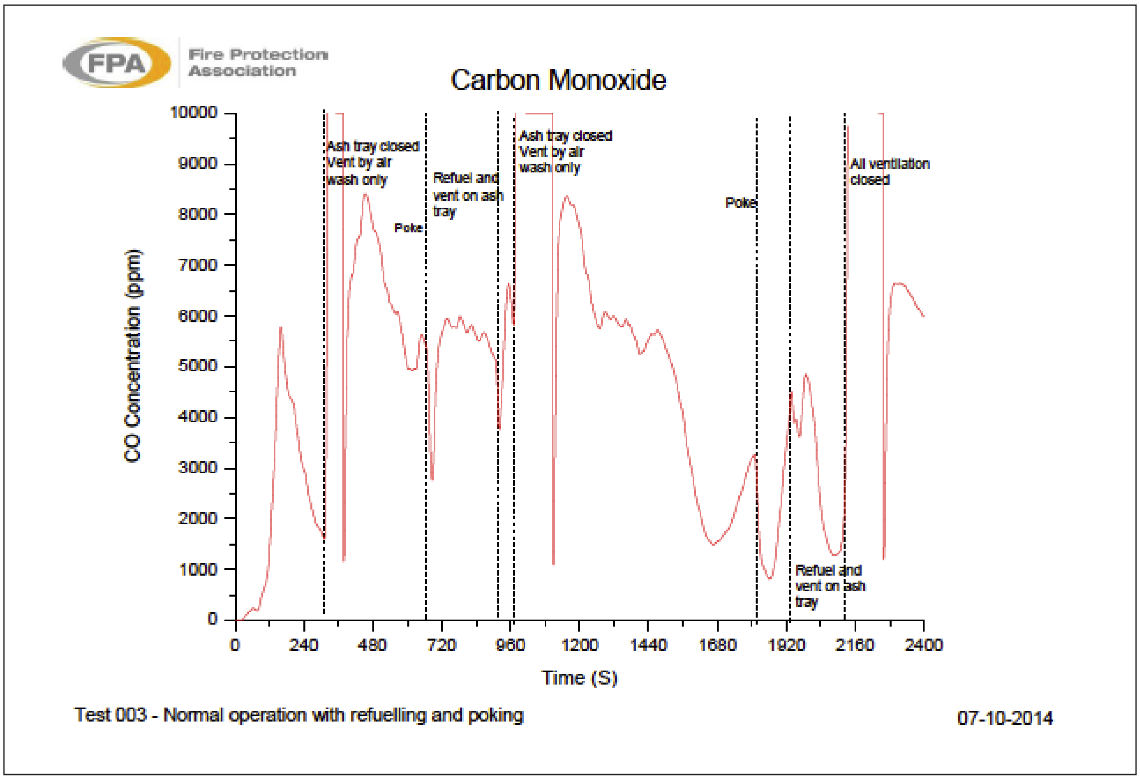



*Figure 45. Carbon monoxide concentrations during normal 4-hour stove use.*

## 7.4 Discussion of Operational Parameters Study

- The OBETR test rig and its associated instrumentation has effectively characterised stove performance within the constraints of the configuration used.

- All data from each sensor coherently describes the impact on stove output for any given applied change in stove operation.

- The trends observed are absolutely in keeping with scientific understanding of heat and mass transfer in such systems.

- Measurement of values, such as velocity accurately describe ‘high risk warning periods’ observable by those in the location of the fire by obvious ‘roaring’ of the fire and resonance within the stove pipe.

- Whilst velocity is a comparatively difficult measurement to make, temperature via magnetic stick-on type devices is very straight forward and can give a very good visual warning of the creation of adverse conditions – high ventilation rates -> high temperatures -> high gas velocities -> increased ventilation, and so on.

# 8 STUDY OF FACTORS PROMOTING EMBER TRANSPORT

## 8.1 Basic Configuration in Unrestricted Flue

Analysis of spark emissions were made by analysis of video footage simultaneously referencing the operation being conducted at the stove and the emission of sparks/ embers and material from the chimney top.

From the work conducted to date the following general conclusions can be drawn:

- Sparks can issue quite readily during the ignition period when, under maximum likely ventilation, when the lightweight fuels used for kindling may lift on the high gas velocities.
- Some ignition methods and fuels create more sparks than others (such as paper and card).
- Some ignition methods create sparks of longer lifespan and weight which can reach well below the chimney exit point following emission – this was particularly noticeable when using heavier paper materials such as cardboard.
- Some stoves might be more likely to eject sparks than others depending on the ability to introduce large quantities of air under the fuel bed (such as through an ash-pan door).
- The process of riddling and refuelling increases the frequency of spark issue owing to the disturbance of lighter fuels in the fire bed and the breaking up of larger fuel types following combustion.
- Random surges in spark emission were observed without stove interference which are probably the result of some fuel friability vs. gas velocity cross-over point in association with internal disturbances such as logs collapsing.
- Following manufacturer’s guidance on safe stove operation is a good idea.

It was evident during these tests is that the emission of solid material from the chimney is a normal and almost constant part of stove operation. Operations at the stove do influence how much of this material emerges as active visible embers that at least have the potential to travel from chimney top to thatch surface. It is not possible to recreate this in the laboratory as statistically the events are so rare. For example:

- There are 50,000 thatched houses in the UK.
- Each lights stove around 100 times per year.
- Around 50 houses lost to fire per year.

Even if spark emission is the sole cause of these fires, the rig would statistically have to be run 100,000 times to observe a successful ignition.

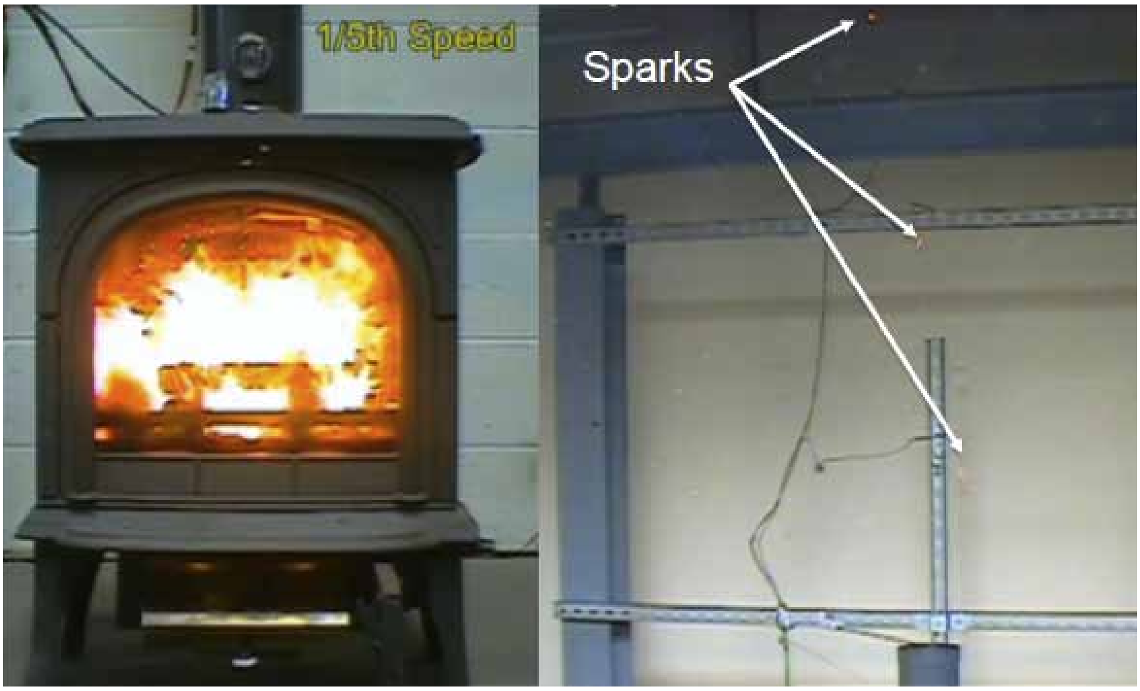



*Figure 46. Spark emission during aggressive ventilation of the stove with the ash-pan door open.*

## 8.2 Influence of Pot-top Devices

Pot top devices exist in many different forms and purport to do one, or a number of jobs such as:

- Prevent rain coming down the chimney.
- Improve chimney draw.
- Arrest sparks.
- Stop birds nesting.

In terms of risk, pot top devices may exert influence both positively and negatively:

### Positive Points

- Stopping birds nesting protects the chimney from obstruction and presence of combustible material.
- Spark arresting could reduce the risk from fires stemming from ember transport.

### Negative Points

- Fear of dislodgment might impair effectiveness of sweeping operations.
- They might form a cold surface for tars to condense out on.
- Fine meshes may block, restricting flow, and even be a source of fire themselves.
- They might direct sparks down to the thatch rather than allowing them to gain ‘safe altitude’.

During this study a number of distinctly different devices were tested for their ability to influence spark emission in association with bird nesting prevention.

## 8.3 Mesh-top Bird Guard Cage

The bird guard cage is the simplest of devices in that it does not attempt to even keep out rain. It’s coarse mesh is unlikely to block by tar deposition and spark emissions will travel unhindered upwards away from the thatch.

Under aggressive stove ventilation with riddling of the grate, sparks emanating were ejected at high velocity and generally progressed upwards vertically to a significant distance from the pot top.

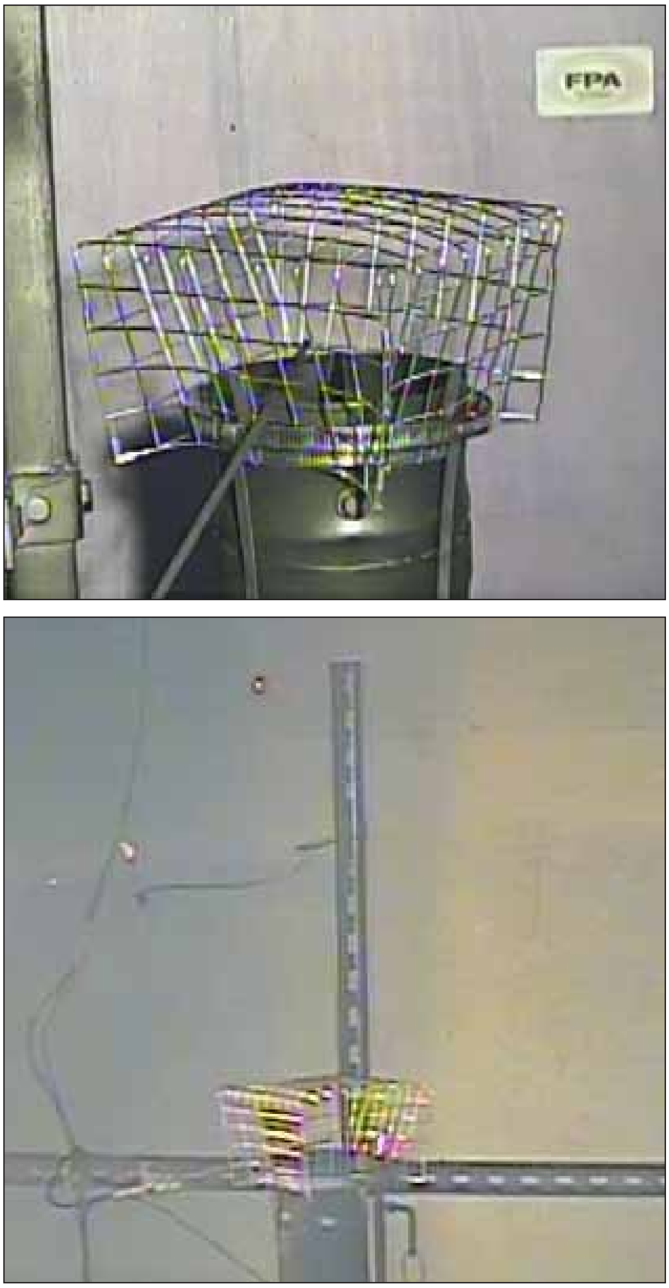



*Figure 47a, b. Mesh-top bird guard cage.*

## 8.4 Capped Spark Arrestor – Coarse Mesh

This type of spark arrestor comprises a cap and double layer of coarse fine metal mesh. The meshes are held within a circular tray that might be there to catch falling debris. Holes in the tray section prevent water collection.

