SIEMENS

Fire protection in historical buildings and museums

Detection, alarming, evacuation, extinguishing

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1. Introduction

Historical buildings represent a significant part of our cultural heritage as they shed light on the building techniques, artistry and even the way of life in a particular period during the history of a region or country. In many cases, however, the contents of the buildings may be of considerably more significance than the fabric of the buildings themselves; these include museums, art galleries, libraries and archives.

Such buildings are not only of importance to professional historians, but also to people from all walks of life. In recent years much effort has been put into the conservation and protection of cultural heritage, with many countries highlighting their unique heritage in promotional campaigns run by their tourism industry. It is our duty to take care of our historical buildings and works of art so that our children and our children's children will also be able to appreciate them. There are, of course, many facets to this task, but a high priority must be given to the protection against the loss and damage caused by fire.

As many visitors and staff may be present in historical buildings and museums, life safety must always be our major concern. It is the duty of the building owners and management to provide the best possible fire protection. This not only includes the appropriate infrastructure (fire detection, alarming, evacuation and extinguishing) but also good organization (staff training, fire drills, enforcement of maintenance schedules and fire-safety regulations).

Fire is the single greatest threat to the fabric and contents of any building and, in the case of a historical building, the loss of any authentic fabric in a fire is usually irreversible. It is vital therefore to minimize the likelihood of fire by the elimination of major risks and careful management of those risks that cannot be eliminated.

This is not a new concern. Loss of historically important documents and artifacts has been a recurring theme throughout history; ever since the fires which are reputed to have destroyed the Library of Alexandria (one of the largest and most significant libraries of the ancient world). In fact, this disaster has become something of a symbol for the loss of knowledge and cultural heritage.

Providing optimal fire protection for people and property, however, often stands in conflict with the conservationists' ideals of minimal intervention regarding the structure and aesthetics of the building in question. The challenge is to maintain the historical authenticity of a building while providing an acceptable level of safety for both occupants and contents. Finding the best compromise is the key to providing an effective fire safety concept for each building. This process involves a case-by-case fire risk assessment and a continuous fire safety management process.

1.1. Executive summary

This document provides an overview on the necessity and difficulties of providing adequate fire protection in historical buildings and museums. A comprehensive fire protection system is essential to ensure personal safety and damage mitigation in case of fire. New museums and libraries will automatically be built to comply with the local standards, codes of practice and insurance guidelines. However, the massive use of wood and other traditional materials in the construction of historical buildings, together with obsolete electrical installations and equipment often found in such buildings, present a high fire risk. The challenge is finding an optimum balance between providing maximum fire protection on the one hand, while maintaining the authenticity and character of the building concerned on the other. By using a methodical approach, based on standard fire risk assessment precepts, a consensus decision can be reached, which best fits the expectations of the fire safety engineer and the heritage protection specialist.

Both passive and active fire protection measures are discussed, with the emphasis being mainly on the technical fire protection possibilities best suited to applications in historical buildings and museums.

Fire detection

The main priorities are to minimize any impact on the structure of the buildings during the installation and maintenance of the proposed fire protection infrastructure and preserve the aesthetics of the structure and décor. Appropriate technical solutions which go a long way to fulfilling these conditions include ASD (Aspirating Smoke Detection) systems and wireless smoke detection networks.

The ASD systems ensure the earliest possible fire detection as they are sensitive to very low concentrations of smoke. Equally importantly, they can be made practically invisible to the naked eye, as the air is continuously sampled by drawing air into a smoke detection chamber through a number of very small holes in a concealed piping network.

In environments which tolerate only a minimum of installation wiring, the wireless detection networks offer an excellent solution. Such systems have now reached a high degree of technical development, providing highly reliable mesh network technology with very long battery lifetimes. A combination of wireless detectors and linear smoke detectors can provide an excellent solution for large rooms with high ornate ceilings, which are often present in historically sensitive buildings.

Alarming, smoke control and evacuation

Smoke presents the greatest danger to life in the case of a fire and all possible measures should be taken to prevent it spreading throughout the building. One of the main factors contributing to the rapid spread of smoke and fire throughout historical buildings is the presence of hidden voids. High priority must be given to the stopping of feedthroughs that were created during the installation of electrical cables and ventilation ducting. These installations were often carried out in an era when the consequences for fire development were considerably less well understood.

Compartmentalization is the key to restricting smoke and fire to the immediate vicinity of the area where an incipient fire was initially detected. The subdivision of roof voids (which in many cases extend over an entire building) is an important preventative measure and the automatic closing of doors in the case of a fire is strongly recommended.

Early detection combined with the efficient suppression of embryonic fires means that evacuation procedures are rarely necessary. In the event that a building evacuation does become necessary, however, it must be conducted quickly and efficiently. An appropriate infrastructure (alarming, exit route signage, etc.) is essential and care must be taken to ensure that escape routes are clearly indicated and kept free from blockages at all times. Considerable importance should also be given to staff training, regular fire drills, and the strict enforcement of internal fire safety regulations (e.g. no smoking in any area, careful storage of flammable materials, etc.). The fire safety procedures should also be reviewed on a regular basis.

Extinguishing

As these buildings are open to the public they must be equipped with the standard firefighting equipment designed to suppress incipient fires at the earliest possible stage. An adequate number of hand-held fire extinguishers must be provided and situated in easily visible locations throughout the building. For general purposes the recommended type is the foam extinguisher, which is suitable for the majority of fires that can be expected in such environments, prevents re-ignition and is easy to use.

Water hose reels should also be provided to prevent a fire getting out of control. These are easy to use for untrained persons and have the advantage of a continuous supply of water, in contrast to the hand-held extinguishers which may soon be empty. At such a stage, limiting the spread of the fire becomes more important than the preservation of the objects or local room décor. The damage caused by a raging fire can be devastating.

Modern, purpose built museums and libraries will generally be equipped with an automatic sprinkler system, however, in many cases it would also be possible to install such a system to provide partial cover in historical buildings.

In small historical buildings the presence of an adequate number of strategically placed fire extinguishers may be sufficient; however in larger museums water hose reels and partial coverage with a sprinkler system are strongly recommended.

Large historical buildings and museums may also contain areas requiring special attention and special solutions. Such areas include archives, electrical plant rooms and kitchens and an optimal solution can be provided for each of these applications.

Archives	An ASD system ensures the earliest possible fire detection and can be programmed to activate a gas/water combined extinguishing system. This combination has proved to be an ideal solution for archive applications. The nitrogen gas effectively extinguishes the fire, while the fine water mist cools the stored objects to below the flash point and prevents re-ignition.
Kitchens	Commercial kitchens present a very serious fire hazard, with the added danger that fire may spread through the kitchen's own air extraction system to the rest of the building. The critical areas (e.g. cooking range, deep fat fryers, ovens and air extraction system) should be protected by specially designed extinguishing systems. Wet chemical fire extinguishers (Class F) should also be provided.
Plant rooms	A gas extinguishing system can provide efficient fire protection for electrical and electronic installations in plant rooms. Any fire will be extinguished immediately, no residues will be left behind and fire damage can be restricted to an individual piece of equipment.

In all cases, regular service and maintenance are indispensable to ensure that the extinguishing systems and fire extinguishers are in perfect working order whenever they need to be used in an emergency situation.

1.2. Buildings in focus

Within the scope of this document, we are concerned with the protection of a wide range of buildings. In some cases the buildings themselves are the focus of our attentions, while in other cases it is the contents of the buildings that demand our full attention.

1.2.1. Historical buildings

Figure 1 Historical building

In this case the primary focus is preserving the structure and fabric of the buildings themselves, with the content of the buildings generally being of secondary importance. We are more interested in how the buildings were constructed, how the artisans of the day used the materials available to them and the artistry employed in the decoration of the buildings. This gives us a detailed insight into how society was structured in the different ages, the skill and techniques employed by the artists and the value put on such objects by the ruling society of the age. In this document we are focusing on large houses owned by the nobility and middle classes throughout the ages, which are now frequently opened to the public. However, from a historian's point of view, a simple dwelling that was occupied by farm workers or factory workers may be of equal interest.

1.2.2. Museums and art galleries

Figure 2 Museum

Here it is the content of the buildings which generally needs to be protected at all costs as many objects on show in museums are irreplaceable and consequently a monetary value cannot easily be placed on their loss: they are priceless.

From a fire insurance point of view displaying priceless artifacts to the public demands the highest levels of security and fire protection. In other words we need to be prepared to make more compromises regarding the introduction of both passive and active measures to provide maximum fire protection. The less sensitive the building is to the introduction of physical protective measures, the more effective the protection can be made. Storing and exhibiting priceless objects in a priceless building is an extremely high-risk strategy.

Modern buildings are designed to provide maximum protection and enable all occupants to exit the building quickly and safely. However adapting a historical building is a much more difficult undertaking and a great many museums are still housed in historical buildings. It is estimated that less than 20% of museums are modern, purpose-built structures, where the appropriate fire-protection building codes have been observed. Such buildings will be capable of providing first class protection including:

- Fire compartmentalization
- State-of-the-art fire detection and alarming equipment
- Smoke control
- Multiple exit routes
- Tailored extinguishing systems

Integrating appropriate fire protection measures into existing older buildings will always demand some degree of compromise.

1.2.3. Libraries

Figure 3 Libraries (historical and modern)

The main objective of a library is to provide public access to large collections of books and manuscripts. In the majority of cases, the focus is again on the protection of the objects, rather than the structure of the building. Frequently the buildings will have been purpose-built and attention will have been given to the lighting, humidity and air-conditioning best suited to the preservation of the publications.

1.2.4. Archives and storage vaults

Figure 4 Archives and storage vaults

An archive may be a dedicated building, such as a state archive etc. However, many museums and art galleries will also contain storage vaults, used to store and catalogue innumerable object that are not currently being displayed. There are also a number of independent art storage warehouses, which often store valuable artifacts for famous museums and art galleries. In May, 2004 a fire in such an art depot in London resulted in losses estimated to have been between €30 m and €50 m.

