Fire Safety for Historic Properties: Five Teaching Modules | 2014-05
Historic Windsor

National Park Service
U.S. Department of the Interior

National Center for Preservation Technology and Training
August 25, 2014

Dear Colleagues:

We are honored to provide you with a copy of Fire Safety and Historic Properties - a Series of Five Teaching Modules. This project has been funded by the National Center for Preservation Technology and Training and developed by the Fire Safety Institute, Preservation Architecture, and the Preservation Education Institute. As part of the project, we are able to make a copy available to each State Historic Preservation Office, each State Fire Marshal Office, and several nonprofit organizations that work in both fields. We are thankful to the National Council for State Historic Preservation Officers and the National Association of State Fire Marshals for their help in distributing the course materials. It is our hope that you will work together to present the teaching modules in your states and local communities. The program is an effective educational program for use with Certified Local Government (CLG) programs in cities and towns and for inclusion in programs at statewide historic preservation or fire safety conferences.

The teaching module PowerPoint presentations are found on the flash drive and there is a full hard copy of the slides with the presenters’ notes. We suggest you add your own case studies and images to it. The material will be available on www.preservationworks.org and www.ncptt.org.

The basis of this educational project is that fire service, historic preservation and code enforcement share the protection of life and property at the core of their respective missions. We hope you find the teaching modules helpful. Let us know and help us make them better.

Sincerely,

Judy L. Hayward
Executive Director
Fire Safety for Historic Properties: Five Teaching Modules

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Fire Safety for Historic Properties- Teaching Modules

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Attachment- flash drive with the presentations and Instructions

For more information about this series please contact:

The Preservation Education Institute

Historic Windsor, Inc. 802 674-6752

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www.preservationworks.org
Instructions for Course Organizers and Speakers

Introduction

This series of teaching modules is designed to provide building professionals and property owners and managers with an understanding of how to mitigate fire risks in historic properties. A second but equally important goal is to provide a means for historic preservationists, fire service professionals, and code enforcement officers to work together to mitigate these risks. By involving each discipline in the instruction of these educational programs, the partners have the opportunity to teach fire prevention in historic buildings and to build team efforts to work toward the prevention of fire in historic buildings after the educational sessions have been completed. The assumption is that it is likely to be someone from the historic preservation community to initiate the educational program but it doesn’t have to be. Fire Service and Code Enforcement Officers can take the lead too. The series has been developed with the core values of protecting people, property, and historic character as shared goals and public responsibilities.

This packet contains a hard copy of the PowerPoint images with the instructors’ notes and a flash drive with the PowerPoint presentations to support copying and presenting the sessions. Consider printing the handout version of the PowerPoint presentation for the participants or providing them with flash drives of the materials.

Getting started

Each Module begins with an overview of the entire series and some reminders of what was covered in the previous session.

1. We suggest that you review each PowerPoint presentation with the notes as a first step.

2. Consider whom you will invite to form your training team from your state or locality to teach with you. You may want to share the PowerPoint information with them as a means of introducing the topic.

Qualities for good speakers to consider are comfort with public speaking, willingness to share information, experience and education with the topic and a desire to build effective coalitions between historic preservation, fire service and code enforcement.

3. This curriculum works well as a learning experience for architects or other groups seeking continuing education credit. The educational program has been registered with the American Institute of Architects CES program by the Preservation Education Institute in Windsor, Vermont, part of Historic Windsor, Inc. a nonprofit 501 c3 historic preservation organization. Please contact the staff via the email listed on the website www.preservationworks.org or by calling 802 674-6752 for information if you wish to offer this for credit to architects. The Preservation Education Institute will charge a nominal fee to register the course session with the AIA of $50 and subsequently, $5 per person for processing credits and providing certificates electronically for architects. This fee is current as of August 2014 but could be subject to increase if costs increase. The program can be run as a daylong educational experience for 5 AIA HSW (Health, Safety, and Welfare) Units or as five, one hour sessions for 1 AIA HSW Learning Unit.
each but you must get approval from HWIPEI at **least 30 days in advance in writing.** The American Institute of Architects has strict procedures about presenting the course and documenting attendance that must be followed for the credit to be approved.

Municipal planners, Fire Service personnel also need continuing education credit and that can be pursued through local, state, and regional groups on your own.

4. The PowerPoint slides are your framework but you can customize this training. Consider how you will introduce case studies into this curriculum from your state or locality. Have there been significant losses of historic buildings? Are their examples of recent upgrades by historic properties with detection and suppression system that can be showcased? Reach out to your community and ask about projects. People love to showcase a good project. As the course leader or presenter you will need to get good illustrations such as before and after images, detail shots of system elements as installed, shop drawings to discuss, and gather anecdotal information from those who own and use the property.

5. The notes section of the PowerPoint will guide you through the basic points of the slides as presented but feel free to add information that expresses the slides from a local, regional, or state point of view.

6. Train the trainer programs can be arranged on a fee basis. Feel free to contact the staff at the Preservation Education Institute to discuss. Sessions can be done over the Internet via Google Hangout or Skype or other service or in person.

7. The curriculum and people with disabilities- Here is checklist of things to consider:

   ✓ Hold the educational sessions in wheelchair accessible spaces with wheel chair accessible restrooms.
   ✓ When registering guests inquire or include on the registration form a question or space to ask if accommodation for disability is needed.
   ✓ Offer to get a sign language interpreter for deaf participants with 72 hours notice, and remember to include this item in your budget for presenting the course.
   ✓ The fonts in the files on the flash drive can be enlarged. You can make large print versions for someone who needs them.
   ✓ Keep the white background and black lettering in the presentation materials. Simpler is better and easier for everyone to read, view, and comprehend the text and images.
   ✓ If you have visually impaired students, discuss the content of the images. Let your discussion flow naturally; describe for everyone in the room not just those with visual impairment. Everyone will benefit from a shared understanding of what the images illustrate.
   ✓ Give feedback to the Preservation Education Institute staff about how to improve the content for people with disabilities. [www.preservationworks.org](http://www.preservationworks.org) and 802 674-6752.

8. Refreshments make everyone feel welcome. Light refreshments are great if you are presenting this one session at a time. If this is presented as a full day option, consider snacks and how to plan for lunch, whether “brown bagging it,” catered, or on one’s own. The instruction time is one hour for each module but you will need to add time for lunch and breaks when offering the whole course.
in one day. If you present all five sessions in one day, feel free to use only one or two icebreaker suggestions.

**Lesson Plan for Module One- Fire Prevention**

1. Review the Learning Objectives and make sure you work toward them. Learning objectives answer the question, “What should participants know or do after attending this session?”
2. **We suggest that this session is a great program to be conducted by someone in Fire Service.**
3. The presenter for this session should begin with an ice breaker by asking everyone to introduce himself/herself and tell why attending the training is important for him or her.
4. After completing the course, which should take about 50 minutes, use the summary slide to review key points.
5. Ask for questions and comments for approximately 10 minutes.
6. Thank everyone for their participation.

**Lesson Plan for Module Two- Working with Codes**

1. Review the Learning Objectives and make sure you work toward them. Learning objectives answer the question, “What should participants know or do after attending this session?”
2. **We suggest that this session is a great program for a code enforcement officer to conduct.**
3. A good icebreaker for this session is to ask students to share experiences of which they are aware where codes saved a life or protected building fabric. The presenter should have a story to share to get things moving.
4. After completing the course, which should take about 50 minutes, use the summary slide to review key points.
5. Ask for questions and comments for approximately 10 minutes.
6. Thank everyone for their participation.

**Lesson Plan for Module 3 Fire Safe Construction**

1. Review the Learning Objectives and make sure you work toward them. Learning objectives answer the question, “What should participants know or do after attending this session?”
2. **We suggest that this session is a great program to be conducted by a preservation professional, architect and fire protection engineer.**
3. The speakers(s) for this session should begin with an ice breaker by asking participants to share about the loss of historic buildings and what this kind of loss means to them.
4. After completing the course, which should take about 50 minutes, use the summary slide to review key points.
5. Ask for questions and comments for approximately 10 minutes.
6. Thank everyone for their participation.

