Fire prevention in historic buildings – approaches for safe practice

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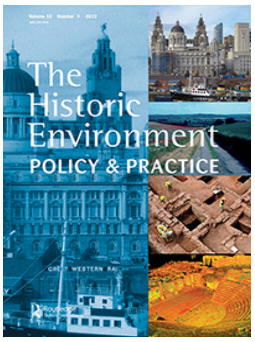

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Fire prevention in historic buildings – approaches for safe practice

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ABSTRACT

There is a continual loss of irreplaceable built heritage as a result of fire and statistics indicate that the numbers are significant and sustained. Fire prevention suggests itself as the best solution to the problem: if there is no outbreak of fire in the first instance, there are no consequent losses. Taking as a starting point recent statistics, which provide insight as to the causes of fires in historic buildings, this article examines the associated key measures that can be adopted to prevent fire. The initiator for all such measures is a risk-based approach tailored to individual buildings and including, beyond the standard life safety concerns, an additional focus on heritage aspects. Constant vigilance and awareness of day-to-day activities within a building, with good housekeeping practices, are essential; particular attention is required towards any construction activity and for any special events. Risk assessment and fire prevention are however only components of what needs to be a holistic approach to protect historic buildings from fire, which should also include the improvement of fire protection measures where possible and establishing or refining emergency planning for the possibility that, despite best efforts, it may not be possible to prevent all cases of fire.

KEYWORDS

historic buildings; fire prevention; heritage management; historic building fires; fire safety; technological solutions

Introduction

Fire prevention suggests itself as the fundamental principle for reducing or even eliminating heritage loss due to fire, since if there is no outbreak of fire, there is no related loss. The significant, ongoing and unsustainable losses related to fire, which include those resulting from catastrophic fires in historic buildings of world importance that are all too familiar, collectively represent fundamental failures in prevention. This article seeks to address the issues surrounding fire prevention in historic buildings, taking as its starting point an examination of the reported causes of fire. Subsequent careful assessment of the interventions that can be used to prevent fire, based on these identified causes, will seek to offer insight and practicable advice for those responsible for historic buildings.

It is useful here to define fire prevention in contrast to fire protection. The British Standard which covers fire-related vocabulary defines fire prevention as 'measures to prevent the outbreak of a fire'; and fire protection as 'measures taken in the design or

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equipment of buildings or other structures to reduce the danger from fire'.[1] Thus, while protection is by nature pre-meditated and incorporated where possible within the design of refurbishment works, or where the upgrading of protection has a low-impact on cultural significance[2] and can be accommodated outside of these works, prevention is an ongoing and continual concern. Although fire prevention in heritage has been defined as 'management steps taken to reduce the likelihood of a fire starting',[3] it should be clearly understood that it is in reality not limited to managerial or procedural aspects and is likely to include technological solutions.

Even though every historic building is unique, there are many commonalities in the challenge of achieving effective fire prevention in such buildings, and these are explored here. The article is based on a multi-mode investigation of fire prevention in historic buildings, which comprised an interrogation of the published literature and a range of semi-structured interviews conducted with key stakeholders and contributors to examine the issues arising in more detail. Visits were also made to a number of historic buildings to gather contextual material relating to fire prevention strategies and solutions adopted. This was synthesised with insight gained from research into various aspects of mitigating the threat from and impact of fire in historic buildings, undertaken by the author over the last 10 years. The aim was to explore the key issues in the prevention of fire in the historic built environment and seek to provide clear advice for dissemination within the sector.

There is relatively limited comment here on privately owned properties that do not have public access, and though it is recognised that there is a vast range of types of property and circumstances, the focus here is on historic buildings that have public access and employ staff. Furthermore, the article is based on UK statistics and guidance, albeit with the use of an international range of examples to illustrate various points. The general principles of heritage fire prevention discussed and the conclusions reached, however, are applicable in some form to all historic buildings.

Identified Causes of Fire in Historic Buildings

In order to give focus to this article a range of data from recent years that identify the key causes of fires in historic buildings have been compiled. It should be stated from the outset that the data are far from satisfactory and lack breadth and completeness. This is because, and despite the lobbying of government by Historic England and others, there is no official recording of fire statistics that relates solely to historic buildings. This lack of good heritage-specific fire statistics is not limited to England but is commonly the case and applies to many countries. The fire and rescue services in England do report details of fires (via the Incident Recording System) including cause, but 'historic'/'heritage' as a building type or category is nowhere recorded.

There have been previous attempts to correlate recorded fire locations with geolocation data of known heritage assets in England, focusing on Cambridgeshire, Hampshire and Suffolk, and this was shown to work in theory, albeit with limitations and unrealistic resource requirements.[4] It was also concluded that it would be far better to include a heritage category when recording incident data. There was also an official drive to collect fire statistics in Scotland using the 'Scottish Historic Buildings National Fire Database' in the early 2000s, though this was unfortunately relatively short-lived. A large-scale and pan-European project, called 'Cost Action C17: Built Heritage: Fire Loss to

Table 1. Causes of fires in historic buildings; note: Historic England figures do not represent an increase in fire incidence from 2018 to 2019 and beyond, rather increased scope and efficiency in the gathering of data.

Cause of fire (expressed as %)	Cost Action C17[5] 2003–2006	Historic England[6] 2018	Historic England[7] 2019	Historic England[8] 2020	Historic England[9] 2021
Electrical	7	12	12.7	14	13.2
Chimney	10	10	9	9.5	11.3
Kitchen	3	5	9.2	10.4	10.1
Smoking materials	1	2	2.3	1.7	0.9
Building Work	2	0.5	0.3	0.8	0.7
Misc (accidental)	8	6	8.4	9	9.6
Deliberate	30	23.5	19.3	18.5	13.2
Unknown (no data)	39	41	38.8	36.1	41
Approx. total fires	*383*	*355*	*1062*	*956*	*1015*

Historic Buildings', which ran from 2003 to 2006 outputted a quantity of useful data and analysis, including causes of fires. These data are presented in Table 1, together with more recent data collated by Historic England.