1.3. Fire damage costs

Damage caused by fire is not a new phenomenon. Over the centuries considerable losses have been suffered and this has been continuing until the present day. It is very difficult to find official statistics directly relating to the number of damaging fires in historical buildings for the following reasons:

- The classification of "historical buildings" varies widely between different countries
- Fire reports generally do not state whether the building concerned was of historical interest or not

However, some countries have tried to quantify such fire losses in their jurisdiction. For example:

- Scotland:
  - approx. 10 damaging fires per year
- England:
  - 1 total loss of a Grade I building per year
  - 3 Grade II buildings lost per year
  - At least 12 listed buildings lost per year
- Canada:
  - 30 incidents per year
- Germany:
  - 70 buildings lost since 2000

The following table shows a number of high-profile fires in historical buildings or museums in recent history, together with the approximate costs of the damage (where this can be estimated) and the suspected cause of the fire. It is significant that in many cases "renovation work" has been identified as a major factor in starting some very damaging fires, which could have been prevented if due care and attention had been taken.

Figure 5 Fire damage in Duchess Anna Amalia Library

Date	Building	Country	Estimated damage (€)	Cause
09.2009	Schloss Ebelsbach	Germany	3.5 m	Arson
08.2009	South Dakota Library	USA	11 m	Sparks from concrete saw
04.2008	Castello di Moncalieri	Italy	10 m	Renovation work
04.2008	Québec Armory	Canada	100 m	Renovation work (lamp)
02.2008	Namdaemun Gate	South Korea	20 m	Arson
10.2007	Armando Museum, Amersfoort	NL	5 m	Renovation work (roof)
04.2007	Georgetown Library, Washington DC	USA	20 m	Renovation work (roof)
08.2006	St.Petersburg Cathedral Dome	Russia	3 m	Renovation work (roof)
10.2005	Nuremberg Transport Museum	Germany	30 m	Unknown
09.2004	Duchess Anna Amalia Library	Germany	80 m	Faulty electrical connection
09.2003	Motorcycle Museum, Birmingham	England	20 m	Cigarette
01.2003	Lunéville Chateau	France	100 m	Electrical fault
08.1993	Chapel bridge, Lucerne	Switzerland	2 m (bridge alone, excluding artwork)	Fire in moored boat
11.1992	Redoutensal, Hofburg Palace	Austria	60 m	Unknown
11.1992	Windsor Castle	England	50 m	Spotlight too close to curtain
06.1992	Christianborg Palace Church	Denmark	7 m	Fireworks
08.1989	Uppark House	England	20 m	Renovation work (blowtorch)

Table 1 Fire damage in heritage buildings

We now have the know-how and appropriate tools to help us drastically reduce the risk of serious fire and we are also able to minimize the damage that has frequently been caused by the use of inappropriate extinguishing agents. Loss of cultural heritage is often not only the direct result of fire damage, but paradoxically water-damage, caused by measures taken to extinguish the fire, may prove to be even more costly. One particular example where the water damage accounted for a significant proportion of the total loss was the Duchess Anna Amalia Library in Weimar, Germany.

1.4. Causes and challenges

The COST Action C17 report: “Built Heritage: Fire Loss to Historic Buildings – The Challenge before Us” by Ingval Maxwell [1] identifies the main causes of fire in historical buildings and the associated challenges that need to be addressed.

1.4.1. Typical causes

The most common causes of fires in historical buildings are as follows:

- Electrical faults
  Electrical installations in historical buildings generally do not comply with current safety standards and are an inherent danger in themselves. However, a number of high-profile fires have been caused by negligence in the use of electrical equipment:
  - Spotlight too close to inflammable materials such as curtains (reputed to have been the cause of the Windsor Castle fire)
  - Hot-plates, toasters and coffee makers in staff kitchenettes left switched on
  - Light bulbs used with too high a rating for the corresponding fitting
  - Hanging clothing on wall-mounted light fittings
  - Electrical equipment unnecessarily left switched on outside opening hours
- Hot works (such as welding, soldering, brazing, cutting etc.) employed during building renovation work
- Open fires and defective flues (a common cause of fire in thatched cottages; although not strictly included in the scope of this document)
- Smoking materials and candles
- Heating equipment
- Arson
- Lightening

1.4.2. Common challenges

The traditional construction techniques commonly used in historical buildings present a number of additional factors which contribute dramatically to the spread of fire and to the extent of the consequential fire damage. These include:

- Open and ill-fitting doors
- Thin wall construction
- Structural discontinuities
- Unknown wall and floor voids
- Open staircases
- Unstopped ventilation and service routes
- Undivided roof voids
- General lack of compartmentalization

1.4.3. Addressing these challenges

To adequately address these challenges we need to achieve a balance between the mindset of the conservationist (to preserve the authenticity of the building) and that of the fire safety engineer (to provide maximum protection for people and property). The guiding principle generally proposed by heritage protection organizations is that of minimal intervention. This implies that any modifications to the building, whether intended to improve compartmentalization, fire detection or the extinguishing infrastructure, should cause as little impact to the fabric of the building as possible.

Deciding what improvements should be made requires a structured approach to achieve the above mentioned "balance" and to provide an optimal solution for the particular building in question. To act as a guideline for this decision-making process, the following (generally accepted) criteria have been proposed in the "Guide for Practitioners 7 – Fire Safety Management in Traditional Buildings" by Stewart Kidd [2].

Essential	Only those systems that are central to meeting the objectives of the protection of life, buildings and contents should be considered.
Appropriate to risk	Any physical measures installed must be appropriate to the level of risk involved.
Sensitively integrated	Aesthetics should have a high priority in determining what improvements should be implemented.
Minimally invasive	Any measures taken should have minimal physical impact on the fabric and décor of the building.
Reversible	Any changes made to the building should be reversible.

1.5. Fire safety management

The risks to human life and property in historical buildings and museums are relatively high, due to the concentration of people and to the combustible nature of the interior furnishings and fittings frequently present in such buildings. These risks, however, can be drastically reduced by taking appropriate fire protection measures.

Good fire safety management is essential to ensure that:

- The probability of a fire occurring is very low
- If a fire should occur, then it should be
  - detected early
  - extinguished quickly
  - restricted to a small area of the building
- If, in spite of all effort to restrict the spread of the fire, it should get out of control, then all people inside the building must be evacuated safely and quickly

First we need to understand the mechanisms involved in estimating and managing fire risks.

1.5.1. Fire risk

The fire risk for each specific hazard can be quantified by multiplying the probability of a fire occurring by the consequences resulting from it. Consequently, in cases where the artifacts are deemed to be priceless, the associated risk will practically be infinite (even when the probability of fire occurring is low).

Risk = Probability of occurrence x Consequential damage

Figure 6 Fire risk

The aim of the building owner is to reduce the probability of a damaging fire occurring by implementing an appropriate fire protection concept. The more effective the fire protection measures are, the lower the probability of a damaging fire will become.

A paper published in the Journal of the Canadian Association for Conservation (Volume 33) entitled “Fire Risk Assessment for Collections in Museums” by Jean Tétrault [3] presents a quantitative analysis based on Canadian museum fire statistics.

1.5.2. Fire risk assessment

We may be confronted with many different types of historical buildings and each building is unique, presenting its own set of challenges. In each case, the key to establishing effective fire risk management is to start with a detailed fire risk assessment. In the UK, for example, the responsible person in all premises with five or more employees must conduct a fire risk assessment and keep a record of the findings: other countries also have similar requirements.

Fire risk assessment is the process of risk identification, risk analysis and risk evaluation, assessing and controlling risks and potential threats to staff, visitors and property.

This process consists of the following steps:

- Identify the hazards and determine who or what might be harmed and how
- Reduce the risk of those hazards causing harm to an acceptable minimum
  - Decide what physical measures (both passive and technical) should be implemented
  - Decide what management procedures should be implemented
- Record the findings
- Regularly review the assessment and revise where necessary

A pragmatic approach to this process is detailed in the article "Fire safety and heritage buildings" by Peter Barker [4] and published on the website of the NBS (National Building Specification) - an organization owned by the Royal Institute of British Architects (RIBA). The proposed procedure breaks the process down into four basic phases, which are summarized below:

- Preparation (document the current situation)
    - Obtain accurate plans of the building together with all available information relating to existing fire safety measures. This should include compartment lines, exit routes, room usage, hidden voids (e.g. disused chimney flues, goods lifts, panel infills etc.), potential ignition sources and flammable materials. These plans will form an integral part of the procedure as they can be successively updated to reflect any new measures that are implemented.
- Prevention (assess fire risk)
    - Identify potential ignition sources and flammable materials. Removing them or improving the way such materials are stored, can greatly reduce the risk of fire. Such improvements can often be made easily with minimal impact on the fabric of the building.
    - When looking at preventing a fire in a historical building these are just some of the questions one should be asking:
        - When were the electrical installations last tested?
        - Have all appliances (both fixed and portable) been tested for safety?
        - Are all curtains, tapestries and soft furnishings a suitable distance from potential ignition sources such as halogen lamps?
        - Are waste and flammable materials stored in an appropriate way?
- Protection
    - Identify what fire protection measures would be appropriate and assess their effectiveness in reducing the risks.
        - Automatic fire detection system (detector types etc.)
        - Alarming infrastructure
        - Evacuation concept
        - Measures to restrict the spread of fire
        - Escape routes (emergency lighting, signage)
        - Extinguishing infrastructure (portable extinguishers, automatic extinguishing systems)
- Management
    - To ensure long term effectiveness a detailed fire safety management plan must be created and strictly enforced:
        - Proposed measures should be regularly reviewed
        - Maintenance schedules should be established and adhered to
        - Regular staff training and fire drills should be conducted
        - The fire risk assessment should be reviewed regularly

1.5.3. Fire protection concept

Based on the results of the fire risk assessment, a fire protection concept should be developed which describes all protection measures which help:

- Reduce the risk of fire breaking out
- Prevent the spread of flames and smoke
- Ensure that all occupants are evacuated safely
- Enable the emergency services to take action

1.5.4. Disaster recovery plan

The first priority is obviously to prevent fire occurring and suppress any potential fire in the incipient stage of its development. However, all museums should also have a disaster recovery plan. In addition to a comprehensive list of telephone numbers (key members of staff, utility and security companies etc.) a priority list should be established stating which artifacts should be moved first, how they should be handled and where they should be moved to.

1.6. Regulations

Building owners are often caught between the demands of the fire authorities and those of the conservationists. The primary concern of the fire authorities is the safe evacuation of the building occupants and the provision of adequate fire-fighting equipment. On the other hand, the conservationists are primarily concerned with maintaining the authenticity of the building itself and are reluctant to see the introduction of preventive measures that have any degree of negative impact on the structure and aesthetics of the building.