**Lesson Plan for Module 4 Fire Detection and Suppression**

1. Review the Learning Objectives and make sure you work toward them. Learning objectives answer the question, “What should participants know or do after attending this session?”

2. We suggest that this session is a great program to be conducted by two of the following: a preservation professional, architect, fire protection engineer, or some who installs and services detection and suppression systems. Presenter(s) must refrain from endorsing products by name. Information presented must be impartial.

3. The speakers(s) for this session should begin with an ice breaker by asking participants to share any experiences they have had with fire detection and suppression systems.

4. After completing the course, which should take about 50 minutes, use the summary slide to review key points.

5. Ask for questions and comments for approximately 10 minutes.

6. Thank everyone for their participation.

**Lesson Plan for Module 5- Fire Safe Renovation**

1. Review the Learning Objectives and make sure you work toward them. Learning objectives answer the question, “What should participants know or do after attending this session?”

2. We suggest that this session is a great program to be conducted by a preservation professional, architect, general contractor, or fire protection engineer.

3. The speakers(s) for this session should begin with an ice breaker by asking participants to share their experiences fire protection on active preservation, rehabilitation or renovation projects.

4. After completing the course, which should take about 50 minutes, use the summary slide to review key points.

5. Ask for questions and comments for approximately 10 minutes.

6. Thank everyone for their participation.

**Evaluations and Information**

For information, questions, and to provide suggestions on making the course better, please contact the Preservation Education Institute, Historic Windsor, Inc. PO Box 21 Windsor, VT 05089-0021 802-674-6752. [www.preservationworks.org](http://www.preservationworks.org)
Module 1

Fire Prevention for Historic Properties
Fire Prevention for Historic Properties

Part One of Fire Safety for Historic Properties
This Project

• This project was developed by the Fire Safety Institute, Middlebury, Vermont with the assistance of the Preservation Education Institute.

• This project is now administered by the Preservation Education Institute, Historic Windsor, Inc. Windsor, Vermont.

• For Information: www.preservationworks.org
Funding

• This publication was developed by a grant from the National Center for Preservation Technology and Training, a unit of the National Park Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training (NCPTT).
Some times the term “Fire Safety” means different things to different people. The term “Fire Protection” is also used but to many that is an activity distinct from “Fire Prevention”. So, when we say Fire Safety we are including both fire protection and fire prevention.

The top part of the Fire Safety Concepts Tree that we will talk more about later. shows the logic of how fire safety can be achieved by either preventing fire from occurring or by managing the impact of a fire if it does occur.

In the property insurance industry, fire safety is sometimes considered equivalent to life safe and does not cover their primary interest in protecting property. As we shall see, the box labeled “Manage Fire Impact” in the Fire Safety Concepts Tree, has a broad connotation. It covers the impact of fire on people as well as on property and other assets that may be threatened by a fire such as cultural heritage and the environment.
Fire Safety for Historic Properties

• Fire safety is sometimes overlooked by preservationists.
• In order to protect cultural resources against natural and human threat of fire, five teaching modules have been developed for delivery or distribution to preservation conferences and academic institutions.
• Each module is compiled electronically for optimum dissemination and presentation technology and includes notes for instructors.

This presentation is one of 5 parts to a fire safety program for historic properties.
The Five Teaching Modules on Fire Safety for Historic Properties

1. Fire Prevention
2. Working with Code Requirements
3. Fire Safe Construction
4. Fire Detection and Suppression
5. Fire Safe Renovation

The five parts are:
1. Fire Prevention

Avoiding the occurrence of fire is the most desirable approach to fire safety. This module discusses conventional approaches and specific features for historic buildings with emphasis on awareness and management.

This is the first module and the subject of this presentation.
2. Working with Code Requirements

An evolving new generation of fire safety codes and standards allows more flexibility and specifically address historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, and performance-based fire safety.

In the second module we look at interactions of code requirements and historic preservation.
3. Fire Safe Construction

Building code objectives for means-of-egress and containment of fire can be met without significant intrusion on the fabric or architecture of a historic building. Fire resistance of archaic materials and evaluating inherent and necessary fire safety are part of this module.

Features of building construction are usually underlying factors in major fire losses.
4. Fire Detection and Suppression

Modern fire safety technology can address many issues in both code compliance and protecting historic buildings from damage or destruction by fire. New types of fire detection and suppression systems have the capability to protect from fire while avoiding physical and esthetic impact on significant and sensitive historic materials and features.

Many fire safety deficiencies can be offset with appropriate fire systems.
5. **Fire Safe Renovation**

A high proportion of fires in historic buildings occur during renovation or preservation activities. This module covers fire precautions needed during the construction phase of a rehabilitation or restoration project.

Any work done at an historic site introduces factors that make it more vulnerable to fire.
We begin our discussion by identifying what it is we are trying to achieve by preventing fire. There are 3 principal objectives of fire safety in historic buildings: Life Safety, Property protection, and preservation of cultural heritage.
Life safety is most often achieved through the application of fire safety codes and standards. The primary purpose of a building code is to protect the occupants from harm. In most situations the legal requirements for life safety from fire also contribute to the other objectives of fire safety.
Property protection refers to the protection of physical assets that are at risk of loss to fire. Most often we quantify the potential loss by considering the financial value of the assets. These would include both the building and its contents.
Preservation of Cultural Heritage

To the extent that structural features and artifacts are of significant historic value, protecting them falls into the category of preserving cultural heritage.
Mission continuity may be important in a historic building that is dependent on its use to produce income.

Environmental concerns associated with fire include large amounts of smoke and toxic products of combustion that are harmful to the environment. Also, water used in fire fighting can become contaminated and run off inappropriately damaging local environment.
Most often preservationists focus on ways to control the effects of time and weather on a building.

However, a fire can destroy in minutes what could take nature centuries.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
Fire Safety Concepts Tree

- One way to gain understanding of relationships of different fire safety strategies

- Diagrammatic logic structure of all possible ways that fire safety can be achieved.

- NFPA 550

This logic diagram as described in the document NFPA 550, *Guide to the Fire Safety Concepts Tree*, is a representation of all the ways there are to achieve fire safety.
Major Branches of the Fire Safety Concepts Tree

These are the major branches of the Fire Safety Concepts Tree. While this module is concerned with the top branch, other modules in this series are represented by other parts of the tree.
We can achieve our fire safety objectives by preventing the fire from occurring or, if it does occur, by controlling the impact it has on a building and its contents, including occupants and our cultural heritage.
This part of the Fire Safety Concepts Tree shows the logic of how objectives of fire safety can be met by either preventing fire from occurring or by controlling and managing a fire if it does occur. The plus sign in the small circle is called an “or gate” and refers to the logic that the concept in the box at the top, fire safety, can be achieved by either of the boxes below.
Fire Prevention for Historic Properties

- Avoiding the occurrence of fire is the most desirable approach to establishing a fire safety program for any building whether it is historic, commercial, residential, or institutional.
- This module includes conventional approaches to fire prevention as well as specific features for historic buildings.
- The emphasis is on increasing evaluation and awareness skills for identifying and mitigating potential fire loss.
- Critical components of a successful fire safety program will be presented.

This presentation introduces the basic concepts of preventing the occurrence of fire in a historic property.
Fire Prevention for Historic Properties

Learning Objectives

Participants will be able to do the following:

• List common causes of fire loss
• Evaluate potential fire sources in historic buildings.
• Recommend steps to mitigate ignition hazards.
• Develop and apply management strategies for increased fire safety in historic and cultural settings.

These learning objectives represent the knowledge and practice that participants should be taking away with them after the course.
Although there are statistics that point to frequent ignition scenarios, they are generalizations that have limited significance for specific buildings. What we do know for sure is that most fires originate with some human activity.