Under aggressive stove ventilation with riddling of the grate, sparks emanating were ejected with apparent ease which raises concerns about the spark-arresting description. With gases directed horizontally by the cap the sparks tend to swirl around in the proximity of the device and thereby remain closer to the thatch.

*Figure 48a, b. Capped coarse mesh spark arrestor.*

## 8.5 Capped Spark Arrestor – Finer 2-part Mesh

This type of spark arrestor comprises a cap and double layer of metal mesh. The internal mesh has holes of a considerably smaller diameter than the outer mesh. The meshes are held within a circular tray that might be there to catch falling debris. Holes in the tray section prevent water collection.

Under aggressive stove ventilation with riddling of the grate, sparks emanating were ejected with apparent ease which raises concerns about the spark-arresting description. With gases directed horizontally by the cap the sparks tend to swirl around in the proximity of the device and thereby remain closer to the thatch.

*Figure 49a,b. Capped spark arrestor.*

## 8.6 Ember Transport and Pot-top Devices Discussion

It is clear that the ejection of solid material, including embers or sparks emanating from the fire-box, is part of normal stove operation. If this is the case then, given the total number of fires that occur in the context of national annual stove-hours operating time, these ejections must present a low hazard.

What is less clear is whether there is any capability of devices calling themselves spark-arrestors, to arrest sparks. The scientific methods that might make them spark-arresting devices is similarly unclear. In industrial applications spark arrestors generally take 2 forms – very fine metal meshes (almost filters), and centrifugal separators. Historically, it is known that spark-arrestors on chimneys block, and can cause fire – could it be the case that these historic spark-arrestors had very fine meshes (which might well have performed their function well), but over time, due to the blocking issues the mesh sizes have been increased to the point that they no longer trap sparks and actually perform only the functions of rain and bird guard? Clearly further work is required in this respect.

# 9 THERMAL CHARACTERISATION OF THROUGH-BRICK CONDUCTION AS A POTENTIAL MEANS OF FIRE-RAISING

Conduction through insulating materials such as brick is a 'slow' form of heat transfer in comparison to thermal radiation (line of sight wave transfer) and convective (fluid flow assisted) means. Using the Convection and Conduction mode test rig (CCMTR) the horizontal transfer of heat from gas, through liner, to heat the chimney gas space, to heat the internal surface of the brickwork, to finally heat the thatch insulated external surface of the brickwork was investigated. Instrumentation was placed as detailed in Figure 50.

All of the following 4 hour tests were conducted with the most aggressive operation of the stove possible with constant aggressive ventilation via the ash-tray pan door, refuelling every 15 minutes, and constant manning for the entire duration of operation. Under these conditions the stove metalwork became red-hot and could not be approached without protective clothing. This was very deliberately done to create worst case conditions (certainly unachievable accidentally, due to the rapid fuel consumption rate of around 4 large logs every 15 minutes) to assist with putting into context the results.

Tests were conducted for:

- perfectly lined uninsulated flue
- split flue liner
- unlined chimney

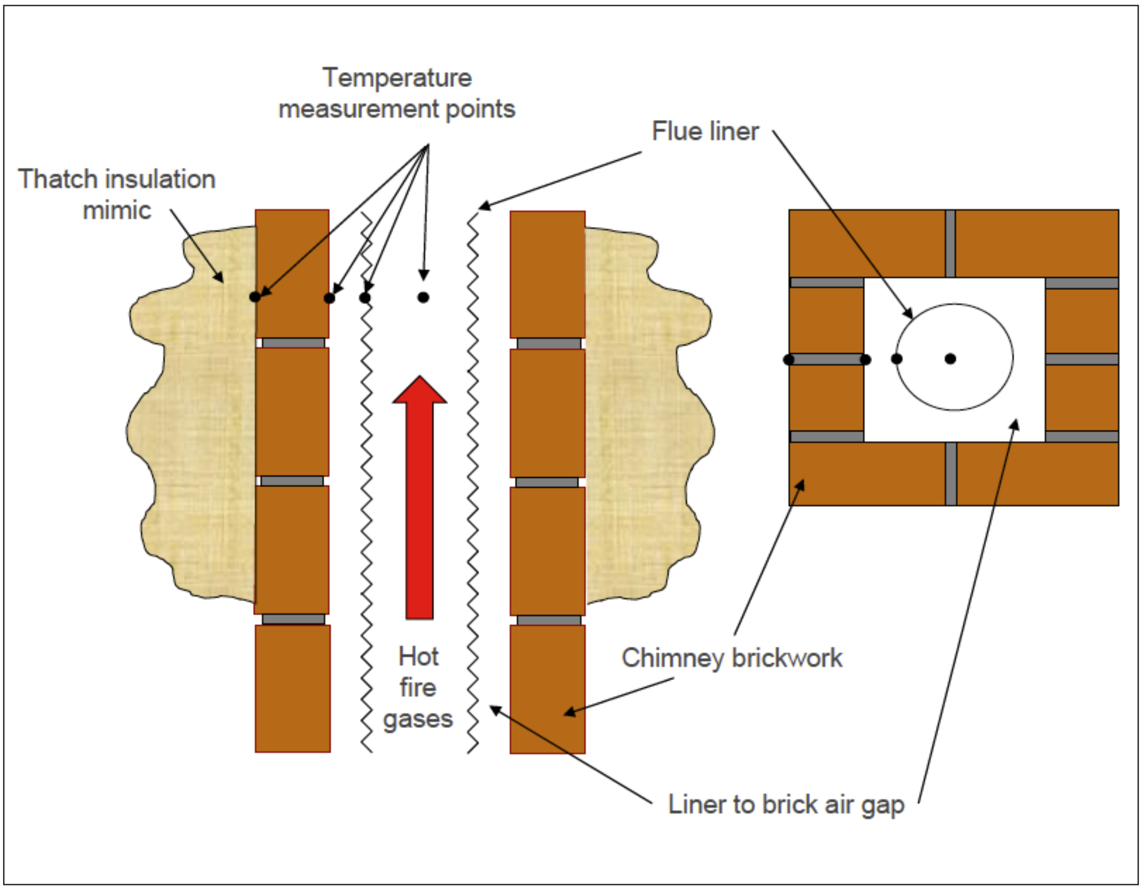



*Figure 50. Instrumentation locations to investigate potential for fire raising through conduction model.*

## 9.1 Perfectly Lined Uninsulated Flue

With the flue perfectly lined with uninsulated flexible liner the test was conducted in accordance with the criteria detailed above. The results are shown in Figure 51.

### Analysis points of note

Maximum temperature achieved at each measurement point after 4 ½ hours of operation are as follows:

- Firebox – 950°C
- Flue gas – 500°C
- Flue liner external surface – 400°C
- Gas space between liner and brickwork – 200°C
- Internal chimney brick surface – 150°C
- Insulated external chimney brick surface – 80°C

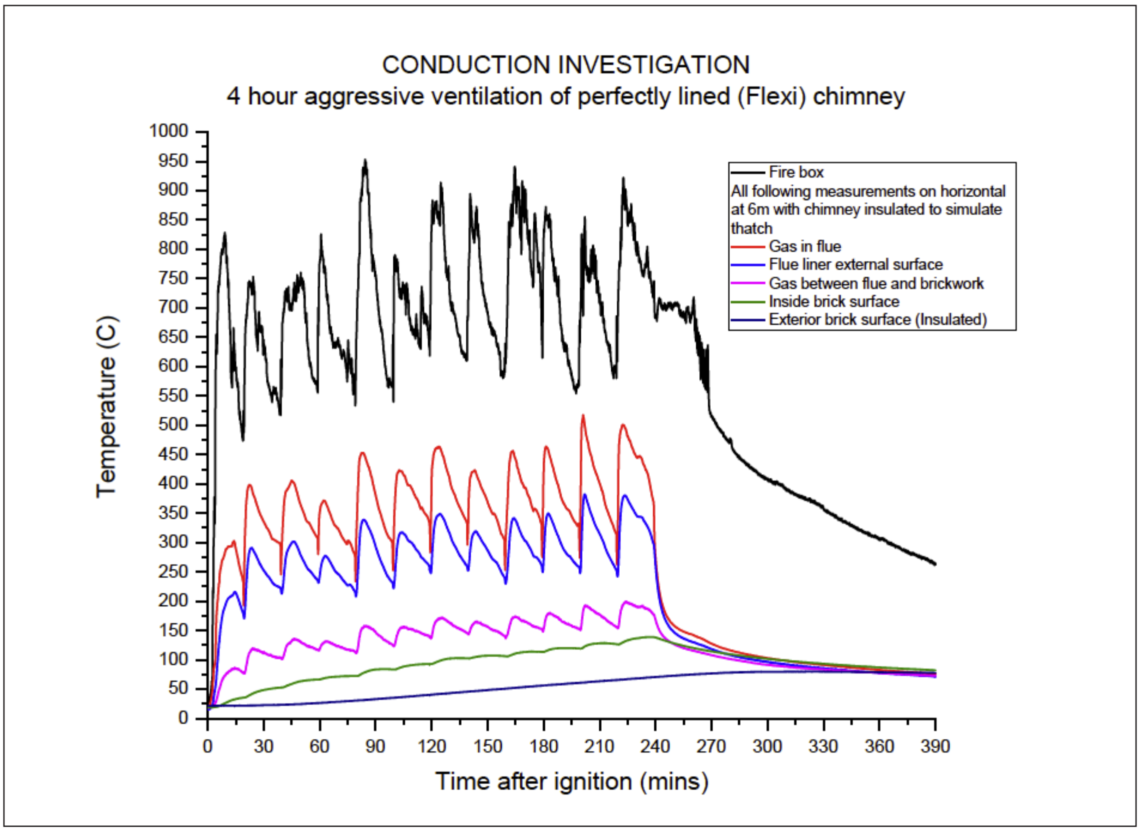



*Figure 51. Conduction investigation for perfectly lined uninsulated fuel.*

## 9.2 Split Flue Liner

With the flue liner now significantly split through and bent to expose 50% of its cross sectional area the test was conducted in accordance with the criteria detailed in Section 0. The results are shown in Figure 52.

### Analysis points of note

- Maximum temperature achieved at each measurement point after 4 ½ hours of operation are as follows:
- Firebox – 1000°C
- Flue gas – 450°C
- Flue liner external surface – 350°C
- Gas space between liner and brickwork – 200°C
- Internal chimney brick surface – 150°C
- Insulated external chimney brick surface – 80°C

These results are little changed from the perfectly lined situation which is not unsurprising given that, when the brickwork is in good order there is no reason or capability for hot gas to flow into the liner/brick air gap since the only route to exit remains the chimney top.

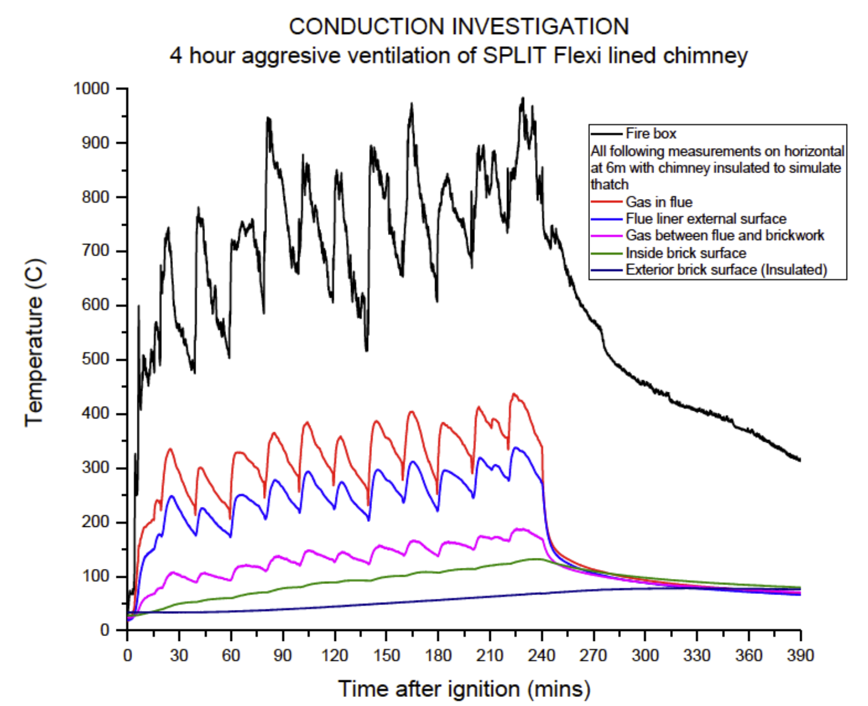



*Figure 52. Conduction investigation for a split liner.*

## 9.3 Unlined Chimney

With the flue liner now removed the test was conducted in accordance with the criteria detailed in Section 0. The results are shown in Figure 53.