In general national and international fire regulations are primarily concerned with life safety and less concerned with protecting assets. Fulfilling these life-safety regulations and the associated building codes is, of course, mandatory. However, the number of national regulations and guidelines related to asset protection is steadily rising, as the importance of cultural heritage on the local economy becomes better understood.

National and international Codes of Practice (CoP) cover all publicly accessible buildings, but do not make any specific recommendations to address the specific risks and demands of historical buildings. In the majority of cases they do not apply to existing buildings, except where the purpose of the building has been changed due to more recent modifications. Typical regulations of this type include the following:

- EU
  - EN54-1 Fire detection and fire alarm systems. Introduction
  - EN54-14 Fire detection and fire alarm systems. Planning, design, installation, commissioning, use and maintenance
- DE
  - DIN VDE 0833-1 Alarm systems for fire, intrusion and hold-up. Part 1: General requirements
  - DIN VDE 0833-2 Alarm systems for fire, intrusion and hold-up. Part 2: Requirements for fire alarm systems
- UK
  - BS 5839-1: 2013 Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises
  - BS 9999:2008 Code of practice for fire safety in the design, management and use of buildings
  - Approved Document B (Fire Safety) Volume 2 (Buildings other than dwelling houses)
- USA
  - NFPA 72 Fire safety CoP for regular buildings
  - NFPA 1 Uniform fire Code
  - NFPA 101 Life Safety Code

However some countries have introduced guidelines specifically aimed at the protection of historical buildings, although mostly on a voluntary basis:

- Scotland (Technical Advice Notes –TANs)
  - TAN 11: Fire Protection Measures in Scottish Traditional Buildings (1997)
  - TAN 14: The Installation of Sprinkler Systems in Historic Buildings (1998)
  - TAN 22: Fire Risk Management in Heritage Buildings (2001)
  - TAN 28: Fire Safety Management in Heritage Buildings (2005)

  These four documents were subsequently replaced in 2010 by the documents:
  - Fire Safety Management in Traditional Buildings Parts 1 and 2 (Guide for Practitioners 7)
- USA
  - NFPA 914: Code for Fire Protection of Historic Structures
  - NFPA 909: Code for the Protection of Cultural Resources

Over and above any codes and regulations, it is the moral responsibility of the building owner and its management to protect visitors and staff from fire hazards. Visitors are usually not familiar with the building layout or the location of fire exits and fire escapes. Visitors may also vary greatly in physical condition, age and mental awareness. Each of these factors can be dramatically intensified during the stress situation created by an emergency event such as a fire alarm or building evacuation.

2. Fire protection in historical buildings

2.1. Fire basics

Awareness of how fires start and how they spread can help to reduce the risk of fire quite significantly. It is common knowledge that it takes an ignition source, fuel and oxygen for a fire to occur.

The basic fire protection objectives are to try to control all three of these factors:

- Reduce the likelihood of fire by controlling potential ignition sources
- Minimize the potential effect by reducing the fire load (i.e. fuel)
- Inhibit fire development by limiting the oxygen supply

2.1.1. Controlling ignition sources

The probability of a fire occurring can be greatly reduced by managing the potential ignition sources and taking appropriate preventative measures. As we have seen in Table 1 (above), a surprising number of damaging fires have been caused during renovation work. In most cases this was a direct result of a lack of due care and attention by the building contractors involved and a lack of appropriate supervision.

So-called “hot work” is the most frequent cause of fire during repair or renovation activities and includes the following:

- Welding, brazing or soldering
- Cutting and grinding
- Paint removal using a heat source (blow-torch, hot iron etc.)

Such activities need to be regulated by a “hot work” permit system, which must be strictly enforced. Such activities may only be carried out when all relevant fire protection measures are fulfilled: e.g. all flammable materials in the immediate proximity are protected, the area is carefully inspected at the end of each hot work session and a fire watch is organized (with a readily available fire extinguisher) that extends at least half an hour beyond the end of the hot work session.

Other measures that should be implemented:

- Check all electrical installation and equipment and ensure that they meet current safety standards
- Portable heaters should not be used
- Electrical equipment should be switched off as soon as it is not being used
- Appropriate fire-proof metal containers should be provided for cleaning rags, cotton waste etc.
- Combustible materials and liquids (used in cleaning, painting, etc.) should be stored in appropriate containers

2.1.2. Managing the fire load

Fire risks are largely determined by the fire load of a room or area. The term describes the latent energy which can be released by the combustion of the flammable material within that area during the outbreak of fire: this includes not only the furniture and furnishings, but also the wooden construction of the building itself.

Figure 7 Example of excessive fire load

The typical fire load in historical buildings can be classified as 'relatively high', due to their (wooden) construction and inflammable furnishings (including furniture, curtains, tapestries and carpets etc.). Care should be taken to reduce the fire load wherever possible, by maintaining a certain distance between articles of upholstered furniture, curtains and tapestries etc. and by the use of fire resisting paints (where applicable).

2.1.3. Controlling oxygen levels

At a very basic level, the air supply that feeds a fire can be reduced by ensuring that all separating doors between different rooms in a building are closed (at least outside the normal opening hours).

A recently developed technique that may be suitable in certain applications is based on reducing the oxygen content of the air to a point that no longer allows a fire to develop. Normally air contains approximately 78% nitrogen and 21% oxygen (with the other 1% being made up of argon, carbon dioxide and small amounts of other gases). By reducing the oxygen levels to between 15% and 16%, combustion can effectively be prevented while at the same time providing sufficient oxygen for people to breathe. This technique was evaluated in the research report “Hypoxic Air Venting for Protection of Heritage” by Geir Jensen [6] (published in support of the COST Action C17 “Built Heritage: Fire Loss to Historic Buildings”) and found to offer certain benefits; however, a number of significant disadvantages were also identified, including:

- The energy costs involved in continuously generating the nitrogen required
- The associated compressor noise and maintenance costs
- Possible restrictions due to employment regulations

2.2. Fire protection measures

Fire protection measures can be divided into passive measures and active measures.

Generally speaking, passive (structural) measures define a building's resistance and endurance after a fire has developed, while active measures are aimed at preventing the outbreak and spread of fire and smoke.

2.2.1. Passive measures

One of the guiding principles during the planning of a fire protection concept in a historical building is preserving the authenticity and the character of the building. However, making the building as safe as possible may require considerable structural alterations, which would include compartmentalizing the building to restrict an incipient fire to a single area and to prevent smoke spreading throughout the building (e.g. fire doors, enclosed staircases etc.). Ideally a smoke control system would be needed to extract smoke from the area of the fire and create over-pressure in other areas of the building, which would mean the installation of appropriately dimensioned ducting and fans. Such modifications are generally incompatible with conservation principles.

Protection of priceless works of art should not be subjected to such compromises. Ideally such artifacts should be housed in purpose-built museums, where the focus is clearly on providing maximum protection for the contents of the building. Although there may be a number of notable exceptions, historical buildings are not generally suitable for the housing of priceless works of art.

Although passive protection measures are not the primary focus of this document, they are extremely important. The majority of passive protection measures are related to the building structure, construction methods and materials used. Due to the materials and building methods used in historical buildings, this presents a major challenge to developing a satisfactory fire protection concept.

The main elements of passive (structural) fire protection include:

- Fire compartmentalization of a building
- Use of materials to prevent building collapse
- Fire-resistant construction elements to limit the spread of fire and smoke
- Provision of fire-resistant escape routes/exits/staircases/elevators
- Selection of materials to reduce the fire load
- Selection of materials to prevent the generation of toxic vapors (in the case of fire)

For museums and art galleries under construction, most of these measures are defined by national or local building codes, especially for larger art centers, which may have complex escape routes. In the case of historical buildings, however, it may often prove difficult to improve effective passive protection without undertaking drastic reconstruction. Any intervention of this nature is generally in contradiction with the requirements of the conservation lobby, who wish to preserve the character and authenticity of the original building as far as possible.

The main objective of passive protection measures is to prevent fire and smoke from spreading rapidly throughout the building. Unfortunately, some features of historical building construction, such as undivided roof voids actually assist the rapid spread of fire. Frequently (as in the case of the Hampton Court fire) the presence of interconnecting voids can become a major hazard to historical buildings in the case of fire. These voids may consist of chimney flues, ventilation shafts or dumb-waiter lift shafts.

Many of these buildings are built largely of wood; the interior decor includes heavy carpeting and furnishings, while this is often compounded by wood paneling, wall hangings and paintings etc. As a result, these buildings have a very high fire load.

2.2.2. Active measures

The limited possibilities of improving passive protection means that even more emphasis must be put on active measures. Active protection can be divided into organizational, detection, alarm and evacuation, and extinguishing measures:

Organizational measures

During public opening hours the majority of museums and historical buildings will be able to summon professional help relatively quickly in emergency situations. Despite this fact, the management of such buildings should aim at achieving a high level of competence within their premises in dealing with emergencies and in recognizing potential sources of danger, independent of outside assistance.

Organizational measures include:

- Staff training (prevention and intervention)
- Provision of alarm and emergency plans
- Periodic maintenance and checking of firefighting equipment
- Keeping escape routes accessible and unobstructed
- Enforcement of good housekeeping rules, e.g.:
  - Correct storage of flammable materials used for cleaning or restoration work
  - Electrical appliances switched off as soon as no longer in use
  - No portable heating equipment permitted
  - No smoking in any part of the building or in the immediate vicinity

Detection measures

The main tasks of an automated fire protection system are to detect (an incipient stage) fire, sound an acoustic alarm, notify the fire service and activate the pre-programmed control functions. Such a system consists of a control unit with peripheral input devices (such as manual call points and automatic fire detectors), output devices (such as sounders and beacons) and output contacts to control other systems (such as smoke control systems, HVAC systems, elevators, automated extinguishing systems, etc.).

To minimize the danger to life and the damage to property, it is important to detect a fire as early as possible. Optimal product selection combined with appropriate knowledge make it possible to design a fire detection system capable of detecting a fire extremely early and virtually eliminate any danger of false alarms.

Section 3 describes the measures needed to ensure that a fire is detected reliably and at the earliest possible stage.

Alarm and evacuation measures

When a fire breaks out prompt warning is essential and buildings must be evacuated within minutes to protect people's lives. Public buildings, which at peak times may have a large numbers of visitors and staff, must fulfill special requirements with regard to alarming and evacuation.

