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Published version

KINCAID, Simon (2018). The upgrading of fire safety in historic buildings. Historic Environment: Policy & Practice, 9 (1), 3-20.

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After the fire at Clandon Park in Surrey. Little is left of Giacomo Leoni's great Marble Hall from the 1730s**;** considered to be his masterpiece and described as one of the great rooms of early Georgian England[1].

The upgrading of fire safety in historic buildings

Abstract

There is a seemingly continual erosion of our cultural heritage due to fires in historic buildings. Some of these fires result in partial loss of the asset, some result in total loss – in all cases irreplaceable historic fabric is destroyed. Accurate recording for fires in historic buildings is problematic, but such data as has been collated indicates that the level of loss is high. One of the key factors in achieving robust fire safety in historic buildings is the upgrading of physical fire protection measures. It has been suggested that we should assume a fire event is probable, and together with a context in which outside help might be some time in arriving, such measures are considered crucial in containing the fire and raising the alarm as quickly as possible. This article considers passive and active fire protection measures, using case study material to provide illustrative examples. Where it might be expected that conservation requirements, aiming to avoid negative impact to character and significance, might hinder disruptive physical interventions to improve fire protection, in fact a great deal can be achieved. Such a pragmatic approach is arguably necessary for the safety and preservation of built heritage, when the alternative might otherwise be yet another burnt-out shell.

Key words: historic buildings, heritage management, historic building fires, fire safety, fire protection measures, passive fire protection, active fire protection.

Introduction

Tangible cultural heritage, defined as 'physical artefacts produced, maintained and transmitted intergenerationally in a society', and including artistic creations and built heritage such as buildings and monuments[2], is subject to many risks which impact on its continued existence and relevance. Built heritage is at risk from a number of factors, including neglect, decay, severe weather and flooding[3]. Most of these can be mitigated with suitable care and repair. Fire however is a particularly aggressive agency, which can quickly result in total or near-total loss; accordingly measures to reduce the impact of fire are worthy of particular consideration.

There are two elements of the risk from fire – that to the building itself and that to the contents. Although loss of original historic fabric may impact on the building's significance, the structures of the buildings themselves may have some resilience; but the contents they contain, be they priceless masterpieces hanging on the walls of galleries, or unique cultural artefacts contained within museums, may well have none. Whilst we might be able to re-plaster a wall or replace a roof after a fire, important and valuable paintings such as the giant 1790s portrait of George III by Sir William Beechey, which was at Windsor Castle, or Johann Zoffany's 1760s painting of the Mathew family, which was at Clandon Park (and valued at £4 million[4]), are lost forever following the fires in these buildings. Fire damage, of course, also arises to vulnerable items not just by flame, but also to contamination by smoke, heat and fire-fighting water.

Previous research by the author looked at the idea that effective fire safety management within the context of a historic building might serve as a counterbalance, enabling a reduction in the level of physical measures required to ensure a satisfactory level of fire safety[5]. This reduction was considered to be advantageous, since

disturbance to historic fabric (potentially having an impact on historic character) as a result of fire safety requirements would be best avoided or kept to a minimum where possible. This would avoid potential conflict with the conservation principle of minimum intervention, or the requirement (as stated in the latest iteration of the widely respected Burra Charter) for 'a cautious approach of changing as much as necessary but as little as possible'[6].

This article looks at what might be possible in terms of the upgrading of fire safety measures in historic buildings, including both physical upgrading and associated improvements to management systems. Case study material is used from a number of buildings where such upgrading has been achieved, including Chatsworth as a main case study, and several of the buildings within the remit of Historic Royal Palaces; and lessons learnt from significant fires in heritage buildings are considered. The focus is on high-rated heritage assets – historic buildings of Grade I or Grade II* designation, though most of the principles discussed are generalizable to all historic buildings.

The research methodology employed a combination of literature review; investigation of case studies; and interviews with experts in fire safety in historic buildings and the fire and rescue services. The interviews were semi-structured in nature, to allow any arising themes to be explored in more detail; and were coded for meaning (using thematic coding) to support analysis.

Rationale

It should be clearly stated that the principle aim of fire safety in buildings is life safety. The laws and regulations related to fire safety; the enforcement of these, and the actions of the fire and rescue service all focus on life safety. This is not just for people in the building, but particularly important for historic buildings where fire behaviour may be unpredictable and structural stability unknown, it is for firefighters as well.