### Analysis points of note

Maximum temperature achieved at each measurement point after 4 ½ hours of operation are as follows:

- Firebox – 900°C
- Flue gas – 300°C
- Internal chimney brick surface – 200°C
- Insulated external chimney brick surface – 80°C

The removal of the liner is observed to reduce the flue gas temperatures due to the increase in cross section area of flow.

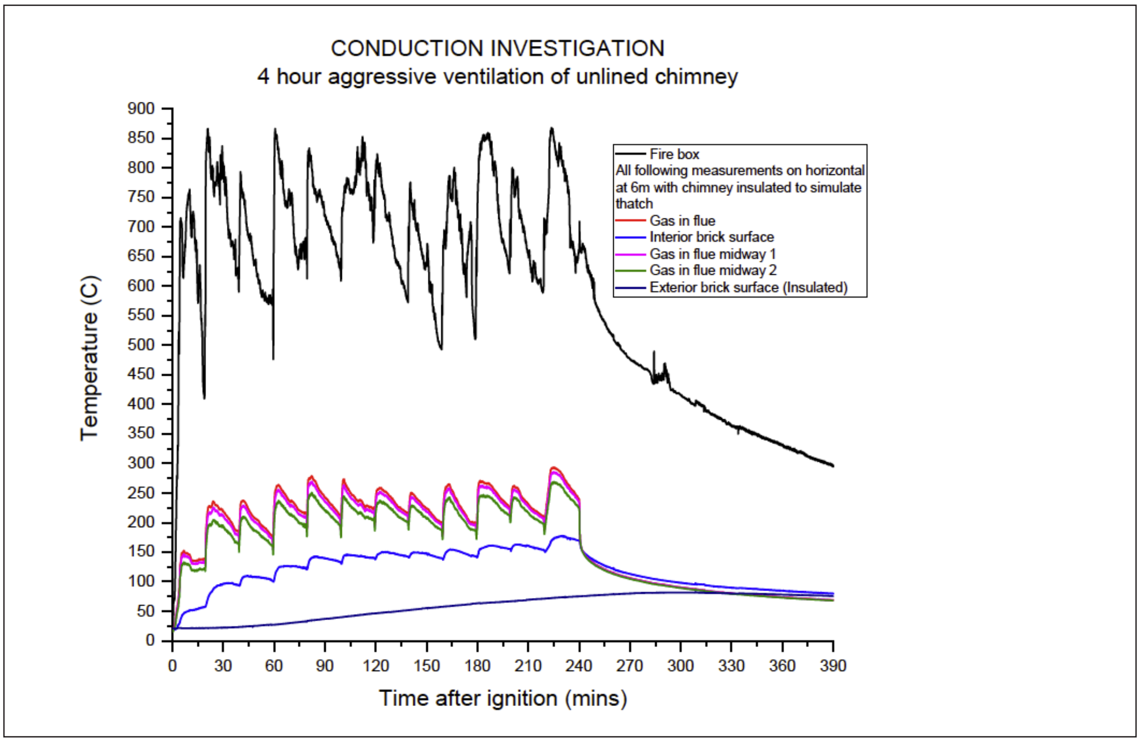



*Figure 53. Conduction investigation for an unlined chimney.*

## 9.4 Unlined chimney with 50% blockage

With the flue liner removed the test was conducted in accordance with the criteria detailed in Section 0 with egress of gas from the chimney impaired by the partial blockage of 50% of its cross sectional area. The results are shown in Figure 54.

### Analysis points of note

Maximum temperature achieved at each measurement point after 4 ½ hours of operation are as follows:

- Firebox – 900°C
- Flue gas – 275°C
- Internal chimney brick surface – 175°C
- Insulated external chimney brick surface – 80°C

These results are little changed from the unblocked scenario.

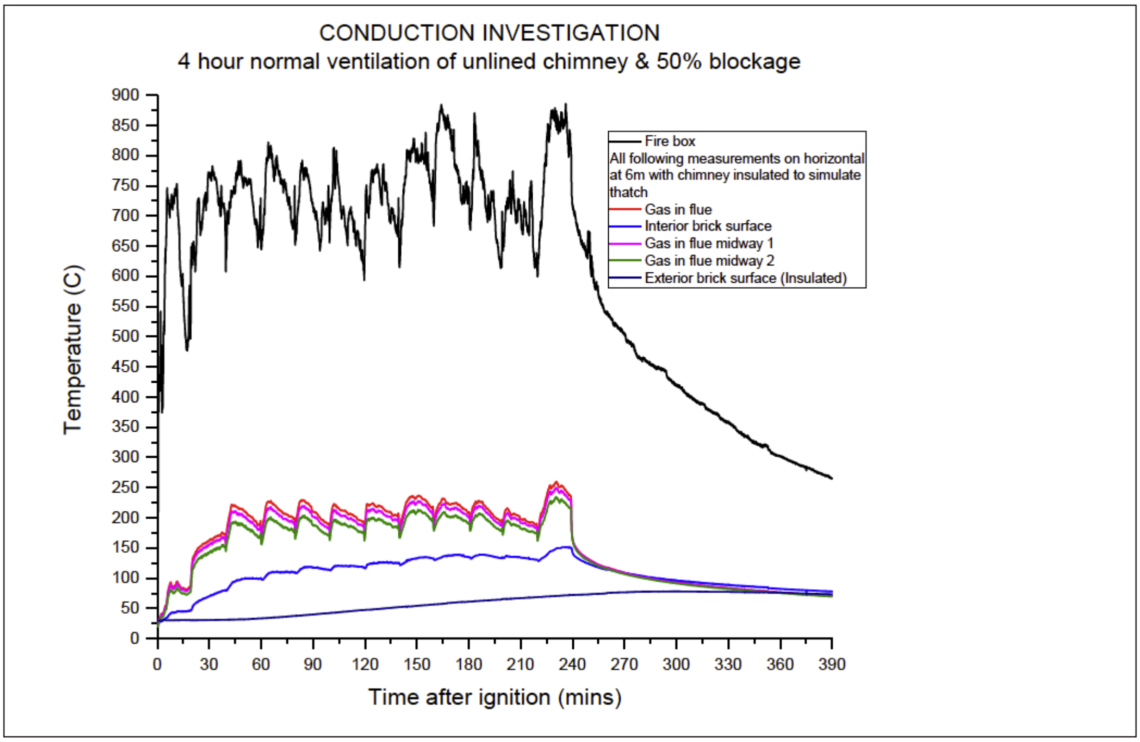



*Figure 54. Conduction investigation for an unlined chimney with 50% blockage.*

## 9.5 Long Duration Tests to Evaluate Scope for Thermal Accumulation under Normal Operating Conditions

Having evaluated the scope for fire-rising in thatch by conduction under a non-realistic 4 hours aggressively ventilated regime similar long duration test were performed to understand thermal accumulation over many days of normal operation.

Normal operation in this case is defined as a morning ignition, followed by restoking as and when required with normal ventilation control to optimise efficient heat output and fuel consumption until evening when the control are set low for rekindling/reigniting the following day. This cycle was performed for 4 days for lined and unlined flues, as before.

Under 'normal' operation, flue gas temperatures are observed to be lower and temperatures at the brick/thatch interface reach a steady-state value after the second day: a minor modification of end-of-first-day values in both cases.