The purpose of an acoustic fire alarm is to warn people of the potential danger. In the case of a historical building or museum three distinct target groups are addressed:

- Visitors for whom a hazardous situation has been detected
- Staff who should coordinate the evacuation
- The people who should deal with the fire

In a basic installation the fire detection system must activate the installed alarm devices and transmit the alarm signal to the fire department.

More sophisticated installations may include a dedicated voice alarm system, which can be instrumental in preventing panic by providing clear information about the danger and any required evacuation procedures through calm and concise announcements.

In addition to the type of alarm and evacuation system provided, evacuation plans, escape route identification, emergency lighting systems and smoke venting systems (where feasible) are essential to ensure a fast and safe evacuation of all persons.

All buildings which are open to the public must have a detailed evacuation plan with detailed procedures for the systematic, safe and orderly evacuation of the building in case of fire or other emergencies. Fire drills should be carried out on a regular basis to ensure that all members of staff are familiar with all aspects of this plan.

If an evacuation of the building becomes necessary visitors, who will normally have little knowledge of the building, must be able to rely on the escape route identification signs to find their way out of the building.

To enable a safe evacuation, the emergency lighting must be turned on in all relevant areas.

In purpose-built museums and art galleries air handling systems remove smoke from the building allowing the escape routes to be kept smoke-free, enabling people to leave the building in a quick and safe manner.

Section 4 describes the measures needed to alert staff, visitors and the intervention forces, and how to ensure a fast and safe evacuation of the building.

Extinguishing measures

Unfortunately fires cannot always be prevented and it may become necessary to deal with a fire in the most effective manner.

The hand-held fire extinguishers situated at strategic points throughout the building allow staff to suppress incipient fires quickly and effectively.

Automatic systems such as sprinklers generally react directly to the heat generated by the fire, releasing water from those sprinkler heads closest to the seat of the fire. The major objective is to prevent fire from spreading to other areas of the building and developing into a raging fire that may cause untold damage.

Special applications require special solutions. Historical buildings and museums may house some areas that fall into this category. In particular we can think of archives, kitchens and electrical plant rooms.

Section 5 describes the measures needed to suppress incipient fires and developing fires, and prevent fire spreading throughout a building.

3. Fire detection

3.1. Basic considerations

The earlier a fire is detected, the more time there is for evacuation and firefighting, and the less damage can occur. Earliest possible detection is thus the key to minimizing damage and gaining precious intervention time. This is particularly true for historical buildings where fires can spread very rapidly, making fire suppression considerably more difficult.

To ensure reliable, early detection of fire, it is important to be familiar with the different fire phenomena, fire propagation and possible deceptive phenomena.

3.1.1. Fire phenomena

Fire phenomena are physical values that are subject to measurable changes in the development of a fire (e.g. smoke, heat, radiation and gas). Large volumes of volatile fire aerosols are produced with almost all hostile fires. Smoke has thus become the most important fire phenomenon for the early detection of fire.

Liquid fires directly develop flames which immediately create a temperature increase and heat radiation.

3.1.2. Fire propagation

The fire phenomena propagate differently, depending on the room size and the room conditions such as a high air circulation, which must be taken into account when planning a fire detection system.

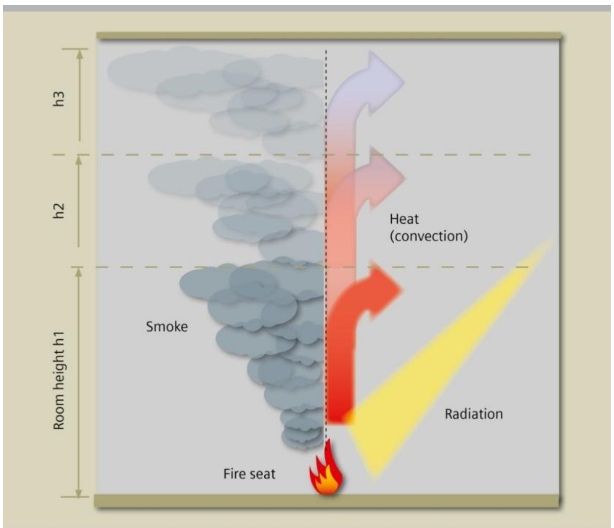

Figure 8 Propagation characteristics of fire phenomena

In general, the higher the room, the greater the distance between the seat of a fire and the fire detectors on the ceiling. Consequently the intensity of the fire phenomenon to be detected (e.g. smoke density, temperature increase or radiation intensity) decreases with increasing ceiling height. It must also be taken into consideration that with increasing ceiling height (and consequent larger room volume) an incipient stage fire can become larger without necessarily increasing the danger of rapid fire propagation. This is of particular importance in historical buildings and museums, which generally have a large number of rooms with high ceilings.

To allow time to extinguish a fire before it has time get a hold and to minimize any damage that may occur, it is imperative that incipient fires are discovered as early as possible: highly sensitive smoke detection systems are essential in this type of application.

3.1.3. Deceptive phenomena

A fire detector has the task of detecting fire from fire aerosols, heat and radiation at an early stage and triggering an alarm. Aerosols, heat and radiation, however, are also generated by production processes, by electrical equipment such as motors, or by environmental factors such as sunlight. If these deceptive phenomena are sufficiently intense and exist over a certain period of time, they may influence fire detectors enough to trigger an unwanted alarm.

State-of-the-art fire detectors are largely capable of distinguishing between deceptive phenomena and genuine fires. If, however, massive deceptive phenomena are to be expected, it is often necessary to combine different fire detectors to provide the best possible solution for that particular application.

3.1.4. Fire detection system

The tasks of an automatic fire detection system are to detect a fire as early as possible, to sound the alarm and to activate the preprogrammed control functions.

State-of-the-art fire detection systems are capable of detecting fire very early and consequently minimizing any damage that may be caused. By optimal product selection and appropriate knowledge it is possible to build systems that virtually eliminate unwanted alarms.

The principal requirement on a fire detection system is early and reliable alarming in the event of fire. As a consequence of this:

- All persons in the danger zone should be able to save themselves
- Fire control systems can be activated to prevent the fire from spreading to more than one fire sector
- Firefighting can be initiated as early as possible, so that damage to property can be kept to a minimum

3.2. Fire detection in historical buildings

We are often confronted with a historical building that does not yet have an automatic fire detection system installed. However, bearing in mind the life safety aspect and the underlying need to protect cultural heritage against fire damage, installation of such an automatic fire detection system must be considered a high priority. However, to allay the fears of the conservationist we need to adhere to the principles of minimal invasive detection.

3.2.1. Rooms with ornate ceilings

Historical buildings and museums typically have high ornate ceilings, with molded cornices and wooden wall paneling. The task is to install a fire detection infrastructure, which has minimum impact on the fabric and décor of the building.

Figure 9 Room with ornate ceiling

ASD (Aspirating Smoke Detection)	The high fire risk in historical buildings and museums means that the earliest possible detection of incipient fire is even more important. ASD (Aspirating Smoke Detection) systems have proved to be ideal in such applications, as they not only provide extremely sensitive smoke detection, but they can also be made practically invisible. The associated narrow pipes can be hidden in ceiling voids or behind the stucco cornices that can frequently be found in ornate ceilings. ASD systems are also an ideal solution for supervising the glass showcases that are often used in museums to display sensitive artifacts. They can identify any incipient fire that may have been caused by an electrical fault or overheating of the associated showcase light fittings.
Wireless detector network	Where they can be positioned without interfering with the room aesthetics, modern, sensitive point detectors may used. By utilizing a wireless network of such detectors it is now possible to fulfill the conservationists' requirement for minimal invasive detection. Earlier generations of such devices exhibited certain disadvantages, such as signal loss and frequent battery replacement. However, recent technological developments have overcome these difficulties. Communication redundancy is now provided by mesh-network constellations, which means that at least two redundant paths are available to transmit the signal back to the fire control panel. Reliability has also been further increased by each detector having two frequency bands with multiple channels. Such networks can now cover a considerable area. Battery lifetime, which was a concern in earlier models, has also been considerably extended and is no longer a problem.

Linear smoke detector

In historical buildings and museums there are many rooms with high ceilings. Any room where the ceiling height is 6 m or more is the perfect application for linear smoke detectors. Such devices can cover distances of up to 100 m. They generally contain an infrared transmitter and detector in the same housing, with only a reflector required on the opposite wall, which greatly simplifies the installation process.

In any space where there is a potential for smoke stratification, detectors installed at ceiling level only might not activate until after a serious delay.

To provide the most effective protection, a total surveillance concept is generally recommended to ensure that the entire building is monitored. This includes not only all rooms, corridors, staircases and anterooms, but also all air conditioning and cable ducts, supply shafts, false ceilings, raised floors, and similar structures which permit smoke and fire to spread.

Special attention should be given to critical areas where many people may be present, areas with numerous heat sources, large fire loads or significant deception phenomena.

Many historical buildings and museums are visited by large numbers of people and in many cases refreshment and catering facilities are provided. Such buildings may contain a number of the following critical areas:

- Exhibition rooms
- Archives
- Restaurants and cafés
- Kitchens
- Electrical plant rooms

3.2.2. Exhibition rooms

Figure 10 Exhibition rooms

Historical buildings and museums generally have a number of large exhibition rooms with high ceilings. Although deceptive phenomena do not generally occur in such rooms, the height of the room (and the large volume of air) will cause the concentration of any fire-related aerosol to be strongly diluted. This demands high sensitivity smoke detection, which can be best provided by an ASD (Aspirating Smoke Detection) system.

In some cases, however, the installation of such a system in a historical building may not be permissible, due to restrictions made by the conservationist lobby. In such cases, an aesthetically acceptable solution could be provided by a combination of linear smoke detectors and a wireless network of sensitive point type smoke detectors.

Exhibition rooms may also contain a number of glass display cases. An ASD system can provide an excellent solution for monitoring such showcases as it can detect an incipient fire (e.g. caused by an electrical fault or overheated light fitting) at the earliest possible stage.

More detailed information regarding fire detection in exhibition rooms is given in the document “Fire detection in exhibition rooms”.

3.2.3. Archives and storage vaults

Figure 11 Archives and storage vaults

Archives and storage vaults may house various different types of object; depending on the building itself (e.g. documents, manuscripts, works of art, archaeological finds, etc.). These are risk areas that need to be especially well protected, particularly from the danger of fire.