This paper doesn't primarily concern itself with life safety and the legislative framework. It is expected that life safety in most high-rated heritage buildings in England and Wales is accounted for by the proactive risk assessment process required by the Regulatory Reform (Fire Safety) Order 2005[7]; supplemented in cases where there is particular public life risk by the active attention of the fire and rescue services. Similar legislation exists in Scotland[8] and Northern Ireland[9]. Where changes are taking place there is additional life safety oversight via the Building Regulations. The focus of this paper then is the protection of the building itself and what it contains.

Furthermore, this article does not address the prevention of fire. Avoiding the outbreak of fire in the first place is clearly fundamental, but it has been suggested that emphasis should be on assuming that fire is probable and efforts should be directed towards minimising the consequences and limiting fire spread[10].

Indeed, there is a continued and regular incidence of destructive fires in historic buildings. Significant and well-documented fires include York Minster (1984); Hampton Court Palace (1986), Uppark House in West Sussex (1989) and Windsor Castle (1992). More recent examples include Glasgow School of Art (2014) and Clandon Park in Surrey (2015). In 2017 there has been almost total destruction recorded at Kelsale Hall in Suffolk and Parnham House in Dorset. In conservation terms loss of historic fabric and artefacts, and sometimes the whole building, is a disaster, and the loss of original, authentic fabric in a fire is irretrievable[11]; what might be produced in its place is often largely reconstruction or replication.

Quantification of the level of loss is problematic, mostly due to the lack of heritage-specific data collection for fire incidents. Previous data put together during Cost Action C17: Built Heritage Fire Loss to Historic Buildings[12]; the National Trust[13] and from the (now defunct) Scottish Historic Buildings National Fire Database[14]; as

well as more recent figures for Cambridgeshire, Hampshire and Suffolk[15], suggests that the level of loss is significant. The latter research also identified the incidence of fire in listed buildings as being approximately three times greater than the incidence of fire in non-listed buildings[16]. The scale of loss is deemed to be unacceptable and it has been intimated that the number, authenticity and quality of European historic buildings is being steadily eroded through the effects of fire[17].

The main case study considered here is pertinent because a good deal has been achieved in terms of physical fire safety upgrading in a high-grade historic building; this having produced a number of challenges which required changes to be made both in what was proposed, and in organisational structure relating to the works and to fire safety in general.

Introduction to main case study

Background

Chatsworth, located near Bakewell in Derbyshire, is a substantial Grade I listed country house; Grade I listed buildings being of 'exceptional interest'[18] and making up only 2.5% of the total of 375,875 buildings on the National Heritage List for England[19]. There are two sections to the main building at Chatsworth - these being the main part of the house, constructed in various phases between 1687 and 1707 in a quadrangle format; and the north wing, constructed 1820-42[20]. Extensive alterations were made to the main house in parallel to the construction of the north wing. Chatsworth is of international fame and attracts a large number of visitors: in excess of 600,000 for 2016[21]. The building also contains important and extensive collections of furniture, artwork and objects[22].

Chatsworth is the seat of the Cavendish family, but is operated by the Chatsworth House Trust. The House Trust was set up in 1981 and endowed by the

Devonshire family. A registered charity, its principle purpose is the long-term preservation of the house, its art collection, garden, woodlands and park for the benefit of the public[23]. The Cavendish family rents accommodation in the house from the Trust and is also closely involved in the management of the house and estate.

A £32.7 million programme of restoration (the Masterplan, phases 1 to 4) has been ongoing since the initial planning stages in 2005, and is due to be completed at the end of 2017[24]. It is in the context of this project that the physical upgrading of fire safety needs to be considered - the fire safety upgrades were carried out in the course of a much larger refurbishment project, which allowed perhaps far more to be achieved than might be the case where only fire safety upgrades were to be considered in isolation.

The Design and Access Statement submitted with the original application for listed building consent established the rationale for the project primarily as the replacement of service infrastructure (the last major refurbishment having been nearly 50 years previously) and the introduction of fire compartmentation; works to alter domestic accommodation and improve the public route through the building being carried out concurrently in this context[25].