The first and most obvious point here is the consistently high percentage of 'unknown' cause of fires. This reflects in part the difficulty of identifying causes for fires, particularly when there is no formal fire investigation and in the context of limited fire and rescue service resources, but also the lack of a heritage-specific systemised official reporting system, as noted above. The latter point also necessitates an indirect approach to gathering data, which have been obtained via fire and rescue services press releases, local and national press archives, internet articles and community websites for fire loss and damage to historic buildings.[10]

Older data, produced by the Fire Protection Association in 1995, analysed 456 fires (limited to fires in which in excess of £50,000 of damage was caused). The results showed 43% of the fires could be attributed to arson; 22% to electrical appliance or equipment failure; 7.2% to smoking; 3.7% to hot work; 1.9% to chimney fires and 1% to cooking.[11] Although a direct comparison needs to be treated with some caution due to the differences in the categories adopted and the numbers and sizes of fires included, a basic comparison is nevertheless instructive. This suggests that arson may have reduced, which possibly relates to improved security measures and appears to be a continuing trend. Electrical fires have also reduced, potentially due to upgraded distribution systems and more extensive use of portable appliance testing; hot work (now within the building work figures) appears to have reduced, presumably due to hot working permits and better control and fires due to smoking materials have decreased, as would be expected given the reduction in numbers of smokers and limitations on smoking within buildings. Lastly, however, chimney fires and kitchen fires have increased.

In relation to the figures presented in the table, it should be borne in mind that these are only for reported fires. In many cases small fires that are extinguished quickly, which nevertheless may cause loss of heritage, are dealt with internally and without recourse to the fire service and thus the true total number of fires, whose causes remain obscure, is likely to be much higher. However, it is logical to assume that the proportion of causes for these cases may be similar to those that are reported. Additionally, though determined efforts have been made to collate details of as many fires as possible, due to the ad-hoc nature of data collection, the true number of reported fires is likely in itself be an underestimation.

Having established as far as is possible the causes of fires in historic buildings, analysis will now be addressed to these causes, together with consideration of the key non-cause specific prevention concerns.

Ignition Sources and Fire Loading

Basic fire science establishes that if it is possible to completely remove sources of ignition then the risk of fire can be reduced to zero. However, this is rarely practicable and the best approach is to reduce these as far as possible and at the same time to limit the impact of a potential ignition by reducing fire loading (which is related to combustible material available to burn in a fire). In some cases it is possible to break the link between the two by keeping combustible materials remote from ignition sources. Ignition sources are numerous and measures to remove or mitigate the risk from these are discussed throughout the article.

Two types of combustible material contributing to fire load need to be taken into account. The first is fixed (or residual), meaning materials that are integral to the building, making up the finishes and structure of the building, or both. Such materials cannot be physically moved and often contribute towards the historic character of the building itself and thus may be protected, where the building is under heritage protection, and consequently problematic to change. Examples are the timber panelling found lining the walls in many historic houses in the UK, or in an international context, the frequent incorporation of timber elements of structure in many fortified churches in Transylvania[12] and in historic temples in Japan.[13] Intervention may be limited to treating these materials in-situ so as to reduce or eliminate their contribution to fire growth or spread, for example by the use of intumescent finishes, possibly in tandem with the establishment or improvement of fire compartmentation to prevent the spread of fire between adjacent spaces, where this is lacking or inadequate.[14] In both cases there are potential limitations implicit in the avoidance of negative impact to historic character, so, for example, an intumescent finish that appreciably altered the appearance of the surfaces to which it was applied might not be acceptable.

The second type of combustible material is temporary, movable and thus often easier to resolve with mitigation potentially falling within the context of good housekeeping, which may encompass both reduction of ignition sources and control of fuel load.[15] A wide variety of specific risks and related mitigation measures might require consideration, examples for historic buildings ranging from the location of stored supplies of cooking oil for a commercial kitchen catering for a visitor restaurant, to preventing build-up of waste materials (discarded packaging for example) in proximity to a gift shop.[16]

Ensuring where possible that ignition sources are kept remote from combustible materials is particularly important in parts of the building where the heritage is of high significance. An example was noted in a Grade I building,[17] which within one of the most significant rooms contained an elaborate plasterwork fire surround (this extended up to ceiling level; the ceiling itself being of timber construction). However, there was a large quantity of firewood being stored on either side of the fireplace and not screened from it. Here the high fire load represented by the stored firewood should ideally be relocated or at least reduced by having more frequent 'top-ups' from a remote store, and suitable fire separation needs to be introduced between the fire and any stored timber (perhaps in the form of a fire-resistant and closed storage box). Examples such as this require only common-sense solutions, but often the risk is taken simply for convenience. It is recognised that for a large building, or complex of buildings, ample space may allow more choice in achieving solutions, which may be problematic in a single, more modest building.

Although the reduction or removal of ignition sources and the reduction or relocation of combustible materials are primary guiding principles, they must also be assessed in relation to the space under consideration. In larger spaces, and in particular tall spaces, there is less potential for flashover to occur and there may be more latitude in terms of what is acceptable. Detailed assessment of a space, taking into account its size, fire loading, potential for surface spread of flame and spacing of combustible materials, can be achieved by use of the 'Matrix for fire doors'.[18] This is intended to assess the potential need to upgrade doors based on fire growth, but offers a useful insight into overall risk.