The high concentration of flammable and very valuable artifacts implies that any incipient fire must be detected as early as possible and effectively extinguished, without the extinguishing agent used causing any further damage to the objects stored in such rooms. As archives often consist of multiple rooms, the fire protection infrastructure should also ensure that a fire in one room cannot spread to an adjoining room or to any other part of the building.

Aspirating smoke detection systems (ASD) are able to detect even the smallest aerosol concentrations and offer the ideal solution for fire detection in archives. An alarm from such a system can be used to automatically activate a fixed extinguishing system. Extremely good results have been achieved by using a mixture of nitrogen together with a fine water mist. The nitrogen effectively reduces the oxygen content of the room atmosphere and extinguishes the fire. The water mist provides additional cooling and eliminates any danger of re-ignition, without causing damage to the stored artifacts.

More detailed information regarding fire protection in archives is given in the document "Fire protection in archives and storage vaults".

3.2.4. Restaurants and cafés

Figure 12 Restaurants and cafés

Many large historical buildings and museums provide restaurant facilities for visitors and for special functions such as weddings or conferences. These areas must be considered as relatively critical zones, due to the variety of ignition sources such as candles or cooking and frying at the table and the number of guests in the room.

Depending on the room dimensions and the expected deceptive phenomena smoke detectors or multi-sensor fire detectors with a smoke/heat combination are recommended for monitoring restaurant areas.

More detailed information regarding fire detection in restaurants is given in the document "Fire detection in restaurants".

3.2.5. Kitchens

Figure 13 Kitchens

Large cooking vessels, frying pans and deep fryers, present a very serious fire hazard in commercial kitchens. This is mainly due to the strong possibility of fire breaking out due to overheating and to the local high fire load.

Multi-sensor fire detector with a smoke/heat combination and sophisticated signal processing are recommended for monitoring these areas. Avoiding unwanted alarms due to the inevitable presence of deceptive phenomena, such as fumes or steam, requires in-depth knowledge and experience in positioning the detectors in such applications.

More detailed information regarding fire detection in kitchens is given in the document "Fire detection in kitchens".

3.2.6. Electrical plant rooms

Figure 14 Plant rooms

Electrical plant rooms, in which power supply equipment, control systems, security systems and computer servers are accommodated, are risk areas that need to be especially well protected. This applies particularly to fire safety in these areas.

Aspirating smoke detection systems (ASD) are able to detect even the smallest aerosol concentrations. They can detect extremely low smoke concentrations which may be caused, for example, by a malfunction of an electrical or electronic component. It may then be possible to prevent fire developing simply by removing the power from the particular unit.

Automated dry extinguishing systems (i.e. systems using inert gases or clean agents) provide a best fit for the protection of delicate and expensive electrical and electronic equipment and prevent costly business interruptions.

Recently, isolated malfunctions of hard drives used for data backup have been reported in server rooms, in connection with the release of some gaseous fire extinguishing agents. For such server room applications the Silent Nozzles mitigate the sound pressure levels caused by the gas discharge process and consequently prevent any damage to computer hard drives (HDD).

More detailed information regarding fire protection in plant rooms is given in the document "Fire protection in plant rooms".

4. Alarming, smoke control and evacuation

4.1. Introduction

Once a fire has been detected by an automatic detector, by sprinkler flow monitoring or by a person activating a manual call point, the fire detection system will generate the preprogrammed control and alarm signals.

A major factor that can affect the success of building evacuation is that many people do not take the sounding of a fire alarm sufficiently seriously or do not understand the meaning of the acoustic signal. Such doubts lead to unnecessary delays in people's reaction to the warning and may mean the difference between life and death. The more clearly the information can be conveyed to the public, the better the situation will be understood and the more quickly the necessary actions will be taken.

A fast and efficient evacuation procedure is essential. This not only saves lives, but once the evacuation of the building has been completed, the fire services can concentrate on minimizing the damage to property.

4.2. Alarming

4.2.1. Objectives

The purpose of a fire alarm is to warn people about the presence of a fire within the premises. In a historical building or museum context these people may be divided into 3 target groups:

- Members of staff
- Visitors
- The municipal fire service

For each of these target groups various technical solutions are available, which can alert the people concerned in the most appropriate and efficient manner.

4.2.2. Alerting members of staff

Alarms intended for in-house staff are always generated without delay to allow the cause of the alarm to be investigated. Time is of the essence: investigation must begin immediately. It is still possible that the fire is small enough to be dealt with by local means. The aim is to prevent any unnecessary disruption to guests or normal business functions until absolutely necessary.

Without activating the main alarm, members of staff may be alerted in one (or more) of the ways listed below. The appropriate choice will largely depend on the size of the establishment and, more particularly, on the number of staff involved.

Pager	Alarm activation via an in-house pager system, causing the pagers carried by all members of staff to vibrate.
Mobile/Cell phone (SMS)	Transmission of a preprogrammed text message.
Smart phone (mobile app)	Modern technology permits a more user-oriented presentation of the alarm message and a reminder of the next steps of the emergency procedure.
Local (discreet) acoustic	Activation of buzzers or speakers in staff areas only: e.g. front desk, manager's office, kitchens, administration offices.
Silent/coded alarm	Broadcasting of a "silent" alarm in the form of a coded message transmitted via the in-house PA system e.g. "Will Mr. Black please report to the manager's office."

4.2.3. Alerting visitors

Visitors can be warned of the impending danger in several ways.

Acoustic alarms	Electronic sounders are regarded as the normal means of raising an alarm and are suitable for most applications. The recommended sound level of such devices (according to EN54-3) should be not less than 65 dB(A) or 5 dB(A) above the ambient noise level.
Visual alarms	Strobes or rotating beacons may be regarded as supplementary alarms which enhance the effectiveness of sounders, with sounder beacons combining the advantages of both device types. Beacons are of particular importance for hearing-impaired persons. Where several beacons may be visible within a single area it is important that they are synchronized to avoid the risk of persons with photosensitive epilepsy suffering a seizure.
Voice alarms	A voice alarm system consists of a network of speakers distributed throughout the building, which permit prerecorded voice messages to be transmitted either manually or automatically by an alarm from the fire detection system. Such systems may be applicable in large municipal museums, as different messages may be conveyed to different areas within the premises. The effectiveness of such a system can be considerably improved by the live voice message feature. This allows the person responsible for an orderly evacuation to address people in specific areas of the building directly and consequently get their full attention. The better the people are informed, the more efficient an evacuation will be.

4.2.4. Alerting the municipal fire service

The municipal fire department may be alerted in one of two ways:

- Automatically via the fire detection system by remote transmission
- Manually from the admission desk or security manager's office by telephone

In certain regions the initial alarm may be transmitted to an Alarm Receiving Center (ARC) which, in turn, will notify the local fire department.

4.2.5. Alarm strategies

General alarm	A general alarm is a defined audible signal which is sounded throughout the building. The alarm is automatically activated by the fire detection system, or manually from the admission desk (or security manager's office). In the majority of historical buildings this should trigger the immediate and total evacuation of the building.
Staff alarm	When the first signs of an incipient fire are detected, only members of staff are initially informed. This gives the designated staff members a short period of time to investigate the cause of the alarm and deal with any incipient fire. If the fire cannot be dealt with within the specified timeframe, then the staff is responsible for an orderly evacuation procedure in accordance with clear evacuation plans. The staff alarm function is based on the standard Alarm Verification Concept (AVC), which is described in detail in the following section. This strategy is particularly suited to situations where a large number of people may be present who are not familiar with the layout of the building.
Staged alarms	Staged alarms are based on systems capable of generating an 'alert signal' and a different 'evacuate signal'. Such systems may be applicable in very large or complex buildings, where the occupants have been trained to distinguish between these two alarm signals. Generally those people potentially most at risk are those closest to the point where the fire was detected or where the manual call point was activated. These people should leave the building immediately and therefore an 'evacuate signal' will be sounded in this area. In other areas of the building an 'alert signal' will be sounded, indicating that people in those areas will only have to leave the building if it becomes necessary, see "phased evacuation" (Section 4.4.2).

4.2.6. Alarm Verification Concept AVC

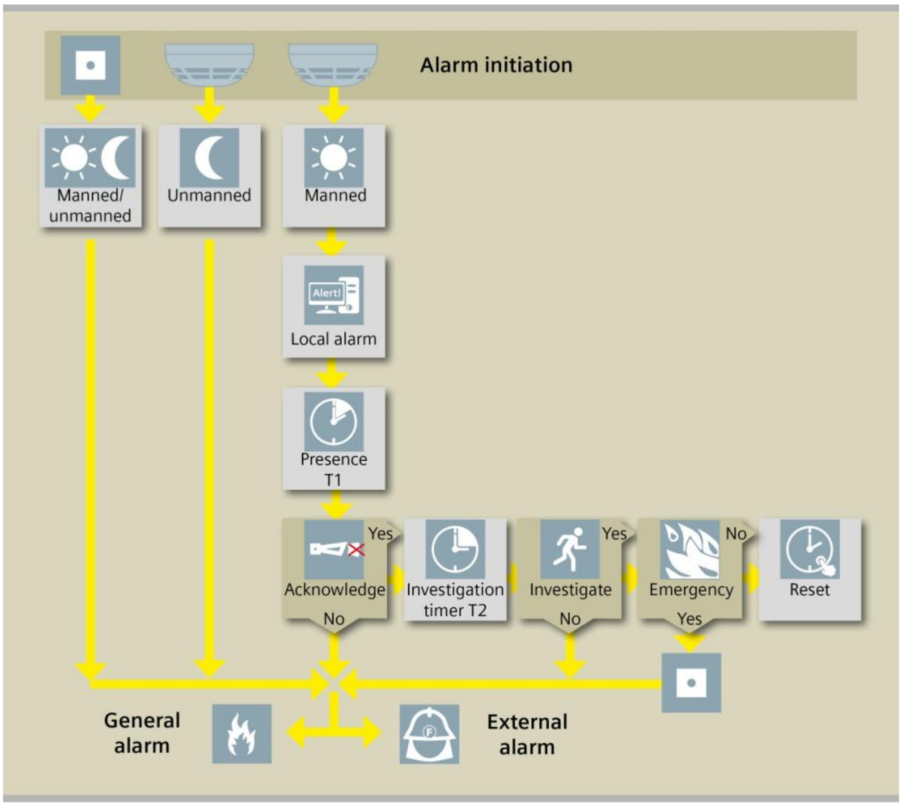

Figure 15 Alarm Verification Concept

The Alarm Verification Concept (AVC) allows in-house personnel to carry out a local investigation before the municipal fire service is alerted or the building is evacuated. This reduces the number of unnecessary calls and is based on a dual timing principle. It is only applicable to the “day/manned” mode of the fire detection system. In the “night/unmanned” mode (when a local investigation cannot be ensured) the fire service will be alerted without delay. Manual call points and sprinkler flow switches also alert the fire service without delay (at all times).