Primary Causes of Fires

- Men
- Women
- Children
Fire Prevention

- Control heat-energy sources
- Control fuel sources
- Control heat-fuel interaction

Fire occurs when something hot comes in contact with something that can burn, i.e. combustibles. The basic concepts of fire prevention are to eliminate or control as many heat sources as possible, to eliminate or control as many combustibles as possible, and otherwise keep the combustibles away from the heat sources.
Moving down the Fire Safety Concepts Tree, it shows the basic concepts of fire prevention are to eliminate or control as many heat sources as possible, to eliminate or control as many combustibles as possible, and otherwise keep the combustibles away from the heat sources. Again, the “or gate” (plus sign in the small circle) refers to the logic that the concept in the box at the top, Prevent Fire Ignition, can be achieved by any of the strategies in the boxes below.

In practice, we are seldom able to completely or reliably carry out a single strategy so we try to do some of all three.
There are many appliances and systems that are intended to produce heat for comfort or cooking. Other appliances and equipment produce heat as by-products of their operation for example computers. Smoking is still one of the most common fire causes. For example there have been outdoor fires in wood mulch from discarded cigarettes. Natural causes include lightning while exposure can be to nearby buildings or wild fires. Special events may include indoor pyrotechnic displays such as led to the disaster in the Rhode Island night club.
Scientifically, ignition sources can be classified by the type of energy produced. In addition to these common forms, there are also nuclear and solar energy. There is an instance of reproduction replacement of bulls-eye glass that so magnified the sun's rays as to cause a fire. It had not happened with the original, more imperfectly formed, bulls-eye.

<table>
<thead>
<tr>
<th>ENERGY FORM</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEMICAL</td>
<td>Fuel burning appliances and equipment</td>
</tr>
<tr>
<td></td>
<td>Cutting and welding</td>
</tr>
<tr>
<td></td>
<td>Smoking</td>
</tr>
<tr>
<td></td>
<td>Spontaneous heating</td>
</tr>
<tr>
<td></td>
<td>Candles and other open flames</td>
</tr>
<tr>
<td>ELECTRICAL</td>
<td>Resistance heating (overloaded circuits)</td>
</tr>
<tr>
<td></td>
<td>Arcing (loose connections)</td>
</tr>
<tr>
<td></td>
<td>Static</td>
</tr>
<tr>
<td></td>
<td>Lightning</td>
</tr>
<tr>
<td>MECHANICAL</td>
<td>Friction (rubbing two sticks together)</td>
</tr>
<tr>
<td></td>
<td>Resonant heating (the principle of diesel engines)</td>
</tr>
</tbody>
</table>
An important relationship regarding ignition is that for many combustible materials the temperature at which it may ignite is a function of how long it is exposed to that temperature. For example in the figure, a material exposed to a temperature $T_A$ for a time $t_A$ will NOT ignite while the same material exposed to the lower temperature $T_B$ for a longer time $t_B$, will ignite. This explains why wooden structural members in contact with heating system components (conductors, vent pipes, etc.) may initiate a fire after many years. Basically, anything that produces heat-energy of any kind can be an ignition source.
Electrical systems and appliances continue to be one of the most frequent causes of fires in historic buildings. We look at Basics (fundamental principles), Problems (primary failure modes), and Fixes (management opportunities).
The most common ways fires are initiated by electricity are failures in the electrical distribution system and failures in electrical appliances from light bulbs to space heaters, and including coffee makers, toasters, and computers.

Ways Electricity Starts Fires

• Overheating – over current from excessively loaded circuits
• Arcing – Spark like discharge from worn or damaged wiring or circuit components
• Exposure to electrical appliances
Knob and tube wiring can be fire safe if properly maintained and protected from possibly causing electrical shock. In most instances it is better to replace it with modern insulated wiring.

**Old Wiring**

- **KNOB & TUBE**
  
  "Hot" and neutral wires were kept separated by space – using ceramic knobs to hold the wires in place and ceramic tubes to pass wires through wooden members.
Plug or screw-in-fuses are over-current protective devices that work but are subject to abuse by replacement with fuses or other objects that are not appropriate for the circuit being protected.

Circuit breakers “trip” when there is an overload and can be reset without replacement when the condition has been corrected.

Arc Fault Circuit Interrupters (AFCIs) are an advanced technology breaker. (See next slide)
Arc fault circuit interrupter (AFCI) includes the overcurrent protection of a circuit breaker plus the ability to detect arc faults.

They are not the same as GFCI (ground fault circuit interrupter) which has the main function of protecting people from electrical shock.

While AFCIs are now required by the National Electrical Code for some areas of new construction, they are more effective at preventing fires in older wiring systems.
Controlling Electrical Fire Risk

- Have a licensed electrician conduct inspections every one to five years
- Make sure new installations and modifications are done by licensed contractors
- Don’t overload circuits
- Avoid extension cords

These are some of the fire prevention considerations that can be incorporated into a fire safety plan.
These are some more fire prevention considerations that can be incorporated into a fire safety plan. The last can be accomplished using infrared thermography, the same technique that firefighters use to find hot spots in a burning building. (See next slide.)

**Controlling Electrical Fire Risk**

- Monitor portable appliances
- Watch for signs of loose connections, damage to wiring or equipment, overheating
- Use AFCIs on branch circuits
- Schedule testing for hot spots
Firefighters use infrared thermography or thermal imaging to identify hot spots inside walls or ceilings. It is also used to assess energy efficiency in buildings. There are companies, including some insurers, that will schedule regular testing (every 1-3 years) to identify any areas of electrical systems that may be unduly hot.
Be alert for:

- Frequently tripped breakers
- Power “blinks” (momentary interruptions)
- Dimming or flickering lights
- Sizzling or buzzing noises
- Loose or damaged outlets

Have a licensed electrician check it.

These are conditions that could indicate an electrical problem and should be attended to.
We looked at the typical sources heat-energy in buildings, now we consider the right hand box of the logic diagram which refers to controlling the fuel or substance that might be ignited by heat-energy sources.
The combustible materials that are typically present include more permanent items such as construction elements, interior finishes, and major content items. But sometimes it is more important to look at the transient fuels such as supplies including flammables, and accumulated waste.
Combustibility of Materials. Ignition is the initiation of combustion. It originates with the heating of a fuel by a heat source, a process controlled by thermodynamic properties of materials and the environment. When the temperature of the material is raised sufficiently, it begins to pyrolyze or decompose from the heat into simpler substances, primarily combustible gases and vapors. Different substances are produced at varying rates and temperature regimes. When an adequate mass of combustible gases and vapors is mixed with oxygen or air and exposed to an energy source of sufficient intensity, ignition will take place.

What happens next is a function of the intensity of the ignition source and the nature of the material ignited, and the surrounding conditions in which the ignition takes place.
Controlling fuel means limiting the amount and combustibility of materials that are present in the facility. Very small amounts of ordinary combustibles are generally not a problem. Larger amounts can lead to a serious fire depending on their nature and location.

COMBUSTIBILITY OF MATERIALS

• Material Properties

• Flame Spread

• Environmental Factors
Material Properties

- Chemistry
- Physical state
- Surface Texture
- Moisture content

Material Properties. The tendency of a material to ignite is a function of its chemistry, physical state, surface texture, and moisture content. Different chemical compositions have different minimum temperatures at which they will ignite. Ignition is a function of time as well as temperature. A potential fuel subjected to a relatively high temperature for a short period of time may not ignite, while the same fuel can undergo ignition when exposed for a longer duration to a lower temperature. For example, wood products have a normal ignition temperature of 400-500°F (204-260°C), but they have been found to ignite when subjected to a much lower heat source of 228°F (109°C) for four days.

Contents of most buildings consist of combustible materials. Accumulations of readily ignitable items constitute a fire hazard. Construction materials such as siding and roofing can increase the possibility of fire spread from other buildings. This is especially true of wood shingles that are not fire retardant treated.
Flame Spread

- Movement of fire across the surface of a combustible material
- Building code requirement for interior finishes

**Flame Spread.** Combustibility is the principal factor contributing to the spread of flame across surfaces. Once ignition takes place the flame heats surrounding material, causing it to ignite and thereby spread across the surface. The rate at which flame spread occurs is measured by test. Building codes have restrictions on the use of materials with high flame spread rates.