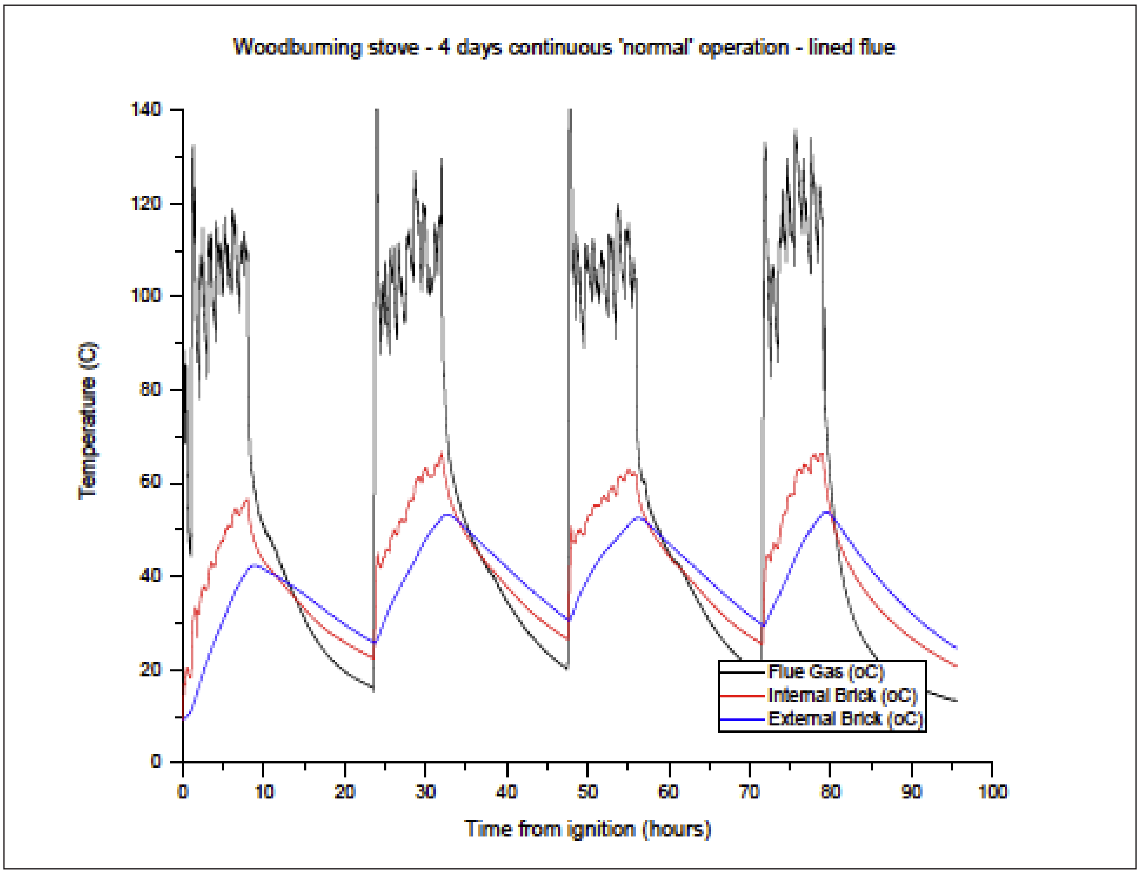



*Figure 55. Long Duration conduction investigation for a lined chimney.*

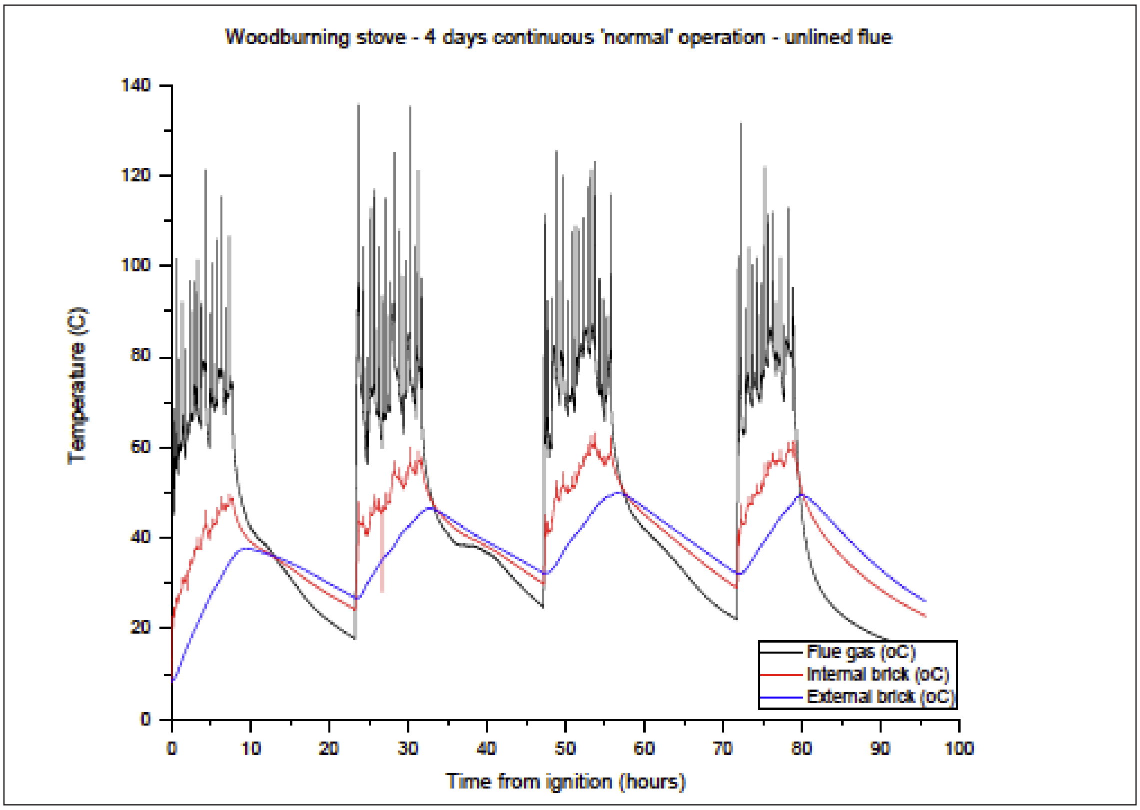



*Figure 56. Long Duration conduction investigation for an unlined chimney.*

## 9.6 Discussion of Results from Conduction Model Characterisation

After 4 hours of near unrealistically aggressive stove operation the temperature under thatch through a single brick layer for each configuration was:

- Perfect liner ~ 80°C
- Cut liner ~ 80°C
- No liner ~ 80°C
- No liner and 50% blockage ~ 80°C

Long duration testing of normal usage over a period of 4 days showed thermal accumulation to have stabilised after the first day to a value of around 50°C at the brick/thatch interface.

Whilst longer and unrelenting unrealistically aggressive stove operation could raise temperatures further it is very difficult to see how, within the constraints of this testing, conduction as a method of thatch fire raising is commonly possible without other factors coming in to play.

Considering this in the context of historic work [Ref] in this area that suggested conduction was a relevant feature we note issues with some of the assumptions made that, with the benefit of full-scale test rigs, we are in a position to correct. The historic research used numerical modelling in association with a test rig in which heat was applied by radiant panel to a configuration of brick with thatch stack on its far side. With reference to Figure 57 the differences between the historic model and findings of the full-scale tests are briefly as follows:

- The numerical model and test rig assumed the brickwork would be challenged at 300°C. Whilst mid-point gas temperatures of this magnitude can be achieved under high ventilation conditions, gas temperature profiles follow a similar profile to the velocity profile of the gases and are very much lower at the brick's surface (250°C in the gas and 175°C at the brick's surface rather than 300°C). Obviously, if the maximum brick temperature is actually lower than the elected autoignition temperature of the thatch it separates, ignition by this method is not possible.

- Using a radiant panel to deliver heat is not a good approximation for a chimney system – it delivers the energy to the brick lining surface with almost lossless efficiency. In reality, the energy comes from the hot gas content flowing within the chimney – most of this energy actually leaves the chimney as hot gas emission to atmosphere rather than conduct into the brick walls of the chimney.

- The chimney system is very dynamic in its operation – changes in ventilation immediately affect temperatures and velocities in the system. Under 'normal use' the highest gas temperature at thatch height might be little more than 100°C at thatch level and will be lower still at the brick surface.

In all, the historic work appears to have utilised inputs that we now know to be unrepresentative of reality in that they were too severe and similarly, the method of heat application in the supporting testing was done with an efficiency much greater than would happen in a real chimney heat transfer system regime.

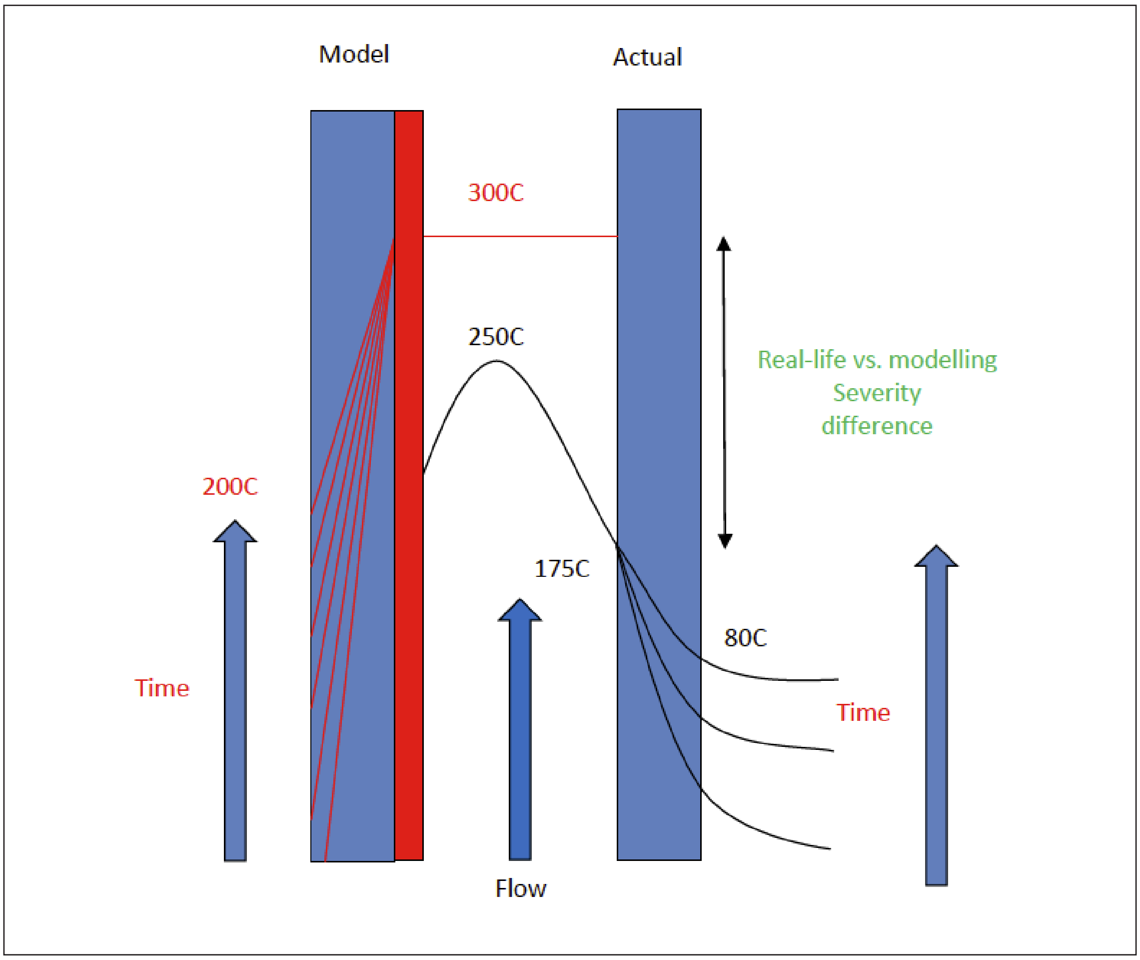



*Figure 57. Comparison of inputs of historic conduction work with full-scale measurements.*

# 10 INVESTIGATION OF CONVECTIVE HEAT TRANSFER MODE AS A POTENTIAL MEANS OF FIRE-RAISING

Convection, the transport of heat associated with the fluid behaviour of hot combustion gases, demands that there is a path for gas flow. In the case of this study we have assumed the route to be created by:

- Failed mortar
  A thin passage 10-15mm in height connecting flue gas and thatch.

- Failed brickwork
  A half brick sized connecting flue between flue gas and thatch.

Hot flue gases will not readily flow into such imperfections because the preferred route for buoyant gases would be upwards towards the largest orifice of the pot top, rather than laterally through a small hole. Changes at the pot top that act to reduce flow (e.g. restriction by soot build up or nest building) will act to encourage gases to travel laterally into the thatch.

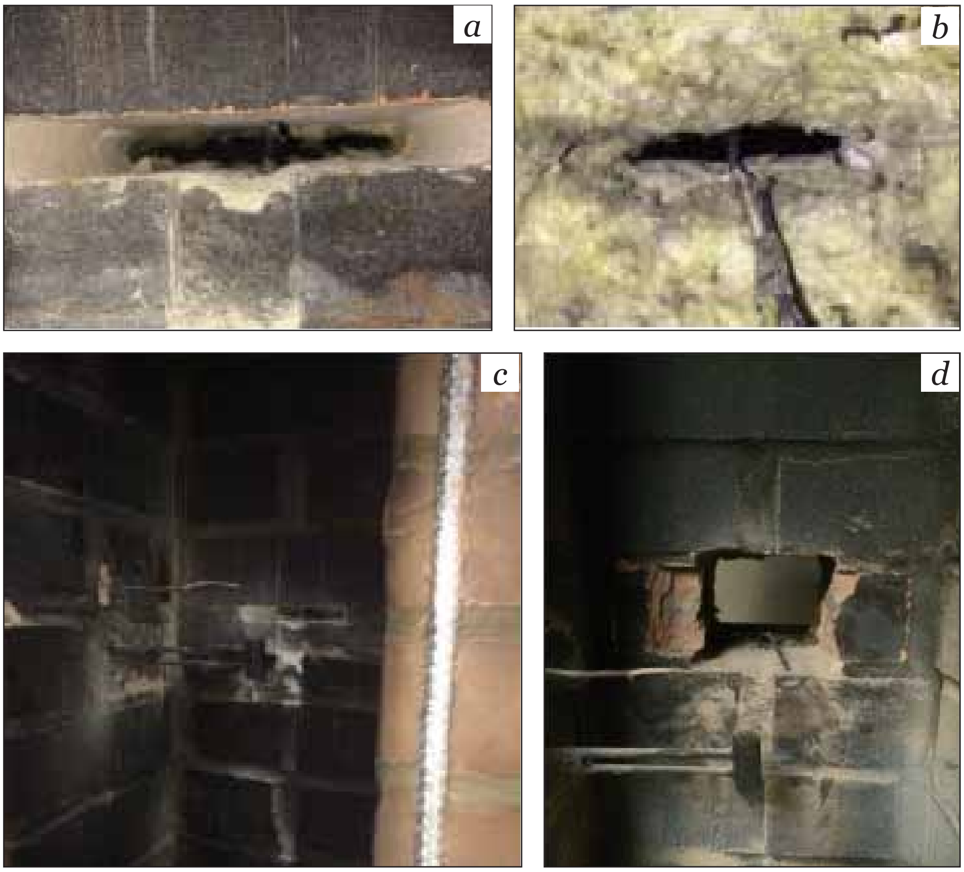



*Figure 58a-c. Details of joints used for 'failed mortar' tests.*
*Figure 58d. Detail of joint used for 'failed brickwork' tests.*

## 10.1 Failed Mortar Test with Normal Stove Operation

Figure 59 shows the fire-box temperature in association with the temperature measured in the gap formed by the failed mortar during normal stove operation.