In the “day/manned” mode any alarm initiated from an automatic smoke detector will generate a Local Alarm and start the Presence Timer T1. If T1 times out without any response from an operator, the fire service is called immediately. If the alarm is acknowledged on the fire alarm panel while T1 is running, the system recognizes this as a sign that an operator is present. In this case the Investigation Timer T2 is started for a predetermined investigation period. The duration of this investigation period should be determined in consultation with the fire service.

If the local investigation verifies the existence of a major fire, the fire service can be summoned immediately by simply activating any manual call point. The fire service will also be called if T2 times out. On the other hand, if the local investigation establishes that only a minor, easily dealt with fire exists, the fire alarm can be reset while T2 is still running.

4.3. Smoke control

4.3.1. Objectives

Smoke presents the greatest danger to life in the case of a fire. This is not only due to smoke inhalation injuries and asphyxiation, but also due to smoke-filled corridors and staircases, which make evacuation considerably more difficult and raise panic levels.

Smoke may also cause considerable damage to room furnishings, paintings or other artifacts on exhibition. Consequently, any measures which could restrict smoke to the immediate locality of the fire for a period of time should be taken into consideration during the risk assessment process. Implementing smoke control measures in existing buildings is feasible, but this would almost certainly require structural modifications that could have a considerable impact on the authenticity of the building structure.

However, in modern, purpose-built museums, libraries and art galleries etc. smoke control should form an integral part of the design process. In particular care must be taken to ensure that such buildings are subdivided into fire compartments by fire doors and fire-resisting walls and floors. Customized smoke control systems will be designed to restrict the spread of fire and smoke, conducting the heat and smoke through the installed ducting into the external atmosphere (generally through the roof of the building).

4.3.2. Addressing general weaknesses

Compartmentalization

Historical buildings were built when the mechanisms determining the spread of fire were not well understood. Continuous roof spaces over entire buildings, hidden voids behind plasterwork and feedthroughs left by the various installation activities over the years all contribute to increase the risk of fire spreading rapidly throughout the building.

The challenge is to find ways to restrict the spread of fire to the immediate vicinity where the fire was initially detected. Compartmentalization is the process of creating so-called fire compartments and finding the most effective ways of preventing smoke and fire from spreading to any of the neighboring compartments. In historical buildings this process is particularly challenging and requires ingenuity, flexibility and experience to achieve the best results from both the point of view of the fire protection specialist and the conservationist.

Fire doors

Fire doors are used to compartmentalize a building, effectively restricting smoke to the immediate locality of the fire. Fire doors are generally held open magnetically and will swing closed as the retaining power is removed when the fire control panel detects a fire.

The doors usually found in historical buildings present a number of challenges:

- They often do not fit as well as they should
- They are often relatively thin, with fire ratings insufficient to prevent the spread of fire for more than a few minutes
- It is often difficult to install any auto-closing mechanism

Modifying the fire resistance of the doors is frequently impracticable; however, if possible the doors should be fitted with an automatic closing mechanism (as described above). The ill-fitting aspect may also be addressed by fitting intumescent strips on the edges of the doors. These strips expand when exposed to heat and can be effective in helping to restrict the spread of fire and smoke.

Hidden voids

One of the greatest threats of smoke and fire spreading in an uncontrolled manner throughout historical buildings is the presence of unknown voids, ventilation shafts and unused service shafts. As a minimum any connected voids should be blocked off to ensure that defined fire compartments are maintained.

In some cases it may actually be possible to utilize the unused flues and ventilation shafts for smoke extraction purposes, without detrimental impact on the aesthetics of the building. Such creative approaches depend heavily on the classification of the building concerned, the ingenuity of the fire engineers involved and close cooperation with heritage protection and the building owner.

If an air-conditioning system is present, this should also be taken into consideration and integrated into the fire protection concept.

Unstopped feedthroughs

Over the years most historical buildings have been subject to the installation of electric cables, heating, or ventilation infrastructure. Frequently this involves cables or pipes passing through walls and ceilings from one room to another. In many cases these feedthroughs have not been sealed and would allow smoke (and fire) an easy pathway to spread throughout the building. It is essential that these feedthroughs are sealed: this is an effective prevention measure that should not encounter any opposition from the conservationist lobby as such feedthroughs are generally hidden.

4.4. Evacuation

4.4.1. Objectives

The basic objective is to move those people in an endangered area to a place of safety. The evacuation of a building, however, is a drastic measure and should only be initiated when absolutely necessary.

The measures required to ensure safe evacuation will vary from building to building and priority must be given to the requirements specified by the local authorities. Unfortunately these regulations differ widely from country to country and the local fire services often specify very distinct and individual evacuation concepts for buildings within their jurisdiction.

Key objectives:

- Visitors should remain undisturbed for as long as possible
- An evacuation should be initiated as soon as it becomes unavoidable
- The evacuation should be carried out as quickly and efficiently as possible

4.4.2. Evacuation concepts

For each building an appropriate evacuation strategy must be defined in accordance with the physical organization of the building, local regulations and in discussions with the local fire authorities. An important consideration must be given to the building occupants and the concentration of people in the various areas within the building. These factors can vary greatly in historical buildings which are also used for staging special events, such as banquets, wedding receptions, concerts, lectures or even conferences.

Simultaneous evacuation (general alarm)

In small-to-medium sized historical buildings and museums, evacuation will simply consist of everyone reacting to the warning signal given when a fire is discovered and then making their way to a place of safety outside the building. This is known as a simultaneous evacuation and will normally be initiated by the sounding of the general alarm (see above) via the fire detection system.

Conducted evacuation (staff alarm)

In buildings where a large number of visitors may be present, who are not familiar with the building layout, it is important to avoid any panic that might occur in a simultaneous evacuation. Conducted evacuation is a strategy that relies on well-trained staff and carefully planned evacuation procedures:

- Members of staff are warned as soon as an initial fire alarm has been triggered.
- Designated staff members investigate the cause of the alarm.
- If the incident requires the evacuation of the building all members of staff are alerted.
- The evacuation is conducted by the members of staff in an orderly manner in accordance with pre-planned (and regularly practiced) procedures.

Phased evacuation (staged alarm)

In large museums or more complex historical buildings a phased evacuation may be considered appropriate. This results in the following advantages:

- Reduced clogging (or blocking) of the escape routes and especially of staircases. When the whole building is evacuated simultaneously, people tend to flock to the staircases on all floors at the same time, which may lead to considerable tailbacks.
- Reduced probability of any panic reaction. The awareness of being in danger without being able to get out quickly (blocked exits) easily leads to panic reactions. This may be accentuated by the presence of particularly narrow passageways or staircases in some types of historical building. The consequences of such panic reactions may be even worse than those of the fire itself.

Restriction of evacuation to the minimum is absolutely necessary. The complete evacuation of an entire building is only recommended when the fire can no longer be controlled. It is mostly sufficient to evacuate one or several fire compartments.

4.4.3. Organization

A successful evacuation can only be achieved when the appropriate infrastructure and management organization are in place and are regularly reviewed.

Up-to-date evacuation plans

In many countries approved plans for fire alarm and evacuation measures are required by law. These plans must detail all necessary actions to be taken during emergencies and designate the persons responsible for the implementation of such actions. In countries where no such legislation exists, the building owner or manager should consult with local authorities and the fire service to formulate the most effective plans for their premises.

Regular fire drills

Regular meetings and fire drills are essential in keeping evacuation plans up to date and the staff fully prepared for any emergency.
Regular checks should also be made to ensure:

- Escape routes are always free from blockages of any sort and that emergency fire exits remain unlocked (although they will generally be supervised by an in-house alarm system for security purposes).
- Emergency lighting is well-maintained and always in perfect working order.

4.4.4. Evacuation instruction

The single most important factor in a successful evacuation is providing people with clear instructions telling them what they have to do. In such environments it is generally considered inadequate to rely on the visitors being able to correctly interpret the meaning of the acoustic 'alert' and 'evacuate' signals from simple sounders.

As described earlier, the Staff Alarm strategy relies on members of staff providing directions to visitors in such a way that an efficient, panic-free evacuation will be carried out as soon as it is considered necessary. In larger buildings this will require some form of public address system (or voice alarm system) to ensure that everyone hears and understands the instructions being given.

In a large modern museum a voice alarm system would be recommended, which provides a microphone input that allows the responsible fire officer to 'speak' directly to people in specific parts of the building as required.

4.4.5. Escape routes

Once the visitors have understood that they need to evacuate the building, following the appropriate escape route must be made as straightforward as possible. Clear signage is essential as the best escape route may not necessarily be the route that people would take under normal circumstances. In an emergency situation the travel distance to a place of safety must be as short as possible. The purpose of the fire exit signs is to help people reach the nearest exit by the most direct route.

Travel distance	The travel distance (or exit distance) should be measured from the farthest point in a room to the door leading to a protected stairway or to the final exit of the building. If there is only a single fire exit, then some guidelines recommend that the travel distance should not exceed 18 m. If there is more than one escape route, the acceptable travel distance is considered to be 45 m. However, in historical buildings it will frequently be difficult to fulfill such stringent guidelines.
Exit width	The acceptable width of emergency exit doors (and exit routes in general) is not only determined by the number of people in the building, but the characteristics of those people and the estimated fire growth rate in the particular building This approach is specified (for example) in the UK "Code of practice for fire safety in the design, management and use of buildings" (BS 9999: 2008), where a risk profile is proposed for visitors in a museum. The number of available exits and the width of those exits can then be used to determine the maximum number of people permitted in the building at any one time.
Escape route doors	All doors should open in the direction of the fire exit route; however re-hanging any doors that were designed to open in the other direction may not always be practicable.
Escape route identification	Visitors are not generally familiar with the layout of the building, making it imperative that the emergency escape routes are adequately signposted to help guide all occupants to a place of safety. As there may be numerous visitors who do not speak the national language, the international pictogram signs (as described in ISO 7010) should be used. The general guideline is that an escape route directional sign should be readily visible from any location within the building. The positioning of such signs in historical buildings can be the subject of heated discussions as indiscriminate use may certainly affect the aesthetics of the rooms and corridors of a building. A compromise solution may involve the use of signs, which are not permanently fixed to the doorways, or are more aesthetically compatible with their surroundings. The escape route should be regularly confirmed by repetition signs, especially at "decision" points, e.g. where corridors meet or open onto landings. All evacuation or escape plans should conform to the format as described in ISO 23601. The ambient lighting levels should also be taken into account when determining which type of sign should be used (e.g. back-lit, reflective, etc.).