An ancillary consideration here is the evolution of the building. In the case of Chatsworth, historic documents show that there have been continual changes to the building, and in particular to its interior layout and detail. This means that not only is there sometimes the evidence to support desired changes (perhaps by establishing historic antedecents or returning to a previous arrangement), but there is also a precedent for actually making changes. At Chatsworth for example, a number of rooms sub-divided what was shown by historic plans to have originally been a corridor, following alterations by Wyatville (the architect responsible for building work and

alterations at Chatsworth in the early 19th century). This was used when seeking consent as the rationale to remove the rooms and reinstate the corridor, and the opened-up space has become a key link in the revised visitor route. The fact that the building might continue to evolve is supported by the planning system which considers conservation to be a process of managing change[26], rather than prohibiting it, and that in fact 'keeping a significant place in use is likely to require continual adaptation and change'[27].

A more general consideration in terms of upgrading is related to the type of historic building under consideration. Chatsworth, as has been mentioned above, has continually evolved, and the building interiors which we see today are both complex and ornate. In some ways, this means that any alterations countenanced to improve fire safety are much less likely to be apparent than would be the case in an older and unaltered building with a similar listing. Examples that springs to mind are Haddon Hall and Hardwick Hall in Derbyshire, both also Grade I, which are much 'plainer' in décor and simpler in arrangement and where changes would perhaps be more readily obvious.

Impetus and approval

The impetus for fire safety upgrading at Chatsworth was the appointment of a specialist conservation architect to oversee the Masterplan. Fire safety matters are one of the key initial consultations of the architect's team. In this case, a well-respected expert in historic building fire safety was consulted, and produced an initial report and proposals concerning compartmentation; and subsequently an exhaustive fire safety audit, which covered in detail all aspects of fire safety, including management. These documents were used as the basis for the fire safety component of the planning applications related to the Masterplan.

The importance of the conservation architect cannot be understated: in understanding the central importance of fire safety; in appointing a suitably specialist and experienced fire safety consultant and, perhaps most importantly of all, in having the specific experience of gaining planning consent for Grade I properties. This latter point means that what is submitted is based on what is likely to be acceptable and the process of gaining consent is likely shorter and faster as a result; at Chatsworth the conservation architect was proactive in consulting with the local authority before the applications were submitted to discuss the proposals, and the actual applications were supported by a clear assessment of the impact on historic fabric and well-reasoned justifications[28].

Upgrading of passive fire protection

The conservation balance

As with all works within historic buildings, the introduction of, or improvement to, fire safety measures is problematic. Changes that are made to the building fabric must be balanced against the needs of conservation; these being chiefly to retain historic character and avoid the loss of historic fabric. The significance of various elements of the fabric requires careful assessment, with earlier or rarer elements less likely to be able to be changed than more recent additions. One Design and Access Statement for Chatsworth, for example, refers to a dressing room which represents a significant survival from the period of the 5th Duke (1748-1811) and his wife Georgiana, where most of the architectural detail from that period has been obliterated[29] and thus retention was very important. In contrast, partition walls that were built in the 1950s, whilst part of the story of the development of the building, do not have the same level of significance.

Information

The first point to be considered is having sufficient information on which to assess whether upgrades are necessary and what needs doing. For a building where little or no recent fire safety upgrading work has been carried out, historic documents, records and plans should be consulted. These might be comprehensive and detailed (as in the case of Chatsworth, where there is an extensive archive) or very limited (as is the case for Clandon Park, where there is little in the way of a historic record about the building[30]). Any existing fire risk assessments; fire consultant reports; communication from the fire and rescue service and so on, should also be consulted. It should be noted that fire risk assessments for historic buildings, in addition to considering the risks to life safety, should also identify risks to historic fabric and contents; and that the degree of any intervention should be appropriate to the level of risk[31].

It is essential to have a full understanding of the existing structure[32], and a measured and fully-detailed building survey is likely to be required for all but the simplest of buildings, since even detailed historical documentation may not be complete, and 'as built' may not match what is shown on any available plans. It should be remembered that buildings such as Hampton Court Palace and Chatsworth have complicated layouts, in combination with extensive alterations that have been carried out over a long period of time, so a complete survey is likely to be a complex undertaking.

Compartmentation

Upgrading of passive fire protection measures is one of the most important factors in preventing the loss of heritage. If we accept that fires will inevitably continue to occur, then preventing or limiting the spread of fire is a key way of reducing the resultant

damage and it may of course also be a factor in achieving the required level of life safety. The main concern is preventing the spread of fire between the area of origin (the seat of the fire) and other areas in the building, and central to this is consideration of compartmentation.