A single layer of paint and most wall coverings add little fuel to a fire. Even if it burns completely, only a small amount of heat is liberated and little damage results. On the other hand, the substrate on which the paint or paper is applied can have a great influence on flame spread. Paint on a metal ceiling may not ignite at all under fire exposure because the heat is dissipated in the metal.

Walls in older buildings may have been repeatedly painted or papered. When five or more layers of paint and paper are present, flame spread may be significantly increased.

The existence of interior wood paneling as found in many historic structures adds to the fuel and thereby increases flame spread. Combustible composition ceiling and wall materials and plastics, both in the form of high density solids and expanded foam products, may also contribute to flame spread. Flame spread in low density cellulosic materials used extensively in some older buildings for ceiling tile and wall panels may be faster than most people can run.
Situation Factors

- Features of the room or space in which something is burning.
- May include:
  - How the fuel is arranged
  - How big the space is
  - Thermodynamics of openings and surfaces

Situation Factors. Sustained burning of the fuel material depends on its combustibility and additional factors such as interaction of surfaces, fluid flows, and thermal absorptions. These are neither well defined nor predictable outside of the laboratory. Observed conditions that produce these effects include arrangement of combustibles, wall materials, and room dimensions.

Furnishings and other combustibles that are close together will cause fire to spread easily from one item to another. A fire starting in a corner will grow in size about four times faster than one in the middle of a room. (See next slide.) Flame spread is much faster on vertical surfaces than on horizontal ones.

In general, fire develops more slowly in larger spaces. This is particularly true with respect to the height of the ceiling. A low colonial style ceiling will allow a fire to develop faster than in a space with a high Victorian ceiling. Fires that can vent themselves to the outside through windows or other means are less likely to spread to other parts of the building. Keeping doors closed, even if they are not rated fire doors can slow down the spread of a fire.

Modern computational fluid dynamics can simulate how a fire will grow and spread based on these factors.
These figures represent a waste basket fire positioned in three different locations within a room; middle, along a wall and in a corner. The diagrams represent the height of the flame at the same time after ignition. The fire in the corner is twice as high as the fire in the middle of the room even though the cross-section areas of the flames are the same in all three cases. Fire prevention should include awareness of how fast a fire in a specific situation will grow. This is part of scenario analysis – envisioning a potential fire and considering how and where it will spread.
Limiting Combustibility

It is often difficult to assess the combustibility of materials outside of the laboratory. In general inorganic materials are least combustible. Metal, marble, and ceramics are about as safe as you can get. Wood burns but not as fast or as hot as modern polymeric materials. Very low-density materials such as foamed plastic have what is called “low thermal inertia” that allows heat to build up on their surface quickly producing rapid flame spread.

The types of materials that can be controlled for their combustibility are furnishings, interior finishes, and structural elements.
Furnishing Materials

- Often the first item ignited
- May be a component of a work space

**Furnishing materials.** Typically the first item ignited in an unwanted fire is an item of furnishing or other typical item in a living or working space such as a computer housing or the contents of wastebasket. Noncombustible materials should be used as much as possible for furnishings and other contents of the building. Where the intended occupancy of the building introduces combustibles that cannot be substituted for, the resultant amount of potential fuel must be considered when fire suppression systems and evacuation systems are designed. The State of California has the most rigid requirements for fire safe furnishings.
Interior Finish Materials

- Walls, floors, ceilings
- Accountable for “flame spread”

**Interior Finish Materials.** Choice of interior finishes should be given careful consideration. For example, where highly combustible wood veneer paneling must be replaced, it may be appropriate to substitute a fire resistive product. Fire resistant carpeting is available, and draperies of glass fiber or other fire resistive materials should be considered.

Coatings and treatments are available that will effectively reduce the surface flame spread rating of many combustible materials. (See slide after next.) Although they may not render a material noncombustible, they significantly reduce the ease with which a material will ignite. Such applications should be considered whenever a noncombustible substitute is either not available or not suited to a particular application. Caution is necessary to avoid a coating that contains a chemical or other product that will damage any historic material on which it will be applied.
Construction Materials

- May be combustible or non-combustible
- Structural elements may need to be fire-resistive.

Construction Materials. Careful consideration should be given to the use of fire resistive materials and methods whenever these materials and methods will not damage the structure's historic character. This is especially true in concealed areas and other areas not exposed to the public.

Inert or fire resistive materials should be used where appropriate including some cases where the structure is to be substantially rebuilt or when items used in original construction are unavailable. Ingenuity can produce fire safe components that simulate wood roofing and numerous other products. In some instances the use of substitute materials for original wood may be appropriate: rough sawn wood can be duplicated in appearance by casting concrete in a mold or form which bears the marks that are desirable on the surface of the finished product, or wood shingles can be easily simulated with fire resistant materials. Wood shingles and shakes that have been given a fire-retardant treatment are commercially available. Even if community fire regulations and codes do not require the use of such materials, they should be considered.
These are the three basic means we have of reducing the combustibility of historic materials. Intumescents are also used as firestopping to prevent the movement of heat and smoke through barriers that are intended as fire walls or smoke compartments.

In addition to limiting combustibility, fire and flame retardant materials will produce different amounts of smoke and toxic and corrosive products of combustion.
While we cannot always practically avoid or control ignition sources and combustible materials, we can also try to control their interaction as an inherent part of daily operations and activities. However, this is most difficult in the case of arson where the motivated arsonist is the mechanism by which a heat source is transmitted to a fuel.
Factors that Bring Heat and Ignitable Material Together

- Misuse of heat source
- Misuse of ignitable material
- Mechanical or electrical failure
- Design, construction, or installation deficiency
- Human error in operation of equipment
- Natural causes (earthquake)
- Exposure (wildfire)
- Arson

Most of these common ways that ignition sources and fuels interact are considered accidental and specific controls can often be applied in terms education, engineering, and enforcement. Arson is an intentional act that needs special attention.
As one of the most common causes of fires, the potential for arson at a historic site is a necessary part of fire prevention planning.

We will look at motives, potential targets, and using security for arson reduction.
The many different reasons why people burn buildings make arson hard to predict. Arsonists are not generally very sophisticated criminals. Very often they repeat their crime at the same or similar location in the same or similar manner. There are typical arsonists and arson patterns. However, since the crime often destroys some of the evidence, it is a difficult crime to prosecute.

Arson Motives

- Vandalism and Malicious Mischief (Juvenile fire setters)
- Revenge or Spite
- Pyromania or Other Mental Illness
- Arson for Profit or Personal Gain
- Arson to Conceal Other Crimes
- Arson as Terrorism to Destroy Iconic Property
While an arsonist can strike anywhere, there are some spaces that are statistically more prone.

**Arson Targets**

- Most parts of most buildings are susceptible to arson
- Fires are frequently set in restrooms, cafeterias, storage rooms, & lobbies
- Vacant buildings or construction areas are many times more likely to have a set fire than occupied buildings.
There are some basic means to help minimize the likelihood of arson at a historic property. Security – keeping arsonists out - is a primary fire prevention practice. Also, avoid giving an arsonist the tools to start a fire.
While most fire prevention focuses on accidental fires, sites may also need to consider reducing the opportunity for intentional fire setting.

Removing Fuel, Accelerants & Ignition Sources

- Relocate and empty dumpsters
- Remove combustible yard storage
- Lock away flammable liquids and aerosols
- Protect sheds, drop boxes, book returns, etc.
- Control ignition sources
Many historic properties rely on a security plan to protect from theft of artifacts. Others need additional planning to consider the risk of terrorism. All facilities will benefit from the reduced risk of arson by implementing basic security measures.
Security involves awareness of the threats and procedures to minimize impact.

Security systems may involve procedures such as key control and parcel control as well as electronic monitoring. Security monitoring can sometimes be combined with fire detection. Security training for staff and docents can include fire hazard awareness, for example, where would an arsonist be likely to start a fire.
All facilities will benefit from the reduced risk of arson by implementing premises security measures. More information on security can be found in Annex U of *NFPA 914, Code for Fire Protection of Historic Structures*. 