Figure 16 Exit route sign

The problem with this type of sign is that they may not be easily visible in smoky conditions. For this reason the concept of way guidance is becoming more widespread in new buildings.

Way guidance

To complement emergency escape signage, way guidance equipment can be very useful in helping people to follow exit routes. Way guidance systems usually consist of photo luminescent material, lines of LEDs, or strips of miniature incandescent lamps, forming a continuous marked escape route at a lower level (e.g. handrail or floor). These systems have proved particularly effective when visibility is already affected by smoke. Such technology can easily be integrated into modern museums or libraries; however some degree of ingenuity will be required to overcome the aesthetic restrictions imposed in the majority of historical buildings. One example may be photo-luminescent strips in carpeting or along handrails.

Emergency lighting

The primary purpose of emergency escape lighting is to illuminate the escape routes, but it can also be helpful in illuminating other safety equipment. Following a power failure the emergency lighting should automatically switch on within 5 s. The size and type of the premises and the risk to the occupants will determine the complexity of the emergency lighting required.

5. Extinguishing

5.1. Introduction

Although preventing the outbreak of fire is the highest priority, the possibility of a fire occurring will always remain present. An automatic fire detection system, as discussed in Section 3 must also be supplemented by an effective fire extinguishing infrastructure. Obviously providing an adequate number of appropriate manual fire-extinguishers is essential, however, one factor that is common to the vast majority of cultural heritage buildings lost to fire is the lack of an automatic extinguishing system.

Due to the high fire load of historical buildings and the difficulties in ensuring effective compartmentalization (as discussed earlier) if the fire is not stopped or controlled in the early stages of development it can rage through a building very quickly. Rapid fire brigade intervention using water hoses may be able to prevent the total loss of the building structure, but it is not uncommon to find that the consequential water damage to the contents of the building is at least equal to that caused by smoke and fire.

Many historical buildings are not situated in urban areas and the closest municipal fire station may be some considerable distance from the building concerned. The time that the fire brigade may take to arrive at the scene of a fire is a factor that should be taken into consideration when assessing what fire suppression infrastructure should be provided locally. Similarly any vehicular access difficulties (e.g. narrow or low bridges, winter access, etc.) or lack of extinguishing water should also be borne in mind.

5.2. Principles

For a fire to exist, three elements need to be present:

- Heat to raise the material to its ignition temperature
- Fuel to support combustion
- Oxygen to sustain combustion

Extinguishing a fire implies interfering with the combustion process in such a way that the preconditions to maintain combustion are no longer present. This can be achieved by removing any one of these three elements or by interfering directly with the combustion process. This results in the four basic extinguishing mechanisms:

- Reducing the temperature of the inflammable materials or the flames (cooling)
- Cutting off the supply of oxygen (smothering, inerting)
- Physically separating the inflammable materials from the flames (starvation)
- Use of chemicals to inhibit the combustion process

An appropriate fire suppression infrastructure may include both automatic extinguishing systems and basic manual firefighting equipment (portable fire extinguishers and water hoses).

5.3. Extinguishing systems

The most appropriate automatic extinguishing systems for historical buildings and museums depend to a large extent on the application.

- In general exhibition areas
  - Sprinkler systems
  - Water mist systems
- In archives, closed storage vaults and electrical plant rooms
  - Gas extinguishing systems
  - Extinguishing systems using gas/water-combined technology

5.3.1. Sprinkler systems

These automatic systems use water as the extinguishing agent and provide a very effective protection both for property and human life. The advantages of sprinkler systems are their high reliability and wide application spectrum in the protection of people and material assets. Not only do they stand out due to their relatively simple and robust technology, there is generally a plentiful supply of the extinguishing agent – water.

Very often the primary fire protection provision is the water sprinkler system, either wet pipe or pre-action arrangements as per NFPA 75 code. Such systems are intended to protect the integrity of the building structures and prevent their collapse. In effect, the purpose of sprinkler systems is to control the fire and to cool the building infrastructure in order to allow firefighters to reach the fire location and to perform their duty.

Sprinkler systems are common in modern purpose-built museums and are required by local building regulations in many countries. The installation of sprinkler systems in historical buildings and museums, however, is somewhat frowned upon for a number of reasons. Of course the installation procedure is quite invasive and can only be considered when the sensitivity of the building allows it. However, the advantages are considerable as sprinklers are very effective in preventing a fire from spreading to other areas of a building. It is a common misconception that all sprinkler heads are activated simultaneous and not just the one(s) in the immediate vicinity of the fire. Any water damage caused by a sprinkler system is very limited as over 80% of all fires can be controlled by only 1 or 2 sprinklers. This is in stark contrast to water damage that can be caused by fire brigade water hoses. Although accidental activation of a sprinkler is often quoted as an additional and unwarranted risk, this is a very rare occurrence (statistically shown to be in the million-to-one region).

It is also feasible to install a sprinkler system quite unobtrusively in historical buildings and museums. Concealed sprinkler heads can be made almost invisible, being hidden by cover plates painted the same color as the ceiling. If this type of sprinkler head is used, however, care must be taken to ensure that they do not get painted shut during any subsequent redecoration exercise. The cover plate also means that the reaction time may be negatively affected. Alternatively, various types of wall mounted sprinkler heads are available, which can also provide a discreet installation and the small bore plastic piping can often be hidden from view by utilizing cornice moldings and the voids behind the paneling.

Further advantages:

- Installation of a sprinkler system can significantly reduce insurance costs
- Sprinklers only extinguish areas which need to be extinguished
- Sprinklers outside the fire source remain closed
- Extinguishing water released reduces smoke and dangerous gases
- The cooling effect of extinguishing water increases the safety of rescue forces
- Low maintenance costs
- Robust and very reliable

Sprinkler systems consist of a network of water pipes with sprinkler heads positioned in such a way that (in case of fire) all areas to be protected would be reached by the extinguishing water spray. The sprinkler heads react individually to heat, opening to discharge a pressurized water spray when the temperature is sufficiently high. In this way an incipient stage fire can be suppressed at its source as only those sprinklers in the immediate vicinity of the fire will be activated, minimizing any unnecessary water damage.

Currently several premiere cultural heritage institutions have installed, or are in the process of installing, complete automatic sprinkler protection. Examples include the Library of Congress, the Smithsonian Institution, the National Library and Archives of Canada and the National Library of Scotland.

Wet-pipe automatic sprinklers represent an effective solution for typical museum and library fire-suppression objectives. To limit the structural intrusion of such a system, partial coverage may be an acceptable compromise where sprinklers are only installed in particular parts of the building.

Wet-pipe systems

As historical buildings and museums are generally not subject to freezing or overheating (+95 °C) during the year, the most appropriate type of sprinkler is the wet-pipe system. Such systems are permanently filled with water, which is maintained under pressure so that in case of fire the water can be immediately discharged from the sprinklers.

Water mist systems

An emerging fire-sprinkler technology which shows great promise particularly for sensitive applications is the use of water mist. A fine water vapor is generated by delivering water to the specially designed sprinkler heads at very high pressures. This maximizes the cooling effect of the water, enabling fires to be extinguished with minimal amounts of water. Experimental tests have shown that many room fires can be controlled with as little as 2-3 liters of water. This type of system is usually activated by control signals from the fire detection system, in response to the alarm signals from the connected ASD devices.

The disadvantages of this type of system compared with traditional wet-pipe systems are that they are somewhat more expensive to install and the maintenance costs are also higher.

5.3.2. Gas extinguishing systems

The main application area for gas extinguishing systems is the protection of closed rooms. They are particularly suitable for rooms that contain sensitive objects or equipment where water cannot be used. These typically include all types of electrical equipment and computer rooms.

The gases are stored in pressurized cylinders:

- The non-liquefiable inert gases Ar, N_2 and gas mixtures are stored in gas cylinders at a pressure of 300 bar.
- In high-pressure systems CO_2 (which does liquefy under pressure) is stored in gas cylinders at 56 bar; in low-pressure systems it is stored in large cooled containers.
- Clean agents such as HFC227 ea and Novec 1230 are stored in gas cylinders pressurized with nitrogen, which acts as a propellant. The industry's most common storage pressures are 25 bar (particularly in the USA) and 42 bar, which allows for higher flow rates, smaller pipe diameters and longer pipe runs.

Extinguishing is controlled either manually or preferably automatically by means of a fire detection system. Only a quick, faultless actuation prevents consequential damage, as a fire should be extinguished during its incipient phase. However, to prevent human casualties, an alarm must first be sounded to warn people of the imminent flooding of the area. The gas will only be released after a predefined delay has given people sufficient time to evacuate the area. The extinguishing gas will then be released and a homogenous concentration is quickly built up throughout the room. To completely extinguish the fire, this concentration must be maintained over a sufficiently long period of time.

Such systems may be appropriate in modern dedicated museums, which have sensitive enclosed archives, computer rooms, or similar electrical equipment facilities.

5.3.3. Gas/water-combined systems

An alternative to the pure gas systems can be provided by proprietary systems using a combination of gas and water mist. Releasing additional N_2 gas into a closed room, where an embryonic fire has been detected, effectively reduces the oxygen concentration in the room and extinguishes the fire, while the water mist cools the combustible material and prevents re-ignition. The fine water mist also serves to provide a smoke scrubbing function, which reduces the health hazard for people entering the room following an extinguishing event: smoke inhalation is the primary cause of death for victims of indoor fires.

Such systems provide an excellent solution for archives, as they combine the following major advantages:

- They ensure that incipient fires are extinguished rapidly and reliably.
- They prevent re-ignition.
- They create no irreversible damage to the artifacts stored in the archive.

5.4. Manual extinguishing infrastructure

5.4.1. Fire extinguishers

Fire extinguishers are mobile or portable manual devices designed for preventing incipient stage fires from getting out of control. The extinguishing agent is expelled under pressure. In some types of extinguisher the agent is kept under constant pressure, while in others the pressure is generated by releasing a propellant gas at the time that the extinguisher is activated.