By nature of their construction some old buildings have reasonable inbuilt levels of compartmentation as a result of thick solid walls and heavy doors; and in some cases this has been deliberately included in the construction. It may also be as the result of the building having originally been a defensive structure, so for example the Tower of London has a natural level of compartmentation for this reason[33]. However, this may have been subsequently compromised where modern services have been introduced into the building (for example plumbing pipework, electric cabling and IT cabling) and attention must be paid to sealing the resultant holes against fire. The initial compartmentation proposals for Chatsworth for example, noted that in the roof space, although considerable work had been carried out previously to sub-divide the space, nine areas were identified where holes up to 300mm by 300mm were present as a result of the installation of services[34]. Service penetrations in the compartment walls have been cited as a contributory factor in the very rapid fire spread in the fire at Clandon Park[35]. Sealing against fire can be achieved with suitable intumescent products; which might include the use of intumescent sealants, collars, pillows and blocks.

The starting point then is to assess where construction form provides some level of existing compartmentation within a building, with a view to using this as the basis for providing a sufficient final compartmentation; this method being much simpler than introducing compartmentation where there are no existing divisions.

In some cases it may not be possible to introduce physical walls or doors to establish a complete compartment line, and a more innovative solution is required.

Good examples of this are provided by Chatsworth. A major compartment line was required between the original part of the house and the North Wing. However, it was not possible to introduce a new doorset[36] here because there was no existing line of division. The solution that was arrived at, after discussions between the House Trust, the architects, the local authority and Historic England, was the installation of fire curtains at this location. A similar solution was adopted on the ground floor of the main house, where it was necessary to sub-divide a corridor. Here the introduction of a new doorset, which was originally proposed, would have meant disturbing a very fine marble floor as well as causing a visual interruption to the view along it, and a half-hour rated fire curtain was used instead to provide compartmentation. These fire curtains are what might be termed 'combined solutions'; they represent passive protection once the curtains are closed at night, but are necessarily part of a managed space, because human intervention is required to actually close the curtains. It is arguable whether this latter action, taken in the event of fire, might mean in this circumstance that the fire curtains could perhaps be considered as an 'active' fire protection measure (this would certainly apply in a case where automatic deployment of a fire curtain was linked to the fire alarm system). Fire curtains have also been used as part of compartmentation measures within the White Tower at the Tower of London[37].

A highly innovative response to a compartmentation problem has been used in Windsor Castle, and this can certainly be categorised as an 'active' fire protection measure. Here there was a large breach in a compartment line on a grand staircase and there was no obvious way to mitigate this. The solution was to use water mist fire suppression to create what is effectively a curtain in a fire situation. This was a bespoke application and the water mist system was designed and tested by BRE[38].

In some cases, compartmentation may be required in floors, perhaps where there are suitable walls, but the walls don't line up from storey to storey and a 'staggered' arrangement is necessary. Such a problem was encountered at Chatsworth and a floor upgraded as a fire barrier. It may also be used where there is a high risk of fire from a particular activity in combination with an important room above. In such cases, it is often much easier to intervene via the floor, rather than disturb the ceiling below.

Compartmentation within roof spaces is of paramount importance, since any fire reaching the roof space has the potential to spread horizontally with devastating effect[39]. Compartmentation therefore should extend from the lowest to the highest level in the building; this most likely meaning from the basement to the underside of the roof covering. The structure of the roof also needs to be taken into consideration, since any elements of the structure lying across the top of compartment walls could carry the fire into an adjacent compartment. At Clandon Park, fire was able to spread across the top of the compartment walls via the roof structure, from where it spread down into neighbouring compartments. In this case there was the added problem of a high fire load due to storage in the roof space and the fact that a new roof structure had been laid over the old one, without the removal of the former[40].

Traditional roof covering in many larger properties is of lead sheet of considerable thickness and in fires this has led to heat build-up internally, contributing to the intensity of the fire. During the fire at Hampton Court Palace the roof was deliberately vented (with considerable difficulty) which greatly eased conditions in the building[41]. In subsequent re-building works to the roof, heat-activated drop-down smoke vent panels were installed to address this problem[42]. Conventional firefighting operations, which might involve breaking into a roof (by removing tiles or slates), to get

water onto the fire from above, are also rendered difficult by lead sheet. This was the case at Clandon Park; though access to the roof was problematic in this case as well[43].

In some cases where there is a specific risk within a building, such as that which might be associated with a plant room, kitchen or server room, consideration could be given to enclosing that room with fire protection – in effect creating a small compartment to contain any fire at source. However, fire suppression is potentially a simpler solution.