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**Restricting Access to Sites**

- Fencing / Barriers
- Lighting
- Entry Control & Staff Identification
- Guard Service
- Emergency Notification Procedures & Equipment
So, the logic tree tells us we can prevent fire by controlling any one three factors: ignition sources, combustibles, and their interaction.
Now that we know some of the concepts of fire prevention, we need to consider how to manage the risk. Typically this involves creating specific policy for dealing with fire safety, identifying an appropriate checklist for awareness of fire prevention activities, and surveying the site periodically to determine that appropriate fire prevention is being carried out.
Fire Safety Plan

- NFPA 914
- Insurer / Local Fire Department
- Fire Prevention Component

Guidance on formulating an appropriate fire safety plan can be found in the document NFPA 914, Code for Fire Protection of Historic Buildings. Your property insurer can also help and your local or State fire marshal can provide appropriate resources.

As we have seen, Fire Prevention is one of 2 ways to meet fire safety objectives so it is a crucial part of a fire safety plan.
There are several guides to developing an appropriate fire safety checklist or you can use an existing checklist such as Annex J of NFPA 914.

Sometimes it is most convenient to have a checklist for each area within the facility.

The checklist should include the regular practices of management in education and assurance of compliance with fire safety policies, for example, smoking.
The checklist can be used to conduct periodic surveys or inspections.

Sometimes this can be enhanced by including your insurance representative or fire department personnel.

A crucial component of the survey is the reporting procedure and follow-up assessment of recommendations.
Fire prevention is primarily a function of understanding and appreciation of the ways fire can start and how to avoid them. The fire safety conditions of an historic site are a direct measure of management competency.

**SUMMARY**

Practices that can prevent fires include:
- Oversight of heat sources & ignitable materials
- Housekeeping (combustibles, waste, storage)
- Protection against arson (security)
- Education of staff
- Upgrade and maintenance of electrical systems and appliances
- Active management commitment to fire safety
Questions and Answers

Thank you for your participation.

We now have time for questions.
Here are recommended sources of additional information covered in this presentation. The first 2 are available at www.nfpa.org. The 3rd is out of print but is available by interlibrary loan. The last is available at www.NTHP.org.

**Resources**

Working with Code Requirements

Part Two of Fire Safety for Historic Properties

This is Part 2 of 5 teaching modules on Fire Safety for Historic Properties primarily sponsored by NCPTT.
Teaching Modules on Fire Safety for Historic Properties

• In order to protect cultural resources against natural and human threat of fire, five teaching modules have been developed for delivery or distribution to preservation conferences and academic institutions.
• Each module is compiled electronically for optimum dissemination and presentation technology and includes notes for instructors.

This presentation is one of 5 parts to the NCPTT fire safety program for historic properties.
This Project

• This project was developed by the Fire Safety Institute, Middlebury, Vermont with the assistance of Preservation Architecture and the Preservation Education Institute.

• This project is now administered by the Preservation Education Institute, Historic Windsor, Inc. Windsor, Vermont.

• For Information: www.preservationworks.org
Funding

• This publication was developed by a grant from the National Center for Preservation Technology and Training, a unit of the National Park Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training (NCPTT).
Teaching Modules on Fire Safety for Historic Properties

1. Fire Prevention
2. Working with Code Requirements
3. Fire Safe Construction
4. Fire Detection and Suppression
5. Fire Safe Renovation

The five parts are:
1. Fire Prevention

Avoiding the occurrence of fire is the most desirable approach to fire safety. This module discusses conventional approaches and specific features for historic buildings with emphasis on awareness and management.

The first module deals with preventing the occurrence of fire.
2. Working with Code Requirements

An evolving new generation of fire safety codes and standards allows more flexibility and specifically address historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, performance-based evaluation and fire risk analysis.

In this second module we look at interactions of code requirements and historic preservation.
3. Fire Safe Construction

Building code objectives for means-of-egress and containment of fire can be met without significant intrusion on the fabric or architecture of a historic building. Fire resistance of archaic materials and evaluating inherent and necessary fire safety are part of this module.

Features of building construction are usually underlying factors in major fire losses.
4. Fire Detection and Suppression

Modern fire safety technology can address many issues in both code compliance and protecting historic buildings from damage or destruction by fire. New types of fire detection and suppression systems have the capability to protect from fire while avoiding physical and esthetic impact on significant and sensitive historic materials and features.

Many fire safety deficiencies can be offset with appropriate fire systems.
5. Fire Safe Renovation

A high proportion of fires in historic buildings occur during a renovation or preservation activity. This module covers fire precautions needed during the construction phase of a rehabilitation or restoration project.

Any work done at an historic site introduces factors that make it more vulnerable to fire.
Primary Fire Safety Objectives

- Life Safety
- Property Protection
- Preservation of Cultural Heritage

We begin our discussion by identifying what it is we are trying to achieve by fire safety. There are 3 principal objectives of fire safety in historic buildings: Life Safety, Property protection, and preservation of cultural heritage.
Life safety is most often achieved through the application of fire safety codes and standards. The primary purpose of a building code is to protect the occupants from harm. In most situations, the legal requirements for life safety from fire also contribute to the other objectives of fire safety.
Property protection refers to the financial value of assets that are at risk of loss to fire. These would include both the building and the contents.
To the extent that structural features and artifacts are of significant historic value, they fall into the category of preserving cultural heritage.
Other Fire Safety Objectives

- Mission Continuity
- Environmental Protection

**Mission continuity** may be important in a historic building that is dependent on its use to produce income.

**Environmental concerns** include large amounts of smoke and gaseous fire products that are harmful to the environment. Also, the water used in fire fighting can be contaminated and run off inappropriately.
Most often preservationists focus on ways to control the effects of time and weather on a building.

A fire can destroy in minutes what could take nature centuries.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
Fire Safety Concepts Tree

- One way to gain understanding of relationships of different fire safety strategies
- Diagrammatic logic structure of all possible ways that fire safety can be achieved.

- NFPA 550, *Guide to the Fire Safety Concepts Tree*

This logic diagram as described in the document NFPA 550, Guide to the Fire Safety Concepts Tree, is a convenient, concise, graphical representation of all the ways there are to achieve fire safety.
These are the major branches of the Fire Safety Concepts Tree. The circle with the + in the middle is an “OR gate” indicating that the box or concept above it can be achieved by either of the concepts below it.
We can achieve our fire safety objectives by preventing the fire from occurring or, if it does occur, by controlling the impact it has on a building and its contents.
This part of the Fire Safety Concepts Tree shows the logic of how objectives of fire safety can be met by either preventing fire from occurring or by controlling and managing a fire if it does occur. The plus sign in the small circle is called an “or gate” and refers to the logic that the concept in the box at the top, fire safety, can be achieved by either of the boxes below.
The primary objective of building and fire codes is life safety. There is an intersection among objectives of preservation, fire protection, and construction codes.
Module 2

Working with Code Requirements
In this second module we look at interactions of code requirements and historic preservation. Options for meeting code requirements and alternative methods of fire safety evaluation are introduced.

Fire Safety for Historic Buildings
Module 2
WORKING WITH CODE REQUIREMENTS

An evolving new generation of fire safety codes and standards allows more flexibility and specifically addresses historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, performance-based evaluation, and fire risk analysis.
Module 2 – Working with Code Requirements

Learning Objectives

The participant will know how or be able to do:

• Explain the development of building and fire codes.
• Use codes for fire protection strategies for historic preservation projects and work with code officials for alternative compliance strategies.
• Evaluate differences between specification requirements and performance-based fire safety regulation.
• Identify common problems and solutions when applying codes to historic buildings.

This program will not make you a code expert but will help you ask the right questions and consider alternatives when there is seeming conflict between code requirements and historic preservation.
In this module we will look at the evolution of building and fire codes in the US, how they are used, and what the alternatives are.
The history of authoritative requirements for buildings in the U.S. dates from the seventeenth century. The first fire law on record was passed in the Dutch city of New Amsterdam in 1625 and consisted of rules as to types, locations, and roof coverings of houses. In 1630, the English Governor of Boston ordered that "no man shall build his chimney with wood, nor cover his house with thatch."