Electrical Fires

The most recent UK National Statistics for all buildings suggest that roughly 12% of fires are caused by faults in 'electrical distribution' and this equates closely to the data for historic buildings.[19] However, the consequences of an electrical fire for a historic building are more serious, partly because of the potential loss of irreplaceable heritage, but also because of commonly higher vulnerability to fire spread. The problem with historic buildings is predominantly in cases where older and, in larger buildings potentially complex, electrical distribution systems have not been replaced. This may be compounded by the frequent use of vulcanised India rubber for insulation in older systems where long-term deterioration leads to the hardening and cracking of the rubber creating a fire risk. Additionally, alterations to systems made over a period of years, or circuits becoming overloaded by the connection of too many appliances, may result in installations becoming unsafe.[20]

Given the preponderance of electrical fires in the statistics, where replacement has not occurred this should be the priority.[21] It is recognised that the cost of replacement work could be prohibitive in some instancesfor example, for a large country house with limited income and which is thus being run on a tight budget. Replacement could also be disruptive and may require permission or consent where historic character may be impacted by the work. It should also be stressed very strongly that any new service penetrations should be carefully fire-stopped, particularly where these are through otherwise good in-situ building divisions or where compartmentation has been established, since such penetrations have proved to be routes for fire to spread (as was the case in the fire at Clandon Park in 2015).[22] Furthermore, interconnecting voids are known routes for unseen fire spread in historic buildings and when advantage is taken of these to locate cabling, any penetrations into these must also be fire-stopped.

Replacement with a modern system, however, is not a guarantee of safety, as the fire in 2015 at Clandon Park showed. In this case overheating caused by a manufacturing fault in the distribution board was established as being the most likely cause of the fire,[23] this having been in place for several years before the fire. This raises the question of how to guard effectively against faults in electrical systems, and the ideal approach involves the addition of thermographic surveys to the standard regime of fixed wire inspection and testing. Modern thermographic surveys can detect, and thus facilitate the elimination of, problems in electrical equipment and circuits, and a thermal scan of the electrical panel and the components of an electrical system can show problems undetectable with the naked eye; the scan can reveal hot spots, excessive or unbalanced loads, loose connections, defective breakers, fuses and switches.[24]

Following the fire at Clandon the owner, National Trust, has adopted this kind of two-pronged approach to checking for electrical safety at its properties. First, there are regular electrical inspections (fixed wire tests), carried out every 5 years at all properties. Additionally, at the mid-point between these inspections, in key properties (around 160 in number), a further check is made which involves a thermographic survey; checking for thermal hotspots within the electrical system. The latter is thought likely to have been able to have picked up the fault at Clandon and is now also included in the advice from London Fire Brigade.[25] Additionally, it has been suggested that the electrical system, particularly the distribution board should be thermographically checked when under full load, to establish a 'worst case scenario' for stress on the system.[26]

Another way to guard against electrical fires, from a system perspective, is the installation of specialist devices either at distribution boards or outlets, which serve to detect either faults or overheating (depending on the type of device).[27] These are able to shut the system down or provide an alert or both should a problem occur.

Where there is the potential of rodents damaging cabling, another possible cause of fire, efforts must be made to inspect wherever possible. The objective here is to eliminate entry points as far as practicable and to eradicate the rodents using pest control measures. Where this is a persistent problem, consideration should be given to anti-rodent cable protection – this is often in the form of flexible braided conduit made using wire. Some specialist electrical cable is equipped with built-in rodent protection and the National Trust has also instigated the use of MICC (mineral insulated copper core) cabling when key properties are refurbished or repaired. This type of cable offers additional protection because it does not contribute to fire load if there is a fire, and from a prevention standpoint also resists attention from rodents. Furthermore, MICC cable offers very good longevity and thus when electrical replacement work is being carried out, given that disturbance to historic fabric should be minimised, represents a good choice.[28]

In addition to fixed distribution systems, and of equal importance, there is the need to consider electrical appliances used in the building, both fixed (such as cookers) and portable (such as kettles). A PAT (or Portable Appliance Testing) regime is standard good practice in places of work, though this is not a legal requirement.[29]

Those responsible for many notable individual historic buildings, and organisations looking after groups of buildings, are conversant with electrical testing, may have a testing regime in place and are aware of the dangers of complacency. However, electrical testing should also be commissioned by those responsible for privately owned and perhaps more modest buildings, since the heritage (and additionally often the families, residences, and possessions) is at risk from fires caused by – electrical problems if this isn't carried out.

A further concern, and one that has confronted the management of many buildings with public access, is the requirement for Wi Fi coverage and the installation of systems to provide it. This is partly due to the connectivity expectations of visitors, but increasingly also to provide information about the building (commonly referred to as 'interpretation') to visitors in a digital format that can be readily accessed on visitors' own devices (this is replacing the handing/renting out of handsets for the same purpose). It is important that all data cabling and wireless access points used with these systems are of a suitable standard; halogen free or plenum rated cable is ideal because it produces very low levels of smoke and is flame retardant (PVC cables and those made of other compounds can produce large amounts of dense black smoke and toxic fumes) and plenum rated junction boxes are ideal.[30] Again, it is essential that all penetrations are correctly fire stopped.

Use of Chimneys

Chimney fires are more common in historic buildings than in modern buildings, which may not have chimneys at all, having been constructed when alternative forms of space heating and cooking were widely available. Chimneys may still be needed in historic buildings due to contemporary space heating requirements in the building (the use of open fires and wood-burning stoves in particular) or may be used for more decorative than practical reasons where there is access for paying visitors.