Voids

A further significant factor is the presence of voids in many old buildings. Fire spread within voids, which may be occurring unknown and is very difficult to fire-fight, has been reported as being a significant factor in a number of key fires, including Hampton Court Palace in 1986[44]; Windsor Castle in 1992[45]; Glasgow School of Art in 2014[46] and Clandon Park in 2015[47].

Voids may be vertical in nature and may be the result of phases of construction or alterations, or may relate to old flues, ducts or shafts[48]. Initial fire spread at Clandon Park was via a lift shaft; the fire getting into this because of a lack of fire stopping above the electrical distribution board cupboard where the fire started, and able to spread to each floor of the building by this route[49]. Voids may also be horizontal in nature and at Windsor Castle, fire spread was reportedly assisted by the presence of a 'large, uninterrupted, high level ceiling void running the entire length (65 metres) of the St. George's Hall'[50]. Voids between floors are common; at Chatsworth, some of these are reported to be storey-height in size[51].

Attention must therefore be paid to identifying any voids, which may require the undertaking of detailed building surveys (as above). Any voids must be effectively fire

stopped, normally with a form of cavity barrier, to prevent fire entry into and subsequent spread within these spaces.

Existing openings

In the context of compartmentation, particular attention must be paid to openings on a compartment line; openings may well represent the weakest link in compartmentation. Historic openings in walls are commonly much larger than the current doorsets would suggest, and may render the improvement of fire performance of a door and door frame irrelevant. Compartmentation improvement works at Chatsworth revealed void spaces, above, to the side of and below openings[52]; these spaces often being sizeable (anecdotally, there are stories of horses being ridden through the house historically, which gives some idea of previous height). Examination of the post-fire scene at Clandon Park, where the structural frame is now evident, reveals that the openings within the building have arches at the top. However, pre-fire photographs[53] show that these arches were previously hidden behind door pediments, and that the openings were in fact taller than they appeared to be. It is not known whether this directly contributed to fire spread, but the point is that the size of the actual opening was larger than that suggested by the doorset within the aperture. Any such spaces that are found should be suitably fire-stopped so as to preserve the integrity of the compartment.

Additionally, upgrading of the doorsets themselves may be required and can have a positive impact in preventing or delaying fire spread. The level of upgrading required can be determined using the matrix developed by English Heritage[54]; intended as an assessment tool so that historic doors can be individually assessed for their effectiveness in resisting the passage of fire and smoke. There is a wide range of upgrading options. In some cases it may be acceptable to remove the original door (and

store it in a suitable environment), substituting it with a door having fire-resisting properties, manufactured to look the same as the original. This has the advantage of complete reversibility. Alternatively, the door may be treated with intumescent finishes or upgraded with the addition of fire-resisting panels. Additionally, doors might be fitted with cold smoke and intumescent seals and fitted with self-closing devices. At Chatsworth, all relevant doors were upgraded to give half hour fire resistance.

In the context of gaining approval, it is interesting in the case of Chatsworth that new fire doors have in some locations been introduced into previously blank openings, in order to subdivide corridors and complete compartment lines. The corridor spaces have undeniably changed, but the new doors were designed to match Wyatville's existing doors, and are unnoticeable as a result. Although new features have been introduced, the final result is not significantly to the detriment of historic character, and in any case, the argument for the changes is compellingly strong, since the end result is much improved fire compartmentation. The alternative of not permitting any change to occur would be to risk fire spread and the potential loss of everything in the event of a fire.

Wall voids

Small voids may be present within rooms behind panelling on the walls. This was mentioned as a major contributory factor to fire spread in the report on the Windsor castle fire[55]. At Hampton Court Palace, panelling was removed following the fire and numerous unknown voids and vents were revealed[56]. Similar voids may exist behind lath and plaster wall finishes, where a stud frame has been used to support the laths. Fire-stopping such voids may require the careful removal and subsequent reinstallation of panelling; this may not be possible in the case of lath and plaster finishes, and it may only be possible to fire stop where access can be gained via a floor.