Between 1800 to 1900 fires destroyed eleven major US cites, killing an untold number of people and destroying hundreds of millions of dollars worth of property. As a result of these fires large cities began to develop and enforce building codes. Chicago, for example, developed a building code in 1875 as a direct result of the National Board of Fire Underwriters (NBFU) threatening to discontinue insurance business in the city after the Great Fire of 1871. By the turn of the century most major cities had their own building codes.

Following the Baltimore fire of 1905, the NBFU compiled the first US Building Code. By the middle of the 20th century there were an additional 3 regional building codes: Southern, Uniform, and Basic. These last 3 merged into the International Code Council by the end of the century.
Fires causing multiple fatalities have had a significant impact on codes and fire safety legislation.

Significant Fires leading to changes in US codes

- Iroquois Theatre (1903, 600+ dead)
- Triangle Shirtwaist (1911, 146 dead)
- Winecoff Hotel (1946, 119 dead)
- Cocoanut Grove (1942, 492 dead)
- Beverly Hills Supper Club (1977, 165 dead)
- Station Night Club (2003, 100 dead)
Unlike that of other developed nations, the system of authoritative requirements in the US is highly fragmented. There are many sources of regulations and many routes leading to the promulgation of standards. The fifty states that make up the US all have their own differing constitutions and in most states the regulation of fire safety is left to the local community. With a diverse population that usually does not feel very close to its federal government, there are misgivings about authoritative intervention in the US. Allegiance to the idea of "self-regulation" persists. Thus, most regulation of the public health, safety, and welfare is relegated to the State Governments and in turn to municipalities and other local or regional jurisdictions. This autonomy of local governments has lead to a wide variety of regulations creating difficulty for historic preservation professionals whose interest crosses jurisdictional boundaries.
Code Writing Organizations

- ICC – International Code Council
  - IBC – International Building Code
  - IEBC – International Existing Building Code
  - IFC – International Fire Code
- NPFA – National Fire Protection Association
  - NEC – National Electrical Code
  - NFPA 914 Code for Fire Protection of Historic Structures

There is nothing international about the ICC. It formed at the end of the 20th century as a merger of 3 regional code writing groups. The IBC is the most commonly adopted building code in the US. The IEBC is developing into a useful code. ICC also publishes a Fire Code, Plumbing Code, Mechanical Code, and others.

NFPA publishes a building code (NFPA 5000) that is not widely used. NFPA 101 Life Safety Code is widely adopted and especially by federal government agencies. The NEC is used throughout the world. Most applicable to historic preservation is NFPA 914.
Sometimes the distinction between codes and standards gets blurred. Basically, codes are written to be adopted as legal requirements. Building codes specify a minimum level of fire safety to be achieved. Sometimes, such as with culturally iconic structures, the minimum may not be enough.

Standards cover the specifics of how the legal requirement can be achieved. For example, a model building code may specify certain buildings be protected by an automatic sprinkler system. They will refer to NFPA 13, *Standard for the Installation of Automatic Fire Sprinklers*, which describes how a sprinkler system should be designed and installed. Standards can also provide guidance on fire safety that is more than the legal minimum.
NPFA (National Fire Protection Association): In the area of fire standards no organization is more prolific than NFPA. Its standards are referenced in its own codes, those of the ICC (e.g., International Building Code), and national codes around the world.

Standards from ASTM (American Society for Testing and Materials) and UL (Underwriters Laboratories) are also prevalent in US codes.

ANSI (American National Standards Institute) is the US representative to the International Standards Organization but does not itself write codes or standards. ANSI confirms that a standard has been developed through an acceptable process including public input and consensus approval.
Unlike most other countries in the world, fire safety codes and standards in the US are developed by the private sector – non-profit membership organizations such as NFPA and ICC.

These organizations have committees of volunteers who assess suggested changes from the public. Any such changes approved by the committees must still be voted on by the organization’s membership.
Each state or jurisdiction must legally adopt a code before it becomes a mandatory requirement.

Once adopted, the enforcement process is overseen by the AHJ (Authority Having Jurisdiction). The process typically involves the steps or stages of initial planning approval, construction conformance inspections, and a final certification that the building is safe for occupancy.

Along the way appeals may be submitted. It is rare for an appeal for exemption from a fire safety provision is approved solely on historic preservation concerns. The most effective appeals suggest an alternative way to meet code fire safety objectives that does not impact historic preservation. And this works much better if it is addressed as part of an early planning discussion rather than by formal appeal.
Working with code requirements can be undertaken using administrative provisions of the code or by implementing technical approaches to alternatives.
Consultation - Meaningful discourse with the authority having jurisdiction (AHJ) is the most effective means of avoiding conflict between fire safety and historic preservation. Many authorities are sympathetic to the difficulties stemming from such conflict and have developed procedures to help resolve such issues.

Hazard Ranking - Some states have developed a hazard ranking scheme that helps them focus on major fire safety issues with less concern for minor variations that do not significantly impact fire safety.

Proportionality - The most recent concept is an increase in regulation according to the proportion of rehabilitation work that is being performed. The regulations are proportional to the extent of the project. That is, the more work that is done on a building, the more code provisions become applicable. Minor changes may not invoke code requirements but a major rehabilitation project will be regulated in a manner more similar to new construction.
Technical Approaches
to regulatory compliance

• Adapting prescriptive requirements
  – Exceptions
  – Recognized solutions
  – Modifications
• Equivalency
• Alternative Means of Fire Safety Evaluation

Exceptions – Many codes have specific variations for historic buildings. For example, allowance for existing exterior fire escapes

Recognized solutions - There may be alternative solutions to certain issues that have been deemed appropriate on an ad hoc basis by local code officials. For example, the State of Vermont, has compiled: Fire Prevention & Building Code Compliance For Historic Buildings - A Field Guide <http://www.firesafety.vermont.gov/code/historic>. This document illustrates and describes successful examples of code compliance that reconcile fire safety considerations with preservation goals.

Modifications - may be appropriate when physical limitations require disproportionate effort or expense with little increase in public safety or welfare. The legal term de minimus is used in reference to conditions that may be considered impractical and would not contribute significantly to life safety. Tolerances and waivers are among the means of such modifications, for example, a door width that is one inch less than required may be acceptable in a low occupancy building.

Equivalency – Codes have specific clauses that allow for equivalent levels of fire safety provided by means other than the specific provisions of the code. For Example, NFPA 101, Life Safety Code has the following provision:

1.4 Equivalency. Nothing in this Code is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety of those prescribed by this Code.

Establishing equivalency can be difficult. There may be established precedents or recognized trade-offs. Otherwise alternative means of fire safety evaluation can be employed.

Alternative Evaluation – Most codes now recognize forms of fire risk indexing and performance-based evaluation. These will be discussed in more detail later.
In the last few decades the interaction between historic preservation and fire safety has been addressed by changes to codes and the evolution of more applicable codes.

NFPA 101, *Life Safety Code*, is one of the most prevalent regulatory documents in fire safety. It includes an increasing number of exceptions for existing and historic buildings.

IEBC – While building codes have traditionally focused on new construction, the *International Existing Building Code* is compiled specifically to deal with the current built environment.

States such as Massachusetts and California, have their own specific codes to regulate fire safety of historic buildings.

NFPA 914 – *Code for Fire Protection of Historic Structures* is the most comprehensive of such documents and is discussed at length.
NFPA 914

*Code for Fire Protection of Historic Structures*

**Goals:**

Provide protection and life safety from the effects of fire, *while*

Maintaining historic fabric and integrity of building

NFPA 914 is a unique code that focuses on both historic preservation and fire safety.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
The challenge is to meet multiple objectives, recognizing the mutual benefits and conflicts. And, in particular, identifying, and giving credit for features of historic buildings that are inherently fire safe, such as heavy timber construction and high ceilings.
Building codes largely focus on new construction with provisions by those most associated with modern structures, such as developers, building regulatory officials, architects, and structural engineers.