Chimney fires may be relatively straightforward to extinguish, but the problem is that these fires may have time to develop unseen before they are discovered and a response activated. There are also examples where combustible building materials, for example, timber elements, extend into the chimney wall, and may, if igniting, result in the fire not being solely confined to the chimney, with the concurrent possibility of wider fire spread and more difficult firefighting.

Another possibility to consider is the potentially poor condition of the flue or the chimney structure, since fires have been known to spread from the chimney into the roof structure, which has the capability to become a much larger fire than one confined within a chimney. Chimneys in historic buildings may have originally been lined with a lime mortar, protecting any timber ends that reach the inside of the flue; this may be lost as the lime has deteriorated and fallen from position. Inspection, ideally from the top of the stack may be required to properly assess the condition of the chimney and whether any repairs might be required. In some cases it may be desirable to re-line chimney flues and though lining with concrete and the use of steel flue liners may be unsuitable choices for a number of reasons, alternatives such as ceramic or pumice flue liners have been successfully used in historic buildings. Ceramic liners have been installed, for example, at English Heritage's Grade I early 17th century property of Audley End House to facilitate the re-introduction of real fires.[31]

The interrelationship between chimneys and thatched roofs is obviously of key concern, with the consequences of a chimney fire or spread by other means to a thatched roof being potentially catastrophic for the building. Historic England research has disproved the idea that heat transfer from hot flues or chimneys might cause thatch fires, but also concluded that wood burning and multi-fuel stoves should not be used in thatch roofed buildings.[32] This notwithstanding, and accepting that many of these stoves are actually in use and remain an attractive choice for property owners, guidance has been produced about protecting thatched roofs in such cases.[33]

Another concern that should be considered is that of the 'hearth fire'. This is a type of fire developing behind or below the hearth and is caused by accumulated soot or resin igniting. Such fires have the potential for unseen spread before detection and may require dismantling of surrounding finishes in order to effectively firefight (for example removal of floorboards or panelling).[34] To prevent hearth fires, careful inspection of the hearth and its surroundings may be required; this in itself potentially requiring some dismantling and the subsequent introduction of fire stopping if appropriate.

For all the variations discussed above regular cleaning of flues and hearths is required to prevent the build-up of potentially combustible deposits and this is normally a specialist task. Correct selection of fuels to be burnt is also of concern, some fuels, for example, producing larger quantities of combustible deposits, and properly seasoned wood must also be used.[35] Where solid fuel stoves are installed, running down after use should also be regulated to sustain a medium temperature in order to give clean burning of the fuel and avoid either excessive heat (by 'opening-up' to consume all the fuel quickly) or incomplete combustion and resin build-up (by turning the stove right down).[36] In use, all fires require constant vigilance and fire guards to be utilised where appropriate.

Kitchens

As suggested by the statistics, fires originating in kitchens are a common cause of fires in historic buildings and this is particularly of concern where historic buildings are visitor attractions and have associated commercial kitchens. Introducing measures to reduce the incidence of kitchen fires is thus an integral component of fire prevention. Since there is ample advice and guidance related to general kitchen fire safety, applying equally to kitchens in historic buildings, this area is covered only briefly here.

Many fires are 'stove top' fires associated with cooking and, beyond the standard vigilance required for cooking operations, some premises insurers have considered the risk high enough to stipulate the installation of technological prevention measures – for example stove-top monitoring systems, or hood-mounted suppression systems where fat frying is undertaken.[37] Other relevant prevention measures include carefully located storage of cooking oils remote from ignition sources and regular cleaning and maintenance of cooking equipment (particularly ovens) to make sure that there is no debris build-up, of what might well be combustible material such as fat or grease, particularly out of sight.[38]

Fires during Construction

Although the statistics point to a relatively low number of fires during building work it is nevertheless an important point to address since the highest risk for a historic building is during the construction period.[3940] Such fires are recognised as being potentially very destructive; recent high-profile fires include those at The Glasgow School of Art in 2018 and at Notre Dame Cathedral in 2019 which both occurred while construction work was being carried out and have stood to highlight this risk.[41] These are only the latest in a series of this type of fire, previous occurrences having been at Heveningham Hall in

1984, at Uppark in 1989, at Cutty Sark in 2007, at the Cuming Museum in 2013,[42] at the Guinigi Chapel at San Francesco (Lucca, Italy)[43] and St. Petersberg Cathedral (Russia), both in 2010.[44]

Any existing passive fire safety measures (such as separation and compartmentation) may be compromised while works are being carried out, for example, where ducts are temporarily open. There is also the likely presence of combustible building materials that might contribute to a larger fire load in the building. Both these factors were cited as contributing to fire growth and rapid spread in the fire investigation report to the 2018 Mackintosh Building fire at Glasgow School of Art.[45] To mitigate this, and although inconvenient and more expensive, both effective temporary separation and compartmentation measures, and off-site storage of materials may be required.

Another particular risk is 'hot work' on site during construction or refurbishment; specifically contractors using heat-producing equipment, for example, the use of blowtorches in the welding of lead sheeting on roofs. Such was the concern following a very destructive fire at Uppark,[46] caused by an Oxy-acetylene lead-welding torch that was being used by workmen renovating the leadwork on the roof,[47] that during subsequent reconstruction work all unavoidable hot work was carried out in a separate building, away from the main structure.[48] The National Trust also issued instructions that no hot works should subsequently be carried on any of its premises.[49] Indeed, in all situations and wherever possible hot works should not be allowed on site, and where these are unavoidable, a strict hot work permit system must be implemented to reduce the risk. This would normally involve checks for several hours after hot work operations have finished for the day. The issue is considered serious enough for Historic England to have issue-specific guidance about hot works.[50] Nor is it just hot works that are of concern however, another common risk for historic buildings is the cutting of stone or other materials for replacement or repair work, which often produces sparks and, therefore, also needs careful control.[51]