In this scenario, even with significant restriction of the flue at high level, the temperature of gasses passing through the failed mortar were insufficient to ignite dry material upon exiting.

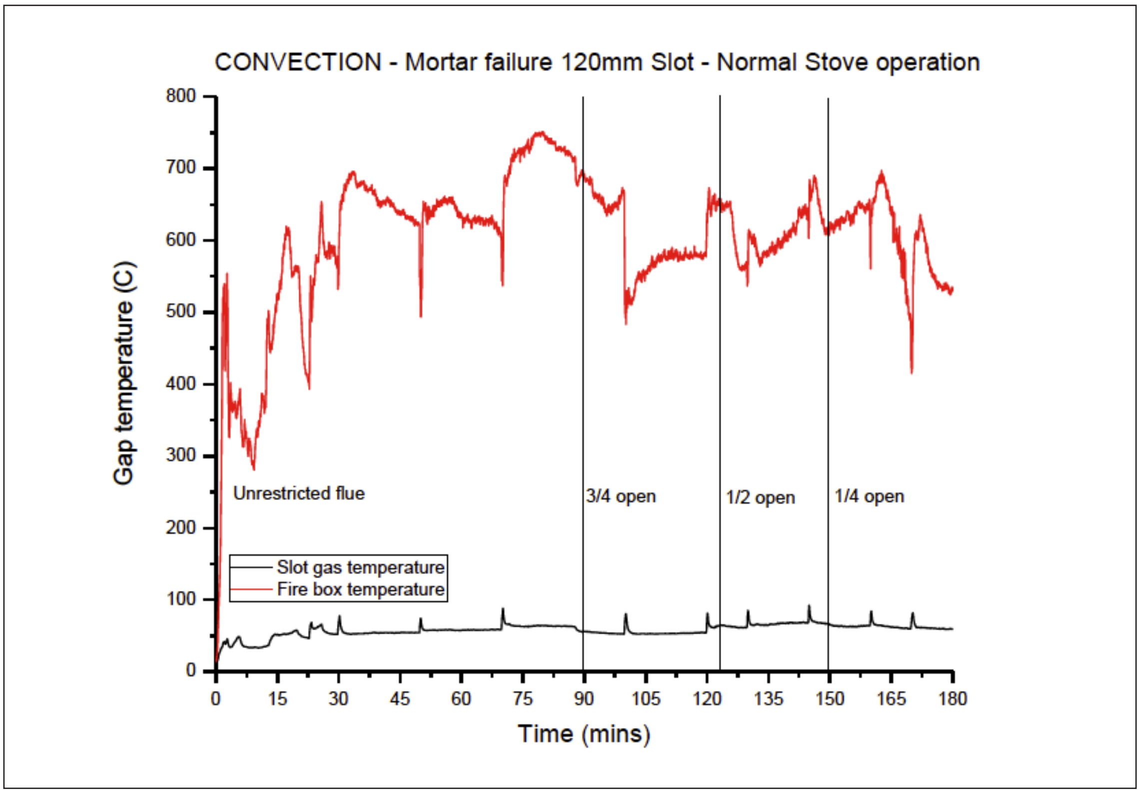



*Figure 59. Convection test through failed mortar joint with normal stove operation.*

## 10.2 Failed Mortar Test with Aggressive Stove Operation

Figure 60 shows the fire-box temperature in association with the temperature measured in the gap formed by the failed mortar during aggressive ventilation of the stove.

In this scenario, even with significant restriction of the flue at high level and aggressive ventilation of the stove, the temperature of gasses passing through the failed mortar, although higher, were insufficient to ignite dry material upon exiting.

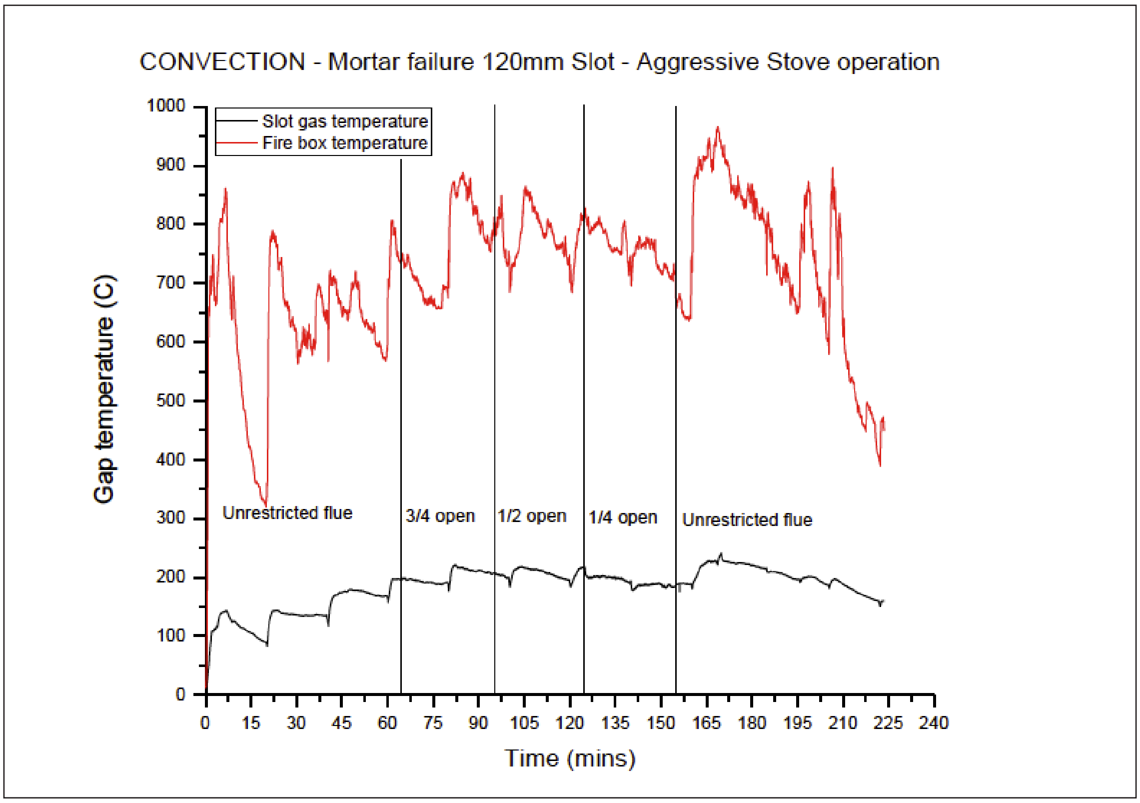



*Figure 60. Convection test through failed mortar joint with aggressive stove operation.*

## 10.3 Failed Brickwork Test with Normal Stove Operation

Figure 61 shows the fire-box temperature in association with the temperature measured in the gap formed by the failed brickwork during normal operation of the stove.

In this scenario, even with significant restriction of the flue at high level, the temperature of gasses passing through the failed brickwork was insufficient to ignite dry material upon exiting, but there were signs that ignition was close to occurring.

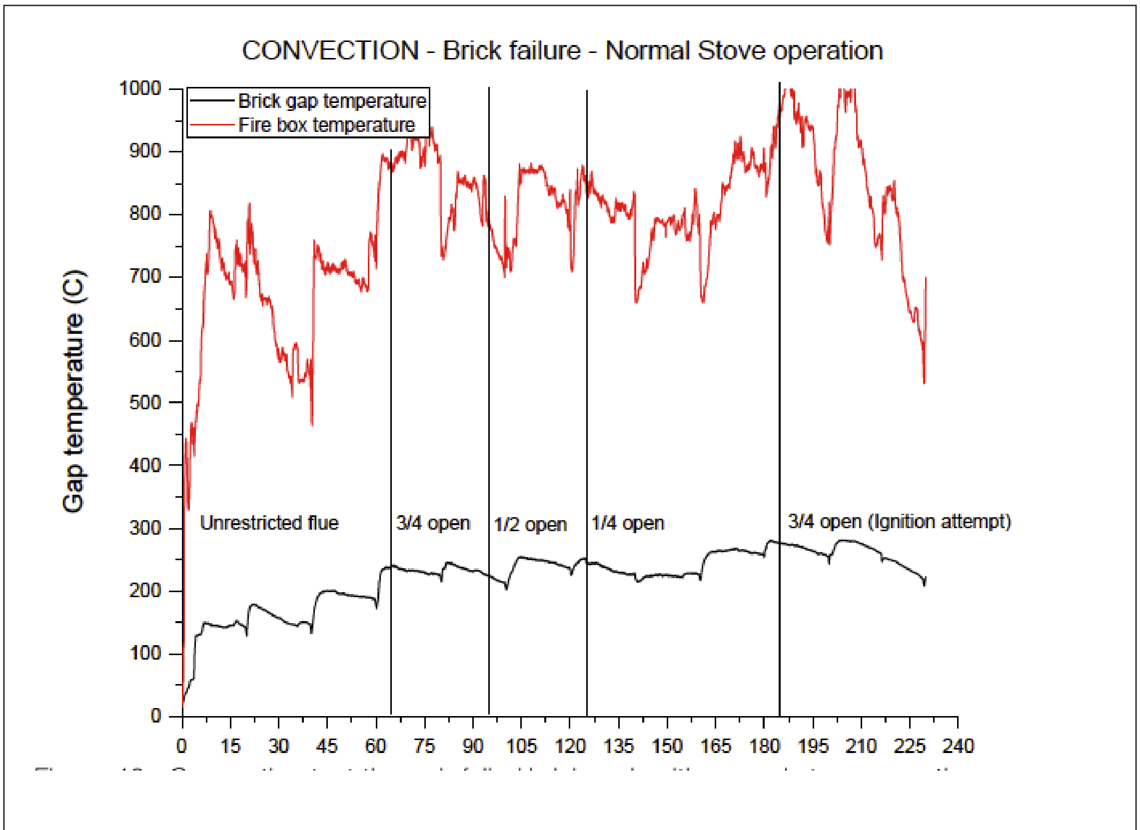



*Figure 61. Convection test through failed brickwork with normal stove operation.*

## 10.4 Failed Brickwork Test with Aggressive Stove Operation

Figure 62 shows the fire-box temperature in association with the temperature measured in the gap formed by the failed brickwork during aggressive ventilation of the stove.

In this scenario, with some restriction of the flue at high level, the temperature of gasses passing through the failed brickwork was sufficient to ignite dry material upon exiting.

It is important to note that the conditions used in these tests that do lead to ignition must be considered worst case, in that the sizes of aperture for gas flow through the chimney are large, the restriction to flow through these gaps less than the blocking capability of thatch, stove function and restriction at the chimney 'advanced', and stove operation 'aggressive'. The conclusion is that fire raising in thatch through convection is possible, but even imperfect chimneys are quite resilient to this given the preference for gases to exit via at the pot top.