Distinctly, NFPA 914 is the product of a “Technical Committee” of the National Fire Protection Association that represents the specific interests of fire safety for historic structures.
NFPA 914 advocates a team process that begins with examination of the issues, analysis of the alternatives, and ongoing awareness of fire safety.
<table>
<thead>
<tr>
<th>NFPA 914 – Management Operational Systems</th>
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<tbody>
<tr>
<td>• Responsibility / Authority</td>
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<tr>
<td>• Management Plan</td>
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<tr>
<td>• Operational Requirements</td>
</tr>
<tr>
<td>• Emergency Response Plan</td>
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<tr>
<td>• Training / Drills</td>
</tr>
<tr>
<td>• Record Keeping</td>
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<tr>
<td>• Periodic Compliance Audit</td>
</tr>
<tr>
<td>• Procedures for Opening / Closing</td>
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<tr>
<td>• Enforcement and Modification of the Plan</td>
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</tbody>
</table>

For example, there is a chapter on Management Operational Systems that specifies planning, documentation, accountability, and continuing activity.
Other aspects of this holistic approach to fire safety include specific situations that may not be included in other codes.

**NFPA 914 – Provisions for:**

- Security
- Additions, Alterations & Renovations
- Fire Precautions During Construction, Repair and Alterations
- Inspection, Testing & Maintenance
- Special Events
The value of NFPA 914 is enhanced by an extensive set of Annexes that provide guidance to the user. In NFPA documents, an annex is not part of the code requirements but is included for informational purposes. The example annexes in this and the following slide provide valuable information to not only help meet code requirements but to go beyond the code with suggestions for improved fire safety.
NFPA 914 – Annexes (2)

- Basics of Fire and Fire Protection Systems
- Resource List
- Bibliography/Related Publications
- U.S. Secretary of the Interior’s Standards
- Fire Ratings of Archaic Materials and Assemblies
- Upgrading the Fire Resistance of Wood Panel Doors

The Annexes also include tutorial information to help managers appreciate the content.
By their very nature codes are subject to some major limitations.

Generalization – Every building is different, especially historic buildings, and codes cannot address all the idiosyncrasies of everyone of them. And the minimum legal level of fire safety may not be adequate in all cases.

Technical – The structural aspects of building codes are responsive to the force of gravity which is rather well known and constant. On the other hand, the very nature of fire is unsure and there are many aspects of fire safety that have limited scientific justification.

Enforcement – Most fire losses can be traced to a lack of enforcement of codes rather than lack of regulations.

Scope – There are limits to what a code can cover, especially when it comes to human activity. (See next slide.)
Here are some of the attributes of fire safety that are not typically covered in codes. (Incunabula are printed material from before the year 1501 in Europe.)

The last one is particularly interesting. While the property insurance industry pays a great deal of attention to the capabilities of the local fire department, building codes essentially ignore emergency response capabilities.
The limitations of codes leads us to consider alternative methods of fire safety evaluation. Some of these such as fire risk indexing and performance evaluation are specified as options in codes.

### Fire Safety Evaluation

**Methods**

1. *Narrative Codes*
2. *Check Lists*
3. *Fire Risk Indexing*
4. *Performance Evaluation*
5. *Fire Risk Analysis*
To consider methods of fire safety evaluation we can begin with an understanding of what we mean by fire safety.

Public – The public often has a perception of fire safety that is different from what codes specify or what science tells us. This is due to their limited experience with specific provisions or technical knowledge.

Codes – As we have seen, codes are limited by their structure and a perceived minimum level of fire safety. The evolution of science-based codes is slow.

Professional – Firefighters have a high degree of appreciation as to what fire safety is about but may not be focused on protection of cultural heritage. Fire safety scientists are learning new things about unwanted combustion and have a different perspective.
One way to look at fire safety evaluation is to ask these 3 basic questions.

• What is important?
• How do we measure it?
• How much is enough?
When we ask what is important we quickly realize there are no singular solutions and that a myriad of factors can play a role.

**What is Important?**

- No magic bullet
- Many components
As we have discussed, codes are basically narrative descriptions of conditions that are deemed necessary. They are prescriptive and reference prescriptive standards. They try to cover details of a limited number of fire safety attributes. The details may not be important in all situations.

Checklists are simpler in that they use basic terms to identify fire safety attributes without descriptive detail. They are often broader in scope than codes as they can identify concepts rather than nitty-gritty specifications.
The primary limitations of codes and checklists are:

1. There is no or little acknowledgement of how fire safety attributes may interact. For example elevators and emergency egress, which is now being studied.

2. Codes prescribe levels but do not acknowledge the value of a better situation. For example, a code may specify a maximum building height of 3 stories but does not recognize that a one story building is inherently much safer.

3. We do not know what the level of risk is. Statistics are one measure of overall fire safety but we cannot say how much safer one building is than another.
The limitations of codes leads us to consider alternative methods of fire safety evaluation. Some of these such as fire risk indexing and performance evaluation are specified as options in codes.
Fire Risk Indexing

- What is indexing?
- What is fire risk indexing (FRI)?
- How is FRI used?

As we will see FRI is a widely used concept.
Most of us are familiar with the regular news reporting on the Dow-Jones average or the wind-chill factor. The concepts of these applications of indexing that are also used in fire safety.

Indexing

• Financial Index – Weighted average of stock market prices.
  – Dow-Jones, S&P 500
  – Index funds

• Wind-Chill Factor
Compared with codes and checklists, Fire Risk Indexing relates and measures the effects of combinations of fire safety attributes. For example, it may try to evaluate a short distance to exits as being more positive than a lack of rated fire barriers is negative.

Approaches to Fire Safety Evaluation

- Code Narratives – verbal descriptions of requirements
- Check Lists – Abbreviated list of safety attributes
- FRI – Arithmetic model of fire safety that analyzes and scores hazards and other attributes to produce a rapid and simple estimate of relative fire risk
The term attribute is primarily used in decision analysis which is also the source of risk indexing theory. The next slide gives examples.
**Some Fire Safety Attributes**

<table>
<thead>
<tr>
<th>Vertical Openings</th>
<th>Compartmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Height</td>
<td>HVAC Systems</td>
</tr>
<tr>
<td>Automatic Suppression</td>
<td>Smoke Control</td>
</tr>
<tr>
<td>Building Area</td>
<td>Dead Ends</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>Interior Finish</td>
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<tr>
<td>Corridor Separation</td>
<td>Occupancy</td>
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<tr>
<td>Fire Alarm</td>
<td>Emergency Program</td>
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<tr>
<td>Means of Egress</td>
<td>Contents</td>
</tr>
<tr>
<td>Fire Detection</td>
<td>Elevator Control</td>
</tr>
<tr>
<td>Special Hazards</td>
<td>Emergency Lighting</td>
</tr>
</tbody>
</table>

These are familiar components of codes and fire safety checklists.
There is a lot of literature on multi-attribute decision making. Basically this equation says that to the left of the equal sign is an evaluation function (E) of some number (n) fire safety attributes (x). The right hand side of the equation says this function can be expressed as the weighted sum (∑) of each attribute’s significance (weight, w) times how much of it there is present in the building R(x).

You will not be tested on the use of this equation.
One of earliest examples of fire risk indexing is in the insurance industry. Initiated in 1902, the SCOPES of today uses the same concepts.

**Insurance Rating**

- Charges and credits for negative and positive attributes
- Dean Analytic Schedule – 1902
- ISO Specific Commercial Property Evaluation Schedule (SCOPES)
Of particular relevance are the FRI systems incorporated in or referenced by codes. The flexibility of these systems can often help deal with situations where not everything is in compliance with specific code provisions.
This is a worksheet from NFPA 101A, *Fire Safety Evaluation System*. Values for each of 12 different attributes (safety parameters) are entered under each of the three categories of fire control, egress, and general fire safety, except where the cell is blacked out. (The symbol /2= indicates where one-half the value is used.) The totals of each column give a measure of fire risk that is then compared to established values deemed equivalent to NFPA 101, *Life Safety Code*.