Since it not always possible to avoid hot works or cutting operations in or on a buildingfor example, where in-situ lead work on a roof requires repairing, it is suggested that oversight of operations by a party independent of the contractor carrying out the work is required. This could be specially trained staff from the building on which the work is being carried out. Such a person, loosely termed a 'firewatcher', is able to be objective (since they are not employed by the person doing the work), as well as being able to focus solely on the fire risk, rather than being preoccupied with the work itself.[52]

Overall, the most important concern is to have very careful and fire-risk specific site supervision, to ensure that all site processes are safe. This might take the form of an informed client, aware of the various risks and with competence and time availability to oversee operations. However, where this is not possible it may be necessary to employ a third-party professional in this role. The key is independence from the contractor carrying out the work. There is the further concern that although procedures may be understood by and agreed on with the main contractor, a multitude of sub-contractors may often outside of this process but nevertheless need to be fully informed and also follow the procedures.[53]

Additionally, site security out of hours needs to be ensured and in the context of the increased fire risk on all construction sites this should be in tandem with suitable site fire detection and alarm. It may be necessary to instal temporary systems during construction where detection and alarm systems have not yet have been installed or may be partially disabled during work. In 2018 at the time of the fire in the Mackintosh Building, it appears that a temporary system was operational, however the night watchman was first alerted to the fire by noises caused by the fire burning and not by an alarm activation.[54] Thus the fire had likely been burning for some time before the alarm was raised, this delay meaning that the fire was already well-developed before firefighting commenced and was rapidly out of control.[55] The serious consequences of the apparent failure of the system in this case (which was reportedly subject to ongoing faults)[56] suggest that such systems, as far as possible, need to be failsafe.

Arson

Given the relatively high incidence of fires whose cause is 'deliberate', careful assessment of arson risk is necessary for all building owners or managers. Arson, defined as the criminal act of deliberately setting fire to a building, is potentially the most serious form of malicious attack on historic buildings, and can perhaps be subdivided into three categories. First, there are the often 'easy targets' offered by buildings that are permanently unoccupied, some of which may be in poor condition,[57] these being disproportionately at risk of arson.[58] Less comprehensive security, or perhaps even a complete lack of security, often increases the attraction of this kind of building to would-be arsonists. Second, there are buildings that offer public access, potentially increasing the risk of arson, but in mitigation of which there may be the possibility to monitor public circulation. Third, there are occupied private buildings that can present a target where security is lax or when the owners are absent. Additionally, it should be remembered that deliberate fire setting may not always be for purely malicious reasons, but also potentially for financial gainfor example, related to a potential insurance claim or where there is the desire to develop a site and the presence of a heritage building is preventing this from happening or reducing potential profits.

Fires resulting from arson can be particularly dangerous compared to a 'normal' fire for several reasons: there may be multiple points of ignition; flammable liquids or accelerants maybe used; fires may be lit deliberately at vulnerable points and fire protection measures may be deliberately interfered with.[59]

It should be remembered that gaining access is not necessarily required for arson, since fires set 'against' the building, or even up to 50 m away in some cases, even though initially small fires may have the desired effect.[60]

In all cases the provision of adequate security, both to prevent unauthorised entry and to monitor persons within and without the building is thought to be the key in arson prevention. However, measures to improve security via remote monitoring, including the installation of CCTV cameras, may be at odds with the need to retain historic character and would require a cautious approach, likely requiring consultation with the local planning authority and potentially the relevant national authority (or body) charged with the protection of the historic environment. Even if such installations were to be favourably considered as being 'temporary' and 'reversible' in heritage terms and thus acceptable, they may still represent a considerable visual detraction from the character of the building. Alternative solutionsfor instance, the use of motion detectors, are potentially smaller and less obvious and may prove to be less visually intrusive.

Lightning Protection

Lightning strike has been the cause of numerous fires, particularly to tall structures such as churches[61] and is thought, for example, to have been the cause of the seriously damaging fire at York Minster in England in 1984.[62] Damage to structures (physical damage due to the mechanical, thermal, chemical or explosive effects of lightning) and to electrical systems may also result from strikes. For electrical systems, in addition to direct strike, damage may also be caused by indirect strikes, transmitted, for example, by buried power lines or aerial telecommunications lines.

Lightning protection was sometimes installed during construction, but where this is not the case it may be necessary to instal a wholly new system, and this will likely require heritage consent due to the often notable visual impact of such systems and the potential impact on historic character. Chatsworth House, (a Grade I country house in Derbyshire, England) installed a new lightning conductor system to give full coverage of the house in 2011. There had been no lightning conductor installation prior to this, but there was evidence on the roof structures of lightning strikes and consequential damage,[63] and thus good justification for the installation, for which listed building consent was required.[64]

As a basis for consideration of retrofitting lightning protection, or potentially for upgrading an existing system, there is a risk assessment methodology that evaluates the need for protection, and potential loss of irreplaceable cultural heritage is taken into account within the assessment framework.[65] It is worth bearing in mind that isolated structures (for example, country houses) and structures on a hilltop (for example, castles) represent an increased risk.

Where protection is already installed, it should be regularly inspected for functionality; age and lack of maintenance may have rendered it inoperative, or it may prove to be inadequate. Where there has been a lightning strike, components may need replacing, since some components in a system are consumable. Such inspections are normally carried out an 11-month cycle (thus over a 10-year period inspections are carried out in every season, mitigating the impact of seasonal influence on readings).

In addition to the equipment required to conduct lightning safely to the ground, surge protection may also be required to protect electrical systems in a building, both from physical damage and as a cause of fire. Any scaffolding erected during construction work should also be carefully earthed.