Upgrading of active fire protection

Detection and alarm

The extent and quality of the fire detection and alarm system installed in a historic building is fundamental in providing the earliest possible warning of a fire. Even where fire strategies rely heavily on having managed spaces (for example having a room steward in every room), there should be an automatic system of modern design and capability, otherwise warning is compromised when the building is closed. Ideally, the system should automatically inform a control room manned 24 hours a day: this might be either on the premises or remote (third party monitoring at an alarm receiving centre when there is no one on site); allowing the fire and rescue service to be immediately alerted. A hub-based signalling system, such as Nimbus or Smartwatch, has advantages over a telephone system in that subsequent activations of the fire alarm system are monitored. Where fire and rescue services do not respond to automatic alarms, a second detector activating will be enough to confirm a fire and get a response. The telephone system does not allow this; further signals do not get transmitted and the fire and rescue service will not respond until someone gets to the site and dials 999[57]. The timing of actual alarm signals within the building should follow an appropriate strategy for the particular building; this might involve confirmation procedures before full alarm, and may be backed-up with voice alerts.

Though the exact choice of system should be apposite to the risk in a particular building, for a complex building an 'L1/P1' system[58], which will give the earliest possible warning of fire throughout the building, is likely to be required. The choice of

system may also be specified to satisfy the requirements of insurers. The system should ideally be an addressable system, where each detector has its own unique address and this enables the exact location of a fire to be pinpointed quickly. Wireless technology could be used to avoid unsightly wires. Tests carried out in Italy attested to both the suitability and reliability of wireless systems for use in heritage buildings and highlighted that such systems were simpler, less invasive and less disruptive to install, with a reduced cost of installation and the possibility of easily modifying the layout to suit different operational requirements[59]. The exact positioning of detector heads may be problematic in some cases, though at Chatsworth the successful activation of heads in other than the optimum positions was proved using tests with a smoke generating machine.

There is obviously an issue with false activation, but modern detectors, particularly multi-sensor detectors, used in appropriate applications are much less prone to this, with the technology able to differentiate between actual and false alarms even if the physical phenomena are similar. This can be augmented by a ‘double knock’ system (where the system is capable of identifying when two sensors activate simultaneously within the same zone/area).

Besides the standard types of single-point heat and smoke detectors, or an alternative multi-sensor device, beam detectors and aspirating smoke detectors also have useful applications in heritage buildings, particularly where painted or ornately plastered ceilings would visually prohibit the use of normal detector heads. A beam detector might allow the equipment to be at the top of a wall, instead of on the ceiling, and aspirating detection is almost invisible in use. At Hampton Court Palace, where smoke detection was required in an area for which conventional detection wasn’t visually acceptable, an aspirating tube was placed in the eye of a peacock painted on the

ceiling and is thus virtually invisible[60]. A similar solution has been used at Chatsworth, again where there is a fine painted ceiling. Equipment is required above ceiling level for aspirating detection, however, and there needs to be space for this, as well as access to it for maintenance.

Fire suppression

Fire suppression is a highly-effective way of either completely extinguishing a fire, or at least of controlling it and preventing fire spread, and may be particularly important where compartmentation is difficult to achieve. Where valuable artefacts might be damaged by water from a conventional sprinkler system, the application of a water mist system or gas suppression system might be appropriate. The introduction of any such systems into historic buildings however is problematic. The end result of having a system in place may not be visually obvious: the pipework for water-based systems can be hidden above ceilings or below floors for example; and the water distribution heads themselves can be recessed and concealed with ceiling plates. However, disruption to historic fabric in the installation process is difficult to avoid (in one case where localised fire suppression was proposed at Chatsworth, an alternative had to be adopted for this reason) and installing heads into some finishes, an ornate plaster ceiling for example, may not be acceptable. There is also the relatively high cost of retro-fit installation.

Despite these concerns, there are numerous cases of high-grade heritage buildings being protected by suppression systems[61], and in particular water mist systems. The Schönbrunn Palace near Vienna, for example, is protected with a water mist system. This is an important, large, complex and multi-tenanted building, where the fire risk and probability of fire spread are both high; and where even a moderately small fire would do significant damage to heritage fabric[62].

In some cases a water mist system might be the only way to address a specific problem. A good example of this at the Grade I listed Banqueting House in London. The problem here was how to protect the 'Rubens ceiling' (the only surviving in-situ ceiling painting by Rubens, which was installed in 1636[63]). The problem was actually above the ceiling (below the ceiling the fire risk was managed adequately), where large motors which raise and lower the chandeliers are housed in the roof space; such motors potentially posing a fire risk. The question was whether fire crews would enter through a narrow opening to fight a fire in the roof space, which was thought unlikely; as well as what would be the effect of firefighting water on the paintings below. The solution was a water mist system to protect the roof space; the relatively high cost of this being justified because of the lack of alternatives and the importance of the ceiling. This is a pre-action system, with no water being stored above the ceiling[64]. This is an important point, since the escape of stored water from fire systems has the potential to cause a lot of damage.