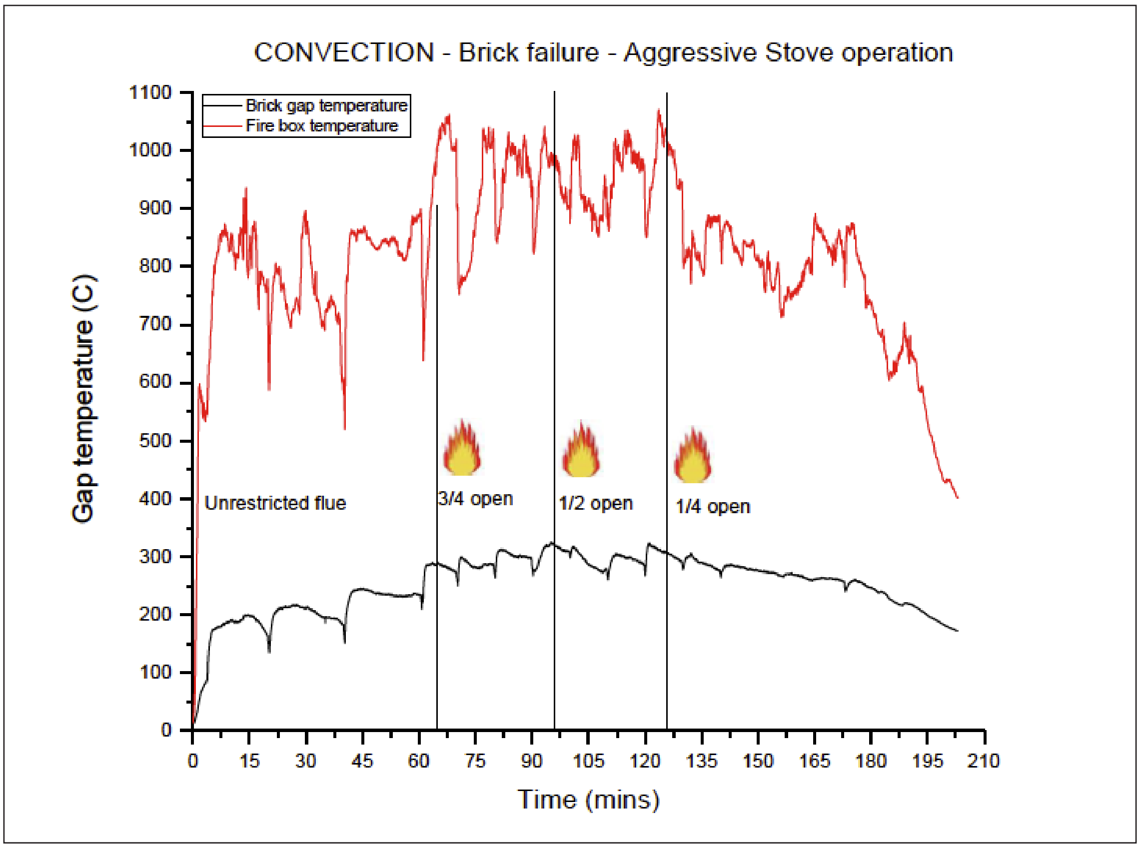



*Figure 62. Convection test through failed brickwork with aggressive stove operation.*

## 11 INVESTIGATION OF 'NEAR-POT-TOP' FIRES AS A MEANS OF FIRE-RAISING

Near-pot-top fires (flames and high energy material originating close to the thatch) can be precipitated for many reasons including tar build up on pot-top devices and chimney fires. In this study we chose to consider the ramifications of nest building within an unprotected chimney.

The specific potential hazard of bird's nests is that:

- The hazard can appear in a day.
- That day could be the day after sweeping.
- It may be built concealed from view.

It places dry combustible material in a location close to the thatch with reduced travel distances.

In this test configuration birds nests were created from realistic material (twigs and moss) and placed within the flue. To assess the ability of any issuing embers to start a fire a section of thatch was placed at stove level (6m below) the pot-top.

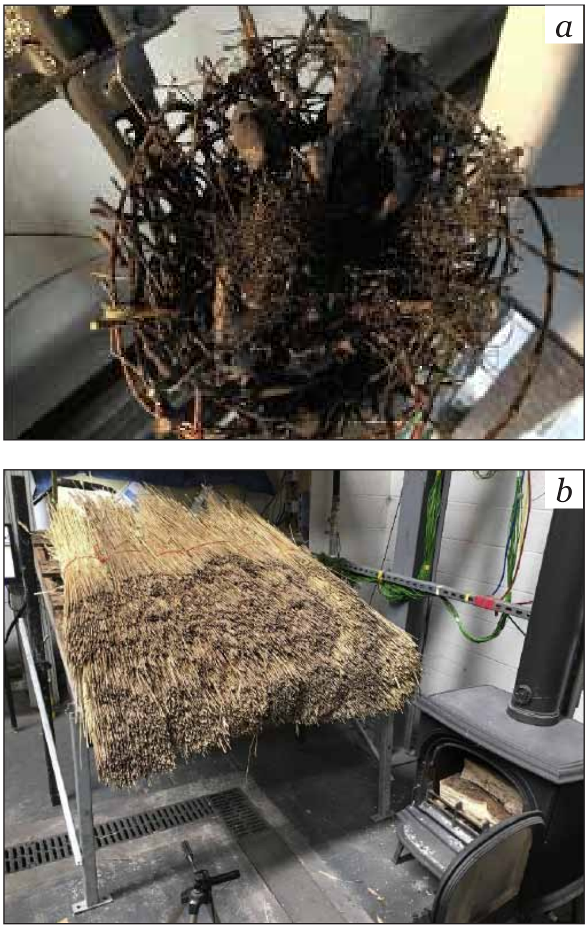
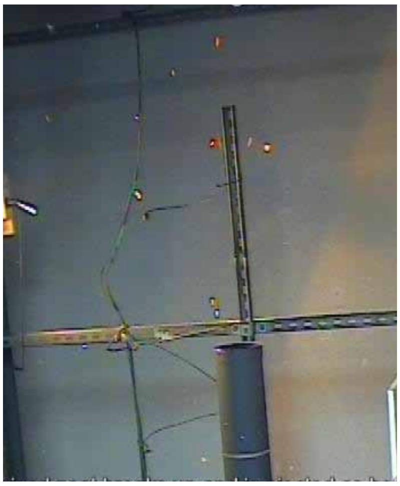



*Figure 63a, b. Bird's nest hazard simulation with thatch below.*

Observation of these tests were as follows:

- Stove ignition.
- 1 minute: white/yellow smoke/steam emission observed as volatiles driven off nest material.
- Long period of normal operation.
- 5 minutes: nest sinks down chimney out of view.
- 20-40 minutes: sudden release of high energy heavy material (whole burning carbonised twigs) that fell to the ground afire.
- One such particle landed on the thatch section and ignited it successfully.
- From the ignition point the particle burrowed to create a large cavity under the thatch with little external signals until it manifested as flame, by which point it was a well established fire.

| | | |
|---|---|---|
|  |  |  |
| 1. Ignition at t=0m 0s | 2. Smoking and volatiles driven off starting t=0m 40s | 3. Nest shrinks and slips down t=5m 0s |
|  |  |  |
| 4. Carbonised nest breaks up and is ejected as hot charcoal which bursts into flames as it meets air t=22m 0s. | | |

*Figures 63c-h. Near-pot-top fire tests.*

The mechanism for fire-raising by this effective method is as follows:

- Bird builds nest.
- During a cold snap the wood burning stove is lit.
- In the oxygen deprived atmosphere of the chimney/liner the volatiles of the nest material are driven off and charcoal is manufactured.
- The now brittle nest collapses and the hot charcoal is ejected out of the chimney on the rising gas.
- On meeting oxygen, the hot charcoal spontaneously ignites, glowing brightly.
- The heavy burning embers fall on to the thatch; their energy is very much greater than anything that commonly produced in the fire-box and ignition of even substantial material some distance from the pot top is plausible.

*Figure 64a-f. Photo sequence of bird's nest test.*

# 12 CONCLUSIONS AND RECOMMENDATIONS

Factors that might potentially contribute to the occurrence of fires in thatched roof buildings from the use of wood burning stoves are many, varied, and interrelated. The research described in this report establishes that wood burning and multi-fuel stoves represent a greater hazard in thatched roof buildings than open fires and as such are not a recommended form for heating. Where they are to be used the revised guidance as described in Appendix B should be followed. The principal findings of the work can be summarised as follows:

- The widely accepted idea that heat transfer by conduction (i.e.' Heat Transfer Theory') is the predominant mode of fire raising in thatched buildings is not supported by the test data.
- Confirmed forms of fire raising stem from the release of high energy embers from birds' nests built in the flue, and convective heat transfer through defective chimney brickwork.
- The emission of solid matter, some in the form of embers and sparks, is part of normal stove operation. Generally, sparks coming from the fire box are of low energy, but specific operations and fuels can change this.
- Flue-top devices termed 'spark arrestors' seem to have little or no impact on spark mitigation. In fact, they may encourage emitted sparks to remain in closer proximity to the thatch.
- Some stove designs are inherently safer than others.
- To minimise the risk of fire raising, it is important that users follow the correct operating procedures for their stove and understand the safe limits of its operation. A stove pipe thermometer is a highly effective means of monitoring the safety state of a stove.

In the light of the research findings, it is suggested that an 'ideal' stove system should incorporate the following features:

A stove design that does not permit exclusive under-fuel venting, either by legitimate (vent control) or illegitimate means (opening ash pan door with fuel loading door closed). If a controlled under-fuel vent is provided to assist in lighting the stove, this should automatically reset to a safe operational setting without requiring human intervention.

- The adoption of a stove pipe temperature monitor in association with good occupant knowledge of how to read it and what it means to safe operation of the stove.
- Use of wide-bore flue liners, preferably of the rigid insulated variety, to reduce flue gas velocities and prevent convective heat transfer methods of fire raising.
- The provision of a mesh-top bird cage on the top of the stack or pot to prevent nesting and accumulation of combustible materials at the pot top.
- The maximum possible separation between pot top and thatch (Approved Document J recommends the minimum allowable).
- 'Stove, flue, pot and bird guard design that supports good access for camera inspection, sweeping, and cleaning.
- Stove designs that present a clear view of the fire (clean glass) without requiring overly high stove temperatures to be generated.

## 12.1 Considerations on Stove Design as a Contributing Factor to Risk

Discussions on Stove design is covered in an article written for FRM Magazine (July 2017) which is included in Appendix A. Whilst the research suggests, possibly controversially, that wood burning stoves are not recommended for use in thatched properties, where they are to be used, some stove designs might be considered to present less risk than others. The focus of this guidance is that, whilst all stoves may be operated safely if the manufacturer's guidance is adhered to, some stoves are more resistive to abuse and incorrect operation than others. These factors generally pertain to the ventilation options, legitimate and illegitimate, available to the user.

## 12.2 Provision of Best Practice Guidance

From the research conducted to date there is an obvious and urgent need to extract benefit by the provision of meaningful guidance particularly since a commonly held belief into root cause of fire raising in thatch (conduction through brickwork) is now considered less likely.

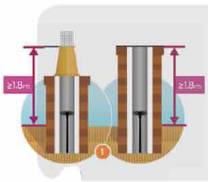
Similarly, since this work, and associated statistics strongly suggest that this is an issue with wood burning stoves, as distinct to other forms of heating, the first recommendation is inevitably not to use wood burning stoves in thatched houses.

Extracts addressing key issues are given in the propose leaflet "Guidance for owners of thatched buildings with wood burning and multi-fuelled stoves". Each recommendation is described below and the full draft leaflet is given in Appendix B. This leaflet has been co-operatively developed by HE, NFUM, and the FPA.

### Overriding Statement

**Wood-burning and multi-fuelled stoves are NOT recommended for use for thatched buildings as they have been demonstrated to present a greater risk to the thatch than other forms of heating INCLUDING traditional open fires. It is accepted that the efficiency advantages of wood-burning and multi-fuel stoves are attractive to householders and this guidance has been produced to assist them in reducing the risk of fire where such stoves are used.**

### Chimney Height and Sweeping




**CHIMNEY HEIGHT & SWEEPING:** Sparks and embers, apart from those generated by chimney fires, are generally of low energy with a short lifespan. Increasing the distance between the top of the chimney and the thatch (by raising the height of the chimney, adding a chimney pot, or reducing the thickness of the thatch) will result in fewer active sparks reaching the thatch thereby reducing the probability of ignition. Tar and soot build-up can lead to chimney fires resulting in extreme flue gas temperatures and burning material being emitted from the chimney top. Chimney fires may cause ignition of building fabric and contents, damage chimney liner and brickwork, and may set fire to thatch directly by radiation or by ejecting burning material that lands on the thatch.

### Fit a Bird Guard

**FIT A BIRD GUARD:** The introduction of a nest of twigs into the chimney provides an assured and proven means of generating heavy, high intensity burning brands, issuing from the chimney that could set thatch alight even after long distances of travel from the pot top. Sweeping alone will not mitigate this risk as birds may build a nest after the chimney has been swept. The chosen device must not impair the function of the chimney; be capable of blocking under any circumstances; and must not impair normal chimney sweeping activities.