Historic England has published detailed guidance about lightning protection for historic buildings, which has general applicability.[66]

'Special Events'

Special events or other temporary occurrences of any kind, either organised by the property internally or by an external provider, provide a significant, sometimes essential, revenue stream for many historic buildings. However, besides the normal 'day-to-day' fire risks that might be addressed to prevent fires, there are for some buildings particular increased risks associated with these events.

A good example of this is the frequent use of historic country houses for filming (television or film). In this case, risks can be controlled through the production and signing-off of agreed guidelines for filming, but strict managerial oversight is required on site to make sure that these are adhered to. Without the latter, guidelines may be ignored: in one example a fire warden in a Grade I property discovered film technicians having a cigarette inside the building in a space that was particularly historically important and susceptible to ignition; completely in breach of the agreed guidelines, which permitted smoking only outside the building in a designated area.

Hosting weddings is another popular offering, the ambience and backdrop of a historic building being popular with wedding planners and their clients. However temporary risks are thus introduced, ranging from those associated the activities of outside caterers to the reduced inhibitions frequently found amongst inebriated guests, resulting, for example, in entry into unpermitted spaces and smoking within the building.

Comprehensive oversight is critical in managing any additional risk and many events will also require careful and detailed planning: this is perhaps easier to achieve when dealing with a wholly internally organised and staffed event, but becomes both more complex and of real importance when dealing with external interests or providers. In addition to addressing direct fire risks, there is the additional requirement for security related to there being relatively unknown persons with potential access to parts of the building not normally accessible. Even once parameters have been agreed and ideally signed-off by all stakeholders, there is the need for vigilance during the event itself and some form of dynamic risk assessment may be called for to account for unexpected situations.[67]

Additional Concerns

Related to some of the points discussed above, but not easily fitted into any discrete category, are a number of other concerns, grouped together here for convenience.

Firstly, in order to prevent **wildfires**, which in some cases may be deliberately set fires, from impacting on a building, it is suggested that vegetation in close proximity to the building is regularly maintained and kept to the minimum acceptable (it is acknowledged that in some cases there may be limitations when such vegetation form a component of the historic character or setting of a building).[68] For example, simply keeping the grass cut short around a building may prevent spread of a grass fire in a dry summer. Overall, owners and building managers should be vigilant and aware of any and all small fires occurring nearby that might have the potential to spread due to wind direction or other climatic conditions.[69]

Another concern is the use of **smoking materials**, this representing a small but persistent proportion of causes of fire. In most buildings other than private dwellings the risk from smoking materials has been reduced because smoking is now not allowed inside; however, there does remain a risk from illicit smoking (as alluded to above). To reduce risk from persons smoking outside the building, it is suggested that clear smoking stations are set up, with smoking not permitted elsewhere. These should be carefully designed with safety ashtrays and not be in close proximity to the building (to prevent potential accidental fire spread and also to minimise visual impact).

The use of **candles** (and occasionally ignited torches) is also problematic, though these are popular in creating atmosphere in certain types of historic building. They should only be used if they can be situated properly and surrounded by incombustible material, and they should be kept under surveillance. They should not be able to tip over or be placed such that anything could fall into hot wax (or a similar fuel), causing splashing and potential ignition of nearby combustible material.[70]

There should be careful positioning of internal **glass and mirrors** in relation to sunlight within a building. A case was noted of a fire in a very important historic building caused by sunlight reflected from a magnifying mirror (two-sided mirror) in a gift shop.[71]

Fires within **roof spaces**, or fires breaking through into roof spaces, are not uncommon. These spaces may often be either overlooked because of difficulty of access or used for storage. In both cases there is the potential for accumulation of combustible materials, contributing to fire loading. In the former case, there may be the accumulation of material from birds' nests, rodents' nests and similar.[72] In the latter, the total amount of storage in an often potentially small space may represent a significant fire load. Awareness of the risk posed, coupled with determination to access problematic spaces and appraise alternative places for storage (preferably remote from the building), respectively, are necessary considerations.

It is thought that the most likely causes of the fire at Windsor Castle in 1992[73] was the heat generated by **spotlights** acting directly on curtains, which may have been actually touching the spotlights.[74] This is of interest because it is thought that this was as a result of lack of familiarity with the building and it's systems on the part of picture restorers working in the area where the fire started, and this illustrates the importance of careful oversight of external contractors (even if not related to construction work), and the need to have a process of ongoing and responsive risk assessment. Additionally, the heat generated by spotlight bulbs (often of high wattage) requires careful positioning of spotlights and any adjacent combustibles. There have been instances, concerning very high-grade heritage, and subsequent to the Windsor Castle fire, where incorrect positioning meant that there was a possibility of fire (discovered during an inspection; the managers in question were then alerted to this danger),[75] suggesting that perhaps the lessons learnt from past fires are not always universally understood.

The Key to Prevention: Fire Risk Assessment

For all the concerns discussed above, and before any decisions can be made about possible solutions, a detailed audit of the building and its users will need to be carried out with the use of a fire risk assessment. This is required to be much wider in scope than a standard fire risk assessment which normally has a focus on life safety (including, for example, the widely used PAS79 methodology[76]), and needs to specifically include property protection; this may necessitate adaptation of a standard format risk assessment to suit the needs of a historic building.[77] In addition, a security survey is required, this being a distinct tool which assesses exactly what security measures are in place and any deficiencies that may exist.[78]

A high level of attention to detail is required in such a fire risk assessment, so that all potential risks are clearly identified. It should be stressed that all risk assessments and surveys need to be reviewed whenever there is a change in circumstances, and specific risk assessments are required for all special events.