At Chatsworth there are several suppression systems in place, though these pre-date the masterplan works. These are used in specific areas, to protect certain high-risk activities, for example the paint shop is protected by a sprinkler system. Such localised suppression systems are a good solution to protect areas of high risk and a further example is the use of small systems to mitigate the fire risk from catering facilities in certain of the Historic Royal Palaces.

Where it is not possible to install fixed fire suppression, perhaps because of conservation constraints, the use of stand-alone or portable systems might be considered as an alternative. Such water mist systems recently developed for other applications could be used in this situation.

When planning officers and conservation officers are making decisions involving fire safety improvements in listed buildings, there is a requirement to balance these improvements against the need to protect whatever contributes to the significance of the building. In some cases, where the level of intervention might be deemed to have a negative impact on this, the conclusion might be that the particular use proposed cannot be accommodated, or that a particular room might not be able to be accessible[65].

Management Aspects of upgrading

High-grade heritage buildings are found in a wide variety of locations, from urban centres (for example Glasgow School of Art and the Tower of London) to rural areas (for example Chatsworth and Clandon Park). It would be reasonable to assume that fire service response in the event of fire might be quicker in an urban area because of geographical proximity and the fact that resources are generally better. However it is suggested that irrespective of location, the owners or operators of historic buildings should not rely on a fast response. This is due to well-publicised cuts to the fire services, in combination with the possibility of a major incident elsewhere drawing resources away. For example Chatsworth and Hardwick Hall (also Grade I) are both close to the M1, and a serious crash here could very well occupy enough resources to delay fire service response to a fire in either property. Perhaps the likelihood of the two events occurring simultaneously is low, but the history of building fires is littered with unlikely coincidences. Rural areas also tend to have more stations manned by retained firefighters, and this could also mean that a response to a fire was slower. The requirement then is to be self-sufficient in the early stages of a fire, and this puts into context the need for effective active and passive fire protection measures, as outlined above, and the management measures to ensure these function as intended.

In addition to the actions normally associated with fire safety management, there is a need to monitor upgrading works related to fire safety. It is not adequate to specify work and then to expect that it is done to the required standard; it would obviously be very dangerous to assume that a certain level of compartmentation exists, when in fact it doesn't because of mistakes or poor workmanship. Compartmentation work carried out in the first phase of the Masterplan at Chatsworth was later found to be sub-standard, with the 2011 fire safety audit noting that some of the work done would not provide an effective fire barrier. The work had to subsequently be redone. The audit acknowledged the difficulties of trying to continually observe the work of contractors and recommended the revision of supervision responsibilities[66]. In response to this, the system now in place is to have a senior member of the Trust's staff acting in the capacity of a 'clerk of works', to ensure that work is carried out to the required standard. Thus, within the organisation commissioning the upgrading work, there is a need for organisational flexibility and the ability to make changes where necessary for any subsequent phases. The cost of oversight of works should be factored into the overall project budget. Additionally, it should be recognised that the incidence of potential problems with works carried out will be reduced by employing contractors with direct experience, both in fire protection work and in historic buildings.

There is also a requirement to record accurately and in detail all of the fire safety upgrading work that has been carried out. This is particularly important since a lot of the work will be hidden from view on completion. Details are also required for all detection, alarm and suppression systems, and a schedule needs to be in place for their maintenance and servicing; it would be dangerous to assume that the building is protected by smoke detection, for example, when in reality the system hasn't been correctly maintained and fails to activate. It is suggested that all this documentation is

kept as an electronic record, suitably backed up off site, in particular since linkages between various sections are more easily navigable electronically than on paper; so for example a floor plan might show the location of installed detection equipment, and link to the product details and a service schedule.

If all the physical measures are as good as they can be in a building (accepting the constraints potentially imposed by cost and the availability of funds) the subsequent consideration is the human engagement with fire safety. Staff training is vital in this regard and such training also needs to be a continuous process, since staff change and people simply forget. A good example would be staff training to minimise the possibility of any action that might compromise the compartmentation, such as propping fire doors open. In one Grade II* building in Derbyshire, the doors were found to be propped open by staff at night to increase ventilation in order to control the significant damp in the building[67].