## Line your Chimney

**LINE YOUR CHIMNEY:** All stove chimneys should be lined, ideally with twin-walled insulated rigid stainless liner. Where not possible due to chimney geometry and access issues, a quality twin-walled flexible stainless liner should be used in its place. The transport of hot fire gases and sparks to internal thatch layers via imperfect chimney brickwork has been demonstrated to be an assured means of starting in-thatch fires. The risk from this mechanism of fire raising may be wholly mitigated by the provision of a liner.

## Ignition

**IGNITION:** During ignition, when the stove controls may be set to a maximum ventilation to get the fire going, there is the potential to lift heavy burning materials, such as paper and card, from the fire box and for it to be ejected from the chimney over the thatch. The use of firelighters and kindling in preference to paper and card will reduce the risk. The wood burning stove should NEVER be used as an incinerator, eg for sensitive paperwork and rubbish.

## Ignition and Fuelling

**IGNITION & REFUELLING:** When the ventilation to the stove is increased to boost the fire during ignition or refuelling it is essential that the stove is attended until the controls are re-adjusted to their normal settings. Failure to do so may result in very high uncontrolled stove and chimney temperatures in association with high flue gas velocities. These factors may act to initiate chimney fires (if tar and soot is present), lift burning material out of the chimney, and raise fires through gas escape under thatch if the brickwork is imperfect and the chimney unlined.

## Fit a Stove Pipe Temperature Gauge

**FIT A STOVE PIPE TEMPERATURE GAUGE:** Stove temperature monitoring is an essential user aid to understanding if the stove is working within its safe limits. Operating at too low a temperature risks coating the chimney with soot and tars which may later lead to chimney fires. Operating at too high a temperature risks fire raising through the ejection of burning material; the starting of chimney fires if tar and soot has built up; and the internal ignition of thatch through faulty brickwork if the chimney is unlined. All members of the household should be aware of the meaning of the gauge sections and know how to control the stove to maintain ideal operating limits.

## 12.3 Consideration of Improving Forensic Data Collection

Thatch fires are relatively few in number and as such it may take a significant amount of time to develop statistically meaningful datasets for the determination of root cause and obviously much unnecessary damage may result during this process. It is therefore all the more important that detailed 'case-data' is collected at every opportunity. This work might suggest that bird nesting, flawed brickwork, and stove design / stove settings, might be contributing factors to fire, yet currently this information is not universally recorded. A proposed data collection form is presented in Appendix C for development. Involvement of all stakeholders would be required to action such a system, but the rewards could be very great and provide measure of the success or otherwise of current mitigation thinking.

## 12.4 Draft Consideration of an Ideal WBS Installation

Based on the work of this study in association with other references the ideal configuration might be to not have a stove at all, and where solid fuel heating is demanded that it be of the more traditional open fire type. Simply put, large amounts of cool air are entrained over the fuel of open fires and up the chimney with the smoke and combustion gases resulting in significantly lower flue temperatures. Additionally, the cross-sectional area of the stack is generally very much greater than the small 6" liners commonly used with stoves, so velocities are significantly less. However, the use of open fires do present other challenges (sparks and burning material on to carpets) which need to be considered to form a balanced view on this.

If a wood burning stove is to be used in a thatched house then, pending further work, the optimised design might encompass:

- A stove where exclusive under-fuel ventilation is not possible by either legitimate (vent control), or illegitimate (ash pan door only open), means. Where control is legitimate and necessary at times of ignition, the controls should reset to a safe operating setting automatically rather than requiring human intervention.
- The adoption of a stove pipe temperature monitor in association with good occupant knowledge of how to read it and what it means to safe operation of the stove.
- Use of wide bore linings, preferably of the rigid insulated variety, to reduce flue velocities and prevent convective methods of fire raising.
- The provision of an open-top bird cage on the top of the stack to prevent accumulation of combustible materials at the pot top.
- The maximum pot-top to thatch separation possible, over that demanded by building regulations.
- Stove, flue, and pot-top device design that supports good access for camera inspection, sweeping, and cleaning.

Stove designs that may present a clear view of the fire (clean glass) without requiring overly high stove temperatures to be generated.

## 12.5 Draft Consideration of Chimney Extinguisher Provision

Whilst the experimental measurements made in this study suggest that chimney fires in wood burning and multi-fuel stove systems with lined flues are unlikely owing to the lack of oxygen within flue, fires are known to happen. This would suggest some other failing within the system, such as extremely leaky stove seals, and indeed in some instances this has been shown to be a root cause (in association with all the errors giving rise to dangerous levels of tar deposition within the flue).

Indicators of a chimney fire include:

- A loud roaring noise, the result of massive amounts of air bring sucked through the burner or fireplace opening.
- Sparks and flames seen shooting from the chimney top, which can be similar to fireworks in appearance.
- A glowing or shimmering outlet or connector.
- A rapid rise in temperature indicated by the stove thermometer.
- A vibrating appliance, outlet or connector.
- Flames visible through any tiny cracks in the outlet or connector.
- Smoke or smells noticeable in adjoining rooms or the loft space.
- The chimney breast of flue pipe heating up in either the same room or other rooms they pass through.

The general advice is to call the Fire and Rescue Services under these circumstances. Recommendations for 1st aid fire-fighting measures by the homeowner are varied and very often conflicting but all agree on, 'safety first' and the need for conducting normal evacuation procedures, and that the benefits of prevention outweigh the benefits of any measure that could be put in place to deal with it once started.

In respect of thatched properties specifically, the emission of flames and heavy burning materials suggest a high likelihood of chimney fires progressing to involve the thatch itself. With this in mind, for 1st aid management to be successful, speed will be of the essence, requiring immediate identification of a problem and prompt attendance, having all necessary equipment close at hand, and fire-fighting procedures rehearsed. Equipment might include safety gloves and a dedicated stove extinguisher, used in association with measures to stop air flow to the fire.

The capability of the different extinguishing methods and extinguishers is out of scope of this study.

# APPENDIX A

## 'Intelligent stove selection could assist in thatched house fire safety', article appearing in ***Fire Risk Management,*** July 2017

Dr Jim Glockling, Technical Director FPA, Director RISCAuthority

*Heritage properties present many challenges when it comes to fire prevention and protection. Construction methods and materials mean often as not if a fire starts the concluding loss is total and nowhere is this more so than in thatched properties. The convergence of heritage properties and modern lifestyle requirements can be at the heart of this conflict and the popular inclusion of wood-burning stoves is an area requiring urgent attention. Over the last 2 years Historic England and NFU Mutual, in association with the Fire Protection Association, have undertaken the first ever full-scale laboratory testing of wood burning stove configurations intensely instrumented to understand every conceivable contributing parameter to thatch fires.*

*This was a 'fresh-eyes' look at the issue where theories of prevalent cause were both entrenched in the thatching community yet also under suspicion of not being quite the full story, leading to solutions that at best might not be useful or address the core issues, and at worst could cause unnecessary damage to heritage material. I will not dwell on the findings in this article as the purpose of this story is to further the work by floating the idea that owners of thatched properties, if they are to install a would burning stove, can make design choices that might influence overall fire safety. Details of the programme of work and the derived definitive guidance are reported elsewhere, but suffice to say assured and demonstrable ways of fire raising included birds nesting, faulty chimney brickwork, and poor stove operation – less likely would be fire raising resulting from conduction and thermal accumulation through perfect brickwork and linings. It is important to say that we are talking about 'likelihood' in the context of already unlikely events.*

*I am a thatch owner myself and on the basis of this work I have decided to remove the wood burning/multi-fuel stove from my house. And to be clear, the initial recommendation made as a result of this work is to not install a wood/multi-fuel burner which seems unthinkable, but it does go on to give helpful mitigation advice if one is present. At the time of installing it I believed it to be a safer option than the open fire that it replaced: this is incorrect. The statistics clearly point to a risk associated with stoves, and not open fires. Whilst this might seem initially odd I hope by the end of this article you will understand why it's actually quite obvious.*

*For the purposes of discussing stove design we need to take it as read that there are certain 'essentials' that are covered off including; the need for approved installers; adherence to Building Regulations; the need for regular sweeping and inspection by those appropriately certified to do so; the fitting of a bird guard; and a knowledge of the latest advice on stove ignition procedures, operation, and installation (see new HE/NFU Mutual/FPA guidance pamphlet).*

*As the Technical Director of the Fire Protection Association, who is meant to know about fire safety, let me tell you about how we live(d) with our wood burning stove:*

- *It has a flue thermometer on it that everyone in the house knows how to read – from the ages of 4 my children knew to inform me if it went into the red zone*
- *Instruction is given to anyone using the house when we are not …. especially my cavalier brother-in-law who craves the idea a roaring fire to lounge on the sofa with (and ultimately to fall asleep to!) as he seeks respite from London living.*
- *Everyone in the house can identify from the sound of its operation when it might be over-ventilating*
- *The glass window's normal state was black – it provided heat and burned steadily – not the idealised beautiful glow of the brochures – to achieve that required it to be hotter than I (or the stove thermometer) felt appropriate*
- *I could at all times evidence to my insurer that their requirements were adhered to*
- *Ignition and refuelling / rekindling were always 'attended' events until the ventilation controls were returned to their steady operational conditions.*

*OK so this will sound odd to many, but I'm a bit of a worrier and I do get to see all too often the consequences of when things go wrong.*

*Safe stove operation is complex and for every good attribute there is usually a balancing counter argument so the solution will inevitably be a compromise.*

*Once a stove is lit control is achieved through management of ventilation; mostly through restriction of the air entering the combustion chamber and sometimes additionally through the control of smoke and gases egressing it. If a stove is over-ventilated it will run very hot. Pro arguments will claim a stove that is hot will fully combust material in the flue so the likelihood of sparks emerging the stack to threaten the thatch is less likely. It might also be true that tar deposition in the flue will be less. Counter arguments may say that the additional heat may challenge imperfect brickwork to potentially set fire within the thatch itself, and that the increased velocity within the flue will be able to lift heavier material out of the combustion chamber which might well have enough energy to emerge as worst case 'heavy sparks' – ones that drop on exit to the thatch rather than float off out of harm's way. High velocities and very high smoke temperatures might also combine to initiate chimney fires and perhaps even cause tar deposits on pot-top devices to dislodge and fall to the thatch surface. Many of these aspects have been demonstrated to be correct in the laboratory and the nature of the spark emergence can additionally depend on both what you are doing at the time (refuelling and riddling), and what you are burning/using as ignition materials.*

*Focussing on ventilation, stove design has a vital role to play in constraining the user to conduct this in a responsible fashion. The critical elements are*

- *How much air the controls allow in.*
- *Where the air enters in relation to the fuel bed.*
- *Whether there is scope to 'illegally' abuse the stove configuration to introduce great quantities of air over and above the maximum achievable through use of the controls.*

*Stoves will often have more than one controllable point of entry for air. In a traditional log burner, where there is no ash pan and the logs sit on the bottom of the stove in the bed of ash itself, ventilation may be provided from a sliding or rotating control in the door, and via an air-wash system designed to keep the glass clean (this enters from the top of the stove through a sparge-pipe arrangement). The only means of getting extra air in is to open the fuel loading door which makes the system during these periods no different to an open fire. All of these points of air entry are above the fuel – it is a gentle form of ventilation in comparison to the next scenario.*

*Stoves of the multi-fuel variety, and some dedicated wood burning stoves incorporate an ash pan; a location for ash from coal / coke burning to fall. With this simple change comes the scope to introduce air under the fuel – intensely aggressive ventilation can be achieved through under-fuel ventilation, and, like a blacksmith's forge, very high temperatures and flue velocities can quickly be achieved. Obviously, the maximum level of ventilation achievable is capped by the limit of the controls that supply to this region of the stove, but, for the reckless and impatient other methods may be possible.*