In addition to being good practice, undertaking a fire risk assessment and acting on the findings of this may form part of insurance requirements for the building, be required by legislation,[79] or both.

A further concern has become apparent for situations where public spaces are well-protected and managed within a building, but at the same time there are immediately adjacent private spaces that are not well controlled but could impact on the whole building. A good example is where a property has public access, with a defined visitor route, with this 'public side' being well-controlled, but at the same time private visitors coming as guests of the owner and often with much less oversight in terms of fire prevention (perhaps, for example, being permitted to smoke in bedrooms or bringing in untested electrical appliances). Careful risk assessment should therefore be applied to all the constituent areas of a building, whatever their functions and occupants.

The Management Input

Fire prevention as a strategy relies on there being in place a robust fire safety management system. This is because a policy of constant fire-risk aware vigilance needs to be operated in order to avoid a building in use accumulating riskfor example, via lax 'housekeeping' (storage of empty cardboard boxes in the storeroom of a gift shop in a country house perhaps, or unprotected storage of firewood inside a building). Indeed, it has been suggested that simple and low-cost actions should be used first in addressing fire prevention, with good housekeeping identified in particular in this context.[80]

This needs, however, to be part of a wider management approach that would also ensure regular checks and servicing of fixed and portable equipment, such as electrical distribution networks, electrical appliances, and so on. (Of course all fire safety equipment should also be similarly checked and serviced.) Additionally, a management regime needs to be responsive when there are changes in circumstances that may have an impact on the risk and have implications for fire prevention. Thus, there is a need for continuing awareness and oversight of the whole spectrum of activities within a building.

It is clear that despite all the best fire prevention efforts, incidents will still occur. Where these are near misses or small-scale in nature, an essential subsequent action is to look at the incident and assess what has happened and whether there is anything that could be done in the way of a change to prevent it happening again, and this might require an adaptive response in processes or procedures.[81]

In addition to this, the training and education of all staff in basic fire awareness is very important. This awareness needs to be maintained, perhaps by a regular cycle of refresher events and reminder emails. An example of the type of concerns to be addressed by this is the introduction by staff of untested electrical equipment (such as coffee makers or Christmas lights) into buildings, which should not be permitted.[82]

Where particular risks have been identified in a fire risk assessment, and these risks cannot be completed eliminated because of the nature of activity within a building, specific procedures must be developed to mitigate these risks. It is also of great importance that these procedures are managed and enforced when necessary. The first fire at the Mackintosh Building in 2014 was caused by flammable gases coming into contact with hot components in a projector, while a student was working on an art project. It had been identified that this was a risk and the student who was involved had not followed instructions and was doing something that they had been told several times not to do.[83]

There may be cases where a procedural solution is not suitable or sufficient and there may be the requirement for a technological solution to achieve effective fire prevention or more accurately, accepting that is not always possible to prevent every outbreak of fire, to quickly deal with any such outbreaks using fire protection measures.[84] Examples range from the localised, including the previously mentioned use of extinguisher hoods above cookers in kitchens, to broader measures, which could incorporate building-wide fire suppression systems.[85]

Conclusion

Achieving a reduction in fire incidence via prevention aims fundamentally to break the link between ignition source and fuel (combustible materials) which contributes to fire load, principally by removing the former when possible and reducing the latter where movable. It relies above all on a comprehensive fire safety management regime that is well-informed,[86] and proactive in its approach. Constant vigilance and awareness of change and temporary risk is also essential. Whilst this is more easily achievable in the context of a large property, or where an organisation is responsible for a group of properties, particularly where there may be commercial activities to fund such management (including, for example, public entrance, special events, etc.), it is potentially harder to achieve in a smaller and perhaps private building, though the basic principles remain the same.

It is acknowledged that although fire prevention is considered here as a discrete topic, the ideal is that it should be incorporated as one of a range of measures, forming together a holistic approach to protecting historic buildings from fire and preventing consequent loss of the finite element that is built heritage. Despite the best efforts that can made towards fire prevention, a complete approach to fire safety management should also include the upgrading of physical fire protection measures within the building whenever practicable (this potentially requiring heritage consent), such that if the worst occurs and a fire does break out, it is detected quickly, the alarm is raised and its growth and spread is minimised, and thus its impact on the building reduced as far as possible. Unfortunate experience has also shown that an emergency response must also be carefully planned for, both that from the building in question and in ensuring that the summoning and deployment of professional help is as effective as possible, as well as careful consideration of impact mitigation post-fire.

The starting point for all the possible actions suggested in this article is a heritage-specific fire risk assessment, which, beyond the possible legislative requirement to consider life safety, should have particular regard to the building and its contents. Even when such risk assessments are not required by fire safety law (for example, in private residences) or stipulated as a condition of insurance, they are an essential tool for looking systematically at all the aspects of risk from fire. It is critical that issues identified in a risk assessment are subsequently acted upon however and that regular review is undertaken, particularly when there is a change in circumstances.