There is a need for overall control of all matters relating to fire safety in a high-grade heritage building, and having the right person in a suitable role is considered important. This is recognised in many organisations, the larger of which have a dedicated person in the role of, or with a substantial portion of a wider role allocated to, fire safety manager (or officer). It is thought that this role is best accomplished 'in house', rather than by employing the services of consultants, because detailed knowledge of sometimes very complicated buildings is required, as well as a working relationship with staff. Chatsworth is well-organised and proactive in this regard, and in addition to the person referred to above, there is a Head of Operations, whose role includes all aspects of fire safety. The cost of employing a person for such a role needs to be balanced against the implications of getting this part of operating the building wrong, since a serious fire, apart from the damage to heritage, could have significant

implications for business continuity. In terms of the asset, this latter aspect is also of high importance, since in many cases the upkeep and ongoing viability of the building relies on having sufficient income.

It is not acceptable to carry out fire safety upgrading works and then simply stop. Fire safety improvement is a continuous, rolling process, and this is recognised in the management strategies of both Chatsworth and Historic Royal Palaces. Technical equipment for example is continuously improved by the manufacturers, and better solutions become available[68].

Conclusion

Notwithstanding the importance of the upgrading of physical fire protection measures as considered in this paper, it should be emphasised that the key to achieving the optimum level of overall fire safety in a historic building is to embrace a holistic approach to fire safety, where all aspects of fire risk are considered. This was identified by Bailey in 1993[69] and continues to be the ideal target, though the continued incidence of fires in heritage buildings suggests that it is not being achieved in all cases.

The adoption of a proactive strategy of what might be referred to as 'total fire safety management' is thus advisable. This necessarily includes several additional key areas: preventing the outbreak of fire; having in place suitably well-developed disaster management plans (including damage limitation) and keeping comprehensive and up-to-date documentation relating to fire safety. Strategic planning is required; and although there are clearly cost implications in the allocation of management resources to fire safety, if there is no building as the result of fire, there is potentially a much bigger cost implication in terms of business continuity.

Many historic buildings, of all types and status, are in a process of change. Depending on the scale of these changes, there is great scope for improving passive and

active fire protection measures. Whilst risk assessments or fire safety audits may identify that certain works are required immediately, it is considered advisable to wait until other refurbishment work is carried out to do any substantial fire safety upgrading work.

The priorities for passive protection are to establish compartmentation including the investigation of all doors and other openings and the installation of fire stopping at all service penetrations. Any voids must be fire-stopped to prevent the ingress of fire. Whether or not large-scale changes are taking place, a detailed, measured survey of the building is required as the basis for understanding any existing compartmentation, or construction elements that might be useful in establishing compartmentation; as well as the location of any voids.

The priorities for active protection are to install an adequate detection and alarm system throughout the building, preferably an ‘L1/P1’ system. It is absolutely crucial that this system should operate when there is a fire and therefore regular inspection and maintenance of the system is fundamental. If the installation is practicable and the heritage is of sufficient value to justify it, installation of a fire suppression system should be considered.

Aspects of the fire safety management strategy related to upgrading work, in particular oversight of work being carried out, as well as systematic maintenance of technical systems, should be reviewed and improved where necessary; and this should be an ongoing process, rather than a once-off exercise. All work carried out should be carefully documented and the records securely stored and backed up.

All of the above measures depend on the availability of sufficient funding, since all are costly to achieve. In this context, high-grade heritage buildings are normally in a relatively good position, with many being run as revenue generating businesses or

charities, and thus able to factor in the costs of carrying out upgrading work, and allocate management resources, as part of overall business planning.

Both Chatsworth and the buildings making up the Historic Royal Palaces are high-grade assets which can be considered as examples of best practice in terms of fire safety. They have been able to achieve considerable improvements in overall fire safety by the upgrading of fire protection, and have had the flexibility to embrace bespoke solutions. They have also adopted a thorough and holistic approach to fire safety, including management aspects.

When considering fire safety in historic buildings, we are really trying to balance the requirements of achieving a sufficient level of life safety and property protection on the one hand, with an acceptable level of impact on historic character and historic fabric on the other. However, given the sad regularity of devastating fires in historic buildings, what exactly is acceptable in conservation terms should perhaps involve a good degree of pragmatism, and there is strong argument that a relatively high level of intervention to improve fire safety should be countenanced since lack of protection could ultimately result in the total loss of the irreplaceable asset.

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