*Where the presence of the ash-pan is an 'optional extra' – allowing a wood-burning stove's capability to be extended to also burn coke and coal, it may have its own door that is separate to, and can be opened separately from, the fuel loading door. These are the type of stoves we have been using in the laboratory for the test programme and using the door as ventilation (obviously against the advice of the manufacturer's operation manual) the stove will sing like an organ pipe and eject significant matter from the pot top without trouble and raise temperatures universally well above anything that would be considered normal.*

*Looking at the full range of stove designs out there I'm of the opinion that this is a known issue. Some designs have a combined fuel loading/ash pan door that prevents this method of over-ventilation being possible. Many designs interlock the two doors such that whilst they are separate, the fuel loading door can be opened in isolation but the ash pan door cannot. In the light of the work done these are excellent features to see but it does beg the question as to whether thatch owners, or anyone else in the supply chain, appreciate that some stove choices may be cleverer than others in curtailing risks in at least one area of thatch house ownership.*

*The next obvious stage of this work would be to work with the stove manufacturers to discuss the findings of the work and, whilst we might have identified a desirable feature here, what other beneficial features are out there (such as automatic ventilation control, easier cleaning provision etc.)*

*Used well, all stoves are 'safe', but the human element at the root of many risk problems can be reduced by good design and end user selection.*

*And to close, reasons why open fires might be safer than stoves. Simply put, large amounts of cool air are entrained over the fuel and up the chimney with the smoke and combustion gases resulting in significantly lower flue temperatures. Additionally, the cross-sectional area of the stack is generally very much greater than the small for 6" liners commonly used with stoves, so velocities are significantly less. At the end of the day though, all this may account for little when relatives at Christmas throw balls of wrapping paper on to the open fire that zip up the chimney to emerge still burning from the pot to the cries and panic of a strangely overexcited host!*

# APPENDIX B

## Best Practice Guidance Z-fold pamphlet

*This pamphlet available to download on the FPA website: www.thefpa.co.uk*

Wood burning and multi fuelled stoves are NOT recommended for use in thatched buildings as they have been demonstrated to present a greater risk to the thatch than other forms of heating INCLUDING traditional open fires. It is accepted that the efficiency advantages of wood burning and multi fuel stoves are attractive to householders and this guidance has been produced to assist them in reducing the risk of fire where such stoves are used.

**CHIMNEY HEIGHT & SWEEPING**: Sparks and embers, apart from those generated by chimney fires, are generally of low energy with a short lifespan. Increasing the distance between the top of the chimney and the thatch (by raising the height of the chimney, adding a chimney pot, or reducing the thickness of the thatch) will result in fewer active sparks reaching the thatch thereby reducing the probability of ignition. Tar and soot build-up can lead to chimney fires resulting in extreme flue gas temperatures and burning material being emitted from the chimney top. Chimney fires may cause ignition of building fabric and contents, damage chimney liner and brickwork, and may set fire to thatch directly by radiation or by ejecting burning material that lands on the thatch.

**FIT A BIRD GUARD**: The introduction of a nest of twigs into the chimney provides an assured and proven means of generating heavy, high intensity burning brands, issuing from the chimney that could set thatch alight even after long distances of travel from the pot top. Sweeping alone will not mitigate this risk as birds may build a nest after the chimney has been swept. The chosen device must not impair the function of the chimney; be capable of blocking under any circumstances; and must not impair normal chimney sweeping activities.

**LINE YOUR CHIMNEY**: All stove chimneys should be lined, ideally with twin-walled insulated rigid stainless liner. Where not possible due to chimney geometry and access issues, a quality twin-walled flexible stainless liner should be used in its place. The transport of hot fire gases and sparks to internal thatch layers via imperfect chimney brickwork has been demonstrated to be an assured means of starting in-thatch fires. The risk from this mechanism of fire raising may be wholly mitigated by the provision of a liner.

**IGNITION**: During ignition, when the stove controls may be set to a maximum ventilation to get the fire going, there is the potential to lift heavy burning materials, such as paper and card, from the fire box and for it to be ejected from the chimney over the thatch. The use of firelighters and kindling in preference to paper and card will reduce the risk. The wood burning stove should NEVER be used as an incinerator, eg for sensitive paperwork and rubbish.

**IGNITION & REFUELLING**: When the ventilation to the stove is increased to boost the fire during ignition or refuelling it is essential that the stove is attended until the controls are re-adjusted to their normal settings. Failure to do so may result in very high uncontrolled stove and chimney temperatures in association with high flue gas velocities. These factors may act to initiate chimney fires (if tar and soot is present), lift burning material out of the chimney, and raise fires through gas escape under thatch if the brickwork is imperfect and the chimney unlined.

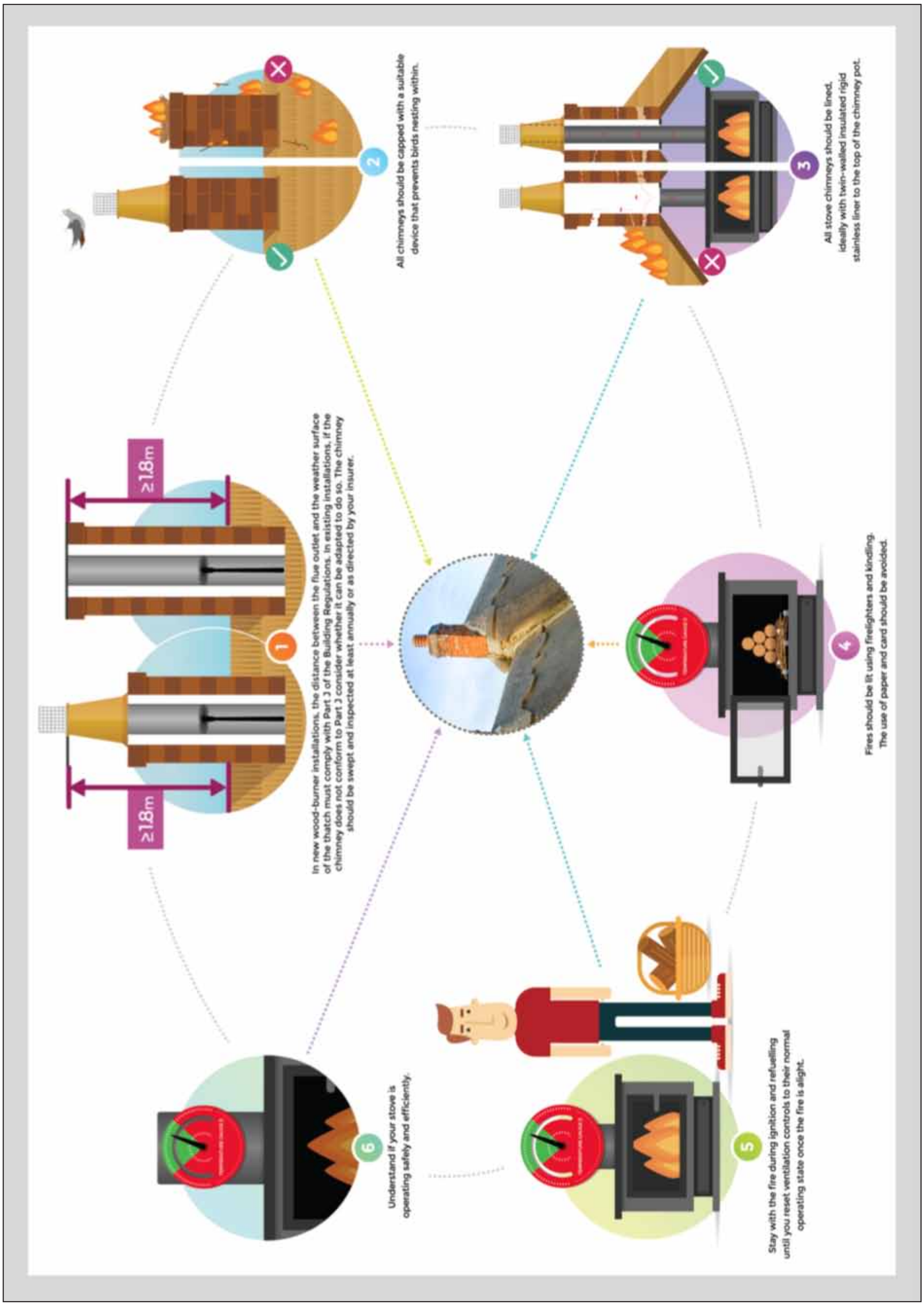
**FIT A STOVE PIPE TEMPERATURE GAUGE**: Stove temperature monitoring is an essential user aid to understanding if the stove is working within its safe limits. Operating at too low a temperature risks coating the chimney with soot and tars which may later lead to chimney fires. Operating at too high a temperature risks fire raising through the ejection of burning material; the starting of chimney fires if tar and soot has built up; and the internal ignition of thatch through faulty brickwork if the chimney is unlined. All members of the household should be aware of the meaning of the gauge sections and know how to control the stove to maintain ideal operating limits.

FPA Fire Protection Association

New Guidance for owners of thatched buildings with wood burning and multi-fuelled stoves

This guidance describes a set of actions that should be taken by householders to reduce the risk of fire in thatched roofs from wood burning and multi-fuel stoves. It draws on the results of research including full-scale fire tests carried out by the Fire Protection Association on behalf of Historic England and NFU Mutual Insurance. These actions are in addition to the stove manufacturer's operating instructions, applicable building regulations and any insurance policy conditions.

Historic England NFU Mutual


≥1.8m
≥1.8m
1
In new wood-burner installations, the distance between the flue outlet and the weather surface of the thatch must comply with Part J of the Building Regulations. In existing installations, if the chimney does not conform to Part J consider whether it can be adapted to do so. The chimney should be swept and inspected at least annually or as directed by your insurer.
2
All chimneys should be capped with a suitable device that prevents birds nesting within.
3
All stove chimneys should be lined, ideally with twin-walled insulated rigid stainless liner to the top of the chimney pot.
4
Fires should be lit using firelighters and kindling. The use of paper and card should be avoided.
5
Stay with the fire during ignition and refuelling until you reset ventilation controls to their normal operating state once the fire is alight.
6
Understand if your stove is operating safely and efficiently.

# APPENDIX C
## Draft Data Collection Form

Fire Protection Association

Wood Burning Stove and Open Hearth Chimney Related Fire Investigation Questionnaire

RISCAuthority

This form is designed to illicit post fire information pertaining to the circumstances surrounding chimney fires in properties using wood burning stoves and open hearth fires.

Date of Incident:

Time of incident:

Address of incident:

County
Postcode
Country

**Heating equipment details**

Open fire

Wood burning Stove

Multi-Fuel stove

- Multi-fuel stove identifiable by ash box and grate

Stove Make / Model no.

**Chimney top configuration (Tick all that apply)**

Brick / stone stack
Pot on stack
Rain guard (i.e. Chinese hat)
Bird Guard (Coarse mesh)
Spark arrestor (Fine mesh)
Other (Please describe)

**Flue configuration**

Unlined stone / brick work
Rendered lining
Ceramic liner
Flexible metal liner
Rigid metal liner
Other (Please describe)

What was the distance between pot top (or stack if no pot present) and roof covering

What was the diameter of the liner or stack

**Circumstances**

Was the heating appliance in use at the time of the fire

What time / date was the fire lit

What the last time / date the fire lit previously to this

What materials / methods were used to light the fire

Paper
Card
Kindling
Fire lighter
Other (please specify)

Gas poker
Electric poker

What fuel was in use

How long after ignition was it before the fire was detected

How was the fire detected

What were the initial signs of fire (i.e. smoke, sparks, flames, sounds

How were the air vent controls configured on the heating appliance at the time of the fire – were they repositioned during the fire

What were the weather conditions at the time of the fire, and over the previous week

| | |
|---|---|
| Had there been evidence of bird nesting activity around the chimney prior to the fire | |
| Had there been evidence of smoke smell in rooms or loft space prior to the fire | |
| Had there been evidence of material falling down the chimney prior to the fire | |
| What date was the chimney last swept | |

**Please provide a narrative of the circumstances of the fire:**

**Please describe the extent of damage to the property:**



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