Notes

1. British Standards Institution, *BS 4422:2005, Fire – Prevention*, 33.
2. Cultural significance is defined as 'aesthetic, historic, scientific, social or spiritual value for past, present or future generations' (Australia ICOMOS, 2013, 2); the main built environment physical manifestation of which is often referred to as 'historic character'.
3. Historic Scotland, *Managing Change in the Historic Environment*, 9.
4. Landis, *Is it possible to*.
5. Mills, *The scale of fire loss*, 25. (Note: figures based on information from the United Kingdom).
6. Figures collated by Charles Harris, National Fire Advisor Historic England, on behalf of Historic England (Note: figures for England only).
7. Ibid.
8. Ibid.
9. Ibid.
10. Mills, *The scale of fire loss*, 17.
11. Reported in Historic Scotland, *Fire Protection and the*.
12. 'Villages with Fortified Churches in Transylvania' are inscribed by Unesco on the World Heritage List; see http://whc.unesco.org/en/list/596.
13. The most significant of these are also inscribed by Unesco on the World Heritage List; see https://whc.unesco.org/en/statesparties/jp.
14. See Kincaid, *The Upgrading of Fire Safety*, 8.
15. As detailed by British Standards Institution, *BS 9999:2017 (Fire Prevention, 41.2 Housekeeping*), 228.
16. Crowdy, pers. comm.
17. Important historic buildings are listed in England to give them statutory protection: Grade I is the highest category, for buildings of 'exceptional interest' (2.5% of listed buildings are Grade I); Grade II* buildings are 'particularly important buildings of more than special interest' (5.8% of listed buildings are Grade II*) (Historic England, *Listed Buildings*). A similar system is used in Wales; the equivalent in Scotland and Northern Ireland are Category A and B listings. The nationally most important building throughout the UK may have the additional protection afforded by being recognised as 'scheduled monuments'.
18. See: The Institution of Fire Engineers, *Guide to the Fire Resistance*.
19. Home Office, *Detailed analysis of fires*.
20. Coull, *Fire Risk Management in Heritage*, 20.
21. For an example of replacement, see https://www.royal.uk/rewiring-buckingham-palace-0?page=11.
22. Clandon Park is a Grade I listed country house in England, completed in 1731. The fire gutted 95% of the interior of the building; the roof and internal floors were lost and post-fire little more than the structural
    shell of the building remained.
23. Strudwick, Report of Fire.
24. CFPA-E, *CFPA-E Guideline No 30*, 10.
25. London Fire Brigade, *GN80*.
26. See note 16 above.
27. Emery, pers. comm.
28. See note above 26.
29. https://www.hse.gov.uk/electricity/faq-portable-appliance-testing.htm.
30. See note above 26.
31. See note 27 above.
32. Glockling, *Fire in Thatched Properties*.
33. https://historicengland.org.uk/content/docs/advice/fpa-fire-thatched-properties-leaflet-2018pdf/.
34. Hunt, pers. comm.
35. See note above 31.

36. Ibid.
37. See note above 26.
38. Ibid.
39. In the current context, 'construction' includes any works of repair, refurbishment, renovation, conservation or maintenance.
40. The Scottish Parliament, *The Glasgow School of Art*, 24.
41. The exact cause of each of these fires remains unknown, despite painstaking fire investigation.
42. Museums Association, *Investigators believe Cuming Museum fire*.
43. FIRE RISK HERITAGE: Engineering for the Heritage Safety, *Fire in church during renovation.*
44. FIRE RISK HERITAGE: Engineering for the Heritage Safety, *Fire of the Dome.*
45. Scottish Fire and Rescue Service, 2022, 14.
46. Uppark is a Grade I listed country house in England built around 1689. A serious fire occurred in 1989 and caused widespread damage throughout the building, including the loss of the roof. After the fire an authentic restoration was carried out, returning the house as close to the pre-fire situation as was possible.
47. West Sussex Fire Brigade, *Fire Investigation Report*.
48. Rowell and Robinson, *Uppark Restored*, 65.
49. Ibid, 64.
50. Historic England, *Fire Safety: Hot Work*.
51. Crowdy, pers. comm.; Emery, pers. comm.
52. See note above 26.
53. See note above 31.
54. Scottish Fire and Rescue Service, 2022.
55. Ibid.
56. Ibid.
57. In England these buildings are often on the 'Heritage at Risk Register'; overseen by Historic England and with input from local authorities, which aims to protect and manage the historic environment; working with all stakeholders to find solutions for 'at risk' historic places and sites.
58. Kidd, *Security for Historic Buildings*; North West Fire and Rescue Services/Historic England, *Arson Risk Reduction*.
59. North West Fire and Rescue Services/Historic England, *Arson Risk Reduction*, 5.
60. Ibid.
61. Ecclesiastical Insurance/English Heritage, *Lightning Protection for Churches*.
62. The York Press, *Remembering the York Minster fire*.
63. Peter Inskip + Peter Jenkins Architects, *Chatsworth House, Revisions to.*
64. Listed Building Consent is required in England before alterations can be carried out to a listed building; it is issued by the local authority, but consultation with the national heritage body (Historic England) is required for Grade I and II* buildings (see note 14).
65. British Standards Institution, *BS EN 62305–2:2012, Protection against lightning*.
66. Historic England, *Lightning Protection Design and Installation*.
67. See note 34 above.
68. Crowdy, pers. comm.; Hunt, pers. comm.
69. See note above 59.
70. See note above 24.
71. See note above 26.
72. See note above 67.
73. A Grade I listed and current royal palace in England; the fire caused severe damage to the building.
74. Scotford G., *Fire at Windsor Castle*, 10.
75. See note above 67.
76. British Standards Institution, *PAS 79–1:2020* & *PAS 79–2:2020*.
77. See note above 26.

78. Kidd, *Security for Historic Buildings*.
79. Such as under the *Regulatory Reform (Fire Safety) Order, 2005* in England.
80. See note above 24.
81. See note above 26.
82. See note above 51.
83. The Scottish Parliament, *The Glasgow School of Art*, 40.
84. See note above 26.
85. The Schönbrunn Palace near Vienna, for example, is protected with a water mist system. Here the fire risk and probability of fire spread are both high, and even a moderately small fire would do significant damage to heritage fabric. (See Kidd, *Fire Risk Improvement Project)*.
86. Good quality guidance is readily available, and for readers of English, that produced by such organisations as Historic England and Historic Scotland (now re-named as Historic Environment Scotland), as referred to in this article, offer excellent advice.

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