Extinguishing agents include water, foam, carbon dioxide and powder. These substances function in different ways and are suitable for different types of fires. Fires are categorized into five main fire classes A, B, C, D and F.

EN Fire class	Description
A Solid materials	Solid materials subject to thermal decomposition which normally form embers. Examples: wood, paper, leather, textiles and coal
B Liquids	Liquids or materials which melt under heat and only create flames. Examples: alcohol, oil, wax, resin, paraffin, petrol, paints, tar and acetone
C Gases	Gaseous materials which are often stored under pressure. Examples: hydrogen, natural gas, acetylene, methane, ethane, propane and butane
D Metals	Strongly ember-forming, combustible metals. Examples: aluminum, magnesium, potassium, sodium, beryllium, lithium and barium
F Cooking oils	Combustible cooking oils and fats commonly found in commercial kitchens.

Figure 17 Material fire classes

Notes:

1. In the European norms electrical fires are not considered to constitute a fire class on their own, as electricity is a source of ignition that will feed the fire until removed.
2. The above table reflects the European classification system. Definitions used by regulatory bodies in other parts of the world may show some minor differences.

   For example in the USA: Cooking materials → Class K
   Liquids + Gases → Class B
   Electrical equipment → Class C

Extinguisher Type	Class of Fire				
	A	B	C	D	F
	Solids	Liquids	Gases	Metal	Cooking oils
Water	Yes	No	No	No	No
Foam	Yes	Yes	No	No	No
ABC Powder	Yes	Yes	Yes	No	No
Dry powder (Metal Fires)	No	No	No	Yes	No
CO_2	No	Yes	No	No	No
Wet chemical	No	No	No	No	Yes

Figure 18 Fire extinguisher applications

5.4.2. Fire hose reels

Fire hose reels are often overlooked or discarded as a possible option in favor of portable fire extinguishers. When fitted with a mist nozzle they can generate a wide spray with a dense mist. These provide a very effective extinguishing tool and are much simpler to use by untrained persons than portable fire extinguishers.

They are particularly suitable in the less vulnerable parts of historical buildings and museums.

5.4.3. Fire buckets

Even the simple fire buckets filled with fine sand may still have their place in certain situations. Although largely superseded by more modern technology, they still retain some distinct advantages in suppressing small incipient fires due to their ease of use by untrained persons. The extinguishing effect relies on the smothering of an incipient fire, effectively starving the fire of oxygen.

The sand must be dry (and free of any flammable materials) and is not suitable for burning metals. However, in small historical buildings the fire bucket may still be a useful aid.

5.5. General recommendations

The research report “Manual Fire Extinguishing Equipment for Protection of Heritage” by Geir Jensen [5] (published in support of the COST Action C17 “Built Heritage: Fire Loss to Historic Buildings”) provides the basis for a number of the recommendations made in this section.

It is reasonable to assume that exhibition objects themselves are not generally the source of an embryonic fire. Consequently there is no immediate risk that artifacts will be damaged by the extinguishing agent during the early stages of a fire, when hand-held equipment is intended to be used.

Fire extinguishers

As historical buildings and museums are open to the public, fire extinguishers must always be provided: National fire codes (e.g. BGR 133) specify the type, size and quantity of extinguishers required with regard to the floor area and danger level of each location. It is important to provide an adequate number of fire extinguishers, which should be installed throughout the building. They should be mounted where they are clearly visible, easily accessible and at a convenient height. Typically the extinguisher handle should be between 0.8 and 1.2 m from the floor.

The extinguishing method that prevents re-ignition will in the end cause less total damage. Foam extinguishers have proved themselves to be the most effective for this purpose. Although they do not necessarily cause the least secondary damage to artifacts, foam should be given preference over other extinguishing agents. The weight of the extinguishers is also a factor that should be taken into consideration during the selection process: the 6 liter extinguishers are recommended.

Other types of extinguisher that need to be provided for special risk areas include, for example, wet chemical extinguishers in the kitchens (for cooking oil fires) and CO_2 extinguishers in plant rooms (for electrical fires).

Fire hose reels

Where access to water mains is available, the installation of fire hose reels should be carefully considered as these have proved to be very effective and easy to use by untrained persons. Care should be taken to ensure that the hoses are fitted with nozzles that are appropriate to the locality.

Sprinkler systems

When planning a sprinkler system, a choice must be made between partial coverage and blanket coverage. In historical buildings partial coverage is more common as a compromise must be found between maximum protection and the impact on the fabric of the building.

5.5.1. Areas requiring special attention

When planning the extinguishing concept for a historical building or museum, the following areas should be given special attention:

- Archives
- Electrical plant rooms
- Kitchens

Archives

A system employing a combination of gas and water mist can provide an effective solution for archives and storage vaults, in which documents, manuscripts, books or paintings are stored.

The high concentration of flammable and very valuable artifacts implies that any incipient fire must be detected as early as possible and effectively suppressed, without the extinguished agent used causing any further damage to the stored objects. As archives often consist of multiple rooms, the fire protection infrastructure should also ensure that a fire in one room cannot spread to an adjoining room or to any other part of the building.

Aspirating smoke detection systems (ASD) are able to detect even the smallest aerosol concentrations and offer the ideal solution for fire detection in archives and storage vaults. An alarm from such a system can be used to automatically activate an extinguishing system. Extremely good results have been achieved by using a mixture of nitrogen together with a fine water mist. The nitrogen effectively reduces the oxygen content of the room atmosphere, while the water mist provides additional cooling and prevents re-ignition, without causing damage to the stored artifacts.

Electrical plant rooms

A gas extinguishing system provides efficient fire protection for electrical and electronic installations. This would be an appropriate solution for the protection of server rooms, particularly as no residues are left behind after an extinguishing incident and fire damage can be restricted to an individual piece of equipment. Such systems are very effective in putting out fires and preventing re-ignition, allowing normal operation to be resumed as quickly and smoothly as possible.

Standard applications include centralized systems and modular systems. In a centralized system, all gas cylinders are installed in a central location outside the protected zone and preferably in a dedicated storage room. Centralized systems always require a site-specific design, as all pipe diameters and nozzles must be calculated individually according to the particular application.

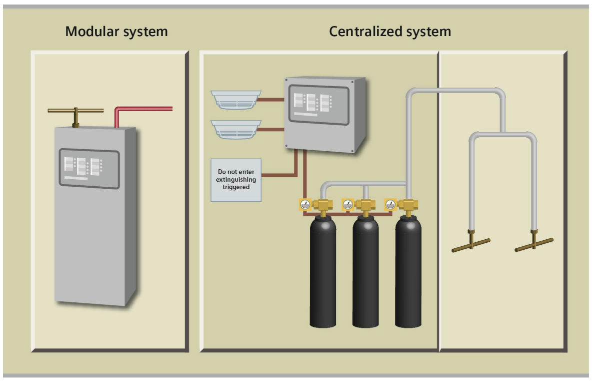

Figure 19 Modular and centralized extinguishing systems

Modular systems, on the other hand, consist of space-saving compact units that are installed within the protection zone itself. These units combine fast and reliable detection with quiet and safe extinguishing in one compact package. Such systems are particularly suitable for the protection of small enclosures with volumes up to 132 m³ that contain electronic and electrical equipment. The main cost-saving advantage of such systems is that they can be installed quickly and easily, and service and maintenance costs are very low.

Technological investigations have shown that malfunctions can occur in hard disk drives when automated dry extinguishing systems are activated. These malfunctions range from automatic shutdowns to more severe disturbances, with a corresponding loss of data. Studies by independent organizations concluded that it was primarily the high noise level generated by conventional extinguishing systems during the discharge process, which caused the hard disk drive malfunctions. Different factors can help to reduce the noise level generated during a discharge, such as improving the room acoustics or extending the discharge time. Research conducted by Siemens identified the nozzle design as one of the main contributors to reducing the noise.

Kitchens

The fire risk in kitchens is relatively high. This is due to a combination of the cooking materials used (cooking oils, fats, etc.) and the heat from the hot cooking equipment (hot-plates, ovens, vats, etc.). Kitchen fires are predominantly fat fires, which often start spontaneously and rapidly generate an intense heat. The flames are also fed by the highly combustible fat vapors and can only be checked by interrupting the oxygen supply and reducing the temperature of the cooking oil.

An additional problem related to kitchen fires is their inherent ability to spread through the kitchen's own air extraction system to the rest of the building. The critical areas (e.g. cooking range, deep fat fryers, ovens and air extraction system) should be protected by specially designed extinguishing systems. Wet chemical fire extinguishers (Class F) should also be provided.

When extinguishing systems are used in commercial kitchens, then these are wet chemical systems, which are installed immediately above the protection area or within the air extraction hoods. They are stand-alone systems, which both detect the fire and extinguish it automatically. The effectiveness of this extinguishing agent relies on the cooling of the hot surfaces together with a highly efficient fire suppression mechanism. On contact with the hot fat, the extinguishing agent foams up to produce a soapy layer. This creates a dense barrier between the hot fat and the surrounding air, effectively preventing the highly volatile fat vapors from escaping and reigniting the fire.

If the building is equipped with a sprinkler system, then this should be extended to protect the other parts of the kitchen. However, it must be ensured that the water spray from the sprinklers cannot reach the critical areas of the cooking range, deep fat fryers, ovens and air extraction system.

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7. References

[1] "Built Heritage: Fire Loss to Historic Buildings – The Challenge before Us" by Ingval Maxwell: a COST[1)] Action C17 report

[2] "Guide for Practitioners 7 – Fire Safety Management in Traditional Buildings" by Stewart Kidd issued by Historic Scotland

[3] "Fire Risk Assessment for Collections in Museums" by Jean Tétrault published in the Journal of the Canadian Association for Conservation (Volume 33)

[4] "Fire safety and heritage buildings" by Peter Barker published on the website of the NBS (National Building Specification)

[5] "Manual Fire Extinguishing Equipment for Protection of Heritage" by Geir Jensen: a COST Action C17 report

[6] "Hypoxic Air Venting for Protection of Heritage" by Geir Jensen: a COST Action C17 report

Footnote:

1) COST – the European CO-operation in the field of Scientific and Technical Research
Action C17 Built Heritage: Fire Loss to Historic Buildings

Siemens Switzerland Ltd
Building Technologies Division
International Headquarters
Gubelstrasse 22
6301 Zug
Switzerland
Tel +41 41 724 24 24

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