<table>
<thead>
<tr>
<th>Safety Parameters</th>
<th>Fire Control (S 1)</th>
<th>Egress Provided (S 2)</th>
<th>General Fire Safety Provided (S 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Construction</td>
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<tr>
<td>2. Segregation of Hazards</td>
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<td></td>
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</tr>
<tr>
<td>3. Vertical Openings</td>
<td>/2 =</td>
<td>/2 =</td>
<td></td>
</tr>
<tr>
<td>4. Sprinklers</td>
<td>/2 =</td>
<td>/2 =</td>
<td></td>
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<tr>
<td>5. Fire Alarm</td>
<td>/2 =</td>
<td>/2 =</td>
<td></td>
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<tr>
<td>6. Smoke Detection</td>
<td>/2 =</td>
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<td>7. Interior Finish</td>
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<td>8. Smoke Control</td>
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<tr>
<td>9. Exit Access</td>
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<tr>
<td>10. Exit Systems</td>
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<tr>
<td>11. Corridor/Room Separation</td>
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<td>12. Occupant Emergency Program</td>
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<tr>
<td><strong>Total</strong></td>
<td>$ 1 =</td>
<td>$ 2 =</td>
<td>$ 3 =</td>
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</tbody>
</table>
Other FRI Applications

- Insurance Services Office, Fire Suppression Rating Schedule
- Industry (Dow Chemical, Fire and Explosion Index)
- Wood frame apartment buildings (In Sweden & Canada)
- Historic buildings (In the US & Canada)
- Wildland fires (archeological site vulnerability)
- Library Collections (US Library of Congress)
- Parish Churches (In the UK)

Fire risk indexing is also used in a variety of other applications.
The next method on our list is Performance Evaluation.

---

**Fire Safety Evaluation**

Methods

1. *Narrative Codes*
2. *Checklists*
3. *Fire Risk Indexing*
4. *Performance Evaluation*
5. *Fire Risk Analysis*
Performance evaluation has evolved as a way to use our greatly increased knowledge of fire behavior. It is now a recognized process in most codes.

Performance-Based Evaluation

Definition

Process that uses quantitative analytical methods to demonstrate achievement of fire safety goals and objectives.
Procedure

Performance-Based Evaluation

• Establish goals and objectives
• Identify performance criteria
• Choose fire scenarios
• Apply fire modeling
• Compare results to criteria
This is a diagram of the performance evaluation process as prescribed by NFPA 101 *Life Safety Code*. At the top of the figure are the goals, objectives, and resulting performance criteria that we are looking for. On the left is the input; characteristics of the building and types of fires we expect. The fires are modeled by computer ("Evaluation of Proposed Design") and, with appropriate safety factors, the outcomes compared to the criteria. If the design achieves suitable performance it is then documented. Otherwise the design needs to be modified and re-evaluated.
Fire Safety Objectives

- Life Safety
- Property Protection
- Mission Continuity
- Environment
- Heritage Preservation

The fire safety objects are typically within these categories.
Performance Criteria

Quantitative statement of objectives in terms of a unit of measure and threshold value

- Life safety-time
- Property Protection-dollars
- Heritage Preservation-???

Performance criteria may seem relatively easy till we get to heritage preservation.
Cultural Value

Heritage Preservation

- Irreplaceable
- Replaceable
- Reproducible
- Expendable

One approach is a qualitative scale. Another technique is level of significance; local, state, national. For example a municipality may designate a local building as significant while most states and the federal government have inventories of significant buildings, e.g., The National Register of Historic Properties.
One of the key aspects of performance evaluation is the identification of appropriate fire scenarios. This concept is one that fire safety engineers use quite often subjectively to assess fire risk, for example, maximum probable loss. NFPA 101 identifies a minimum list of specific fire scenarios that must be used.
There are a lot of computer models to assess outcomes of fire scenarios. This is a highly skilled activity that often precludes application for smaller institutions.

Computer Analysis of Fire Hazard

Performance-Based Evaluation

• The most advanced performance analysis uses computational fluid dynamics (CFD) simulation to assess the outcome of each scenario.

• Other modeling techniques may be appropriate.
Here is a typical graphic output of a CFD (Computational Fluid Dynamics) fire model. It shows the fire spread from the room or origin approximately 9 minutes after ignition.
In addition to such fire models, significant work is ongoing to model the evacuation of people from a building. There are less sophisticated models that assess the effect of heat on various materials and structural components. And in a very limited state of development are models to predict the impact of smoke and corrosive gasses.
Some of the difficulties encountered in sophisticated fire modeling include:

Safety factor – We don’t yet have enough experience to know just how accurate the models are.
Subjective attributes – Modeling human behavior.
Existing buildings – The modeling can help us in the design of new building but is less rewarding for existing buildings.
Cost – This is a very expensive undertaking and is usually limited to iconic structures.
The SFPE (Society of Fire Protection Engineers) Guide is the basic reference on performance evaluation.
## Fire Safety Evaluation

Methods

1. *Narrative Codes*
2. *Checklists*
3. *Fire Risk Indexing*
4. *Performance Evaluation*
5. *Fire Risk Analysis*

The final method we will discuss is Fire Risk Analysis.
Just what we mean by fire risk analysis is not always clear. Sometimes it is only a visual sweep of the premises by an experienced person. At the other end of the analytical spectrum, it can involve researching appropriate probabilities to assign to outcomes of computer modeled fire scenarios.

The range of cost is proportional to the degree of detail.
The cost for a simple fire risk analysis is low but it may not adequately discriminate among options. A detailed, quantitative fire risk analysis can be very sophisticated but also very costly.
Axioms of Fire Risk

- Risk is always greater than zero
- A universally acceptable level of risk does not exist
- A totally objective or scientific way to measure risk

1. It is important to note that we should never contemplate a goal of no risk. The conditions of fire risk are always present in any human endeavor.

2. One reason codes do not identify a level of risk is that they could never reach agreement on what it should be.

3. While a lot work has been done and continues to be done, there remain many different approaches to fire risk analysis.
The basic insurance concept of risk is simply an uncertainty of loss.

As more quantitative approaches have evolved, the expected loss is most common form for calculating fire risk. Expected loss is defined as the frequency or likelihood of an event multiplied by the outcome or severity.

Definition of Fire Risk

- Uncertainty of loss
- Frequency $\times$ Severity
There are 4 basic steps in a quantitative fire risk analysis:
1. Identify hazards or fire scenarios that pose a threat
2. Associate with each hazard a probability or likelihood that it will occur
3. Estimate the consequence of severity of the outcome for each hazard or scenario
4. Calculate the risk as the product of probability and consequence.
This is a graphic representation of risk indicating the relationship of frequency and severity in estimating the magnitude of risk.
Consider as an example 3 basic scenarios. Should a fire occur it may be extinguished manually, e.g. with portable fire extinguishers, or it may be controlled by an automatic sprinkler system. Both of these strategies could fail.

**Fire Risk Scenarios**

1. Failure of both manual intervention and automatic suppression

2. Failure of manual intervention and success of automatic suppression

3. Success of manual intervention
This event tree represents the basic fire scenarios with 4 possible outcomes.

At the top is the scenario where a fire occurs and is not extinguished or controlled.

At the bottom is the scenario of no fire occurring.

In between the fire has been controlled by either manual intervention or suppression.
Fire risk is then calculated as the product of probability and consequence for each scenario.

These values are then added to get the overall expected loss.
NFPA 551 is a guide for code officials but can also be used by others to identify appropriate concepts of fire risk analysis.
This module covered the evolution of building and fire codes in the US, how they are used, and what the alternatives are.

**WORKING WITH CODE REQUIREMENTS**

**SUMMARY**

- Historical Background
- US Regulatory Environment
- Compliance Approaches
- Rehabilitation Codes
- Code Limitations
- Alternative Methods of Fire Safety Evaluation
Questions and Answers

Thank you for your participation.
These books expand on the principles of codes and fire safety and provide more details on specific methods of fire safety evaluation.
Module 3

Fire Safe Construction
Fire-Safe Construction

Part Three of Fire Safety for Historic Properties

This is 3 of 5 teaching modules on Fire Safety for Historic Properties primarily funded by NCPTT.
This Project

• This project was developed by the Fire Safety Institute, Middlebury, Vermont with the assistance of Preservation Architecture and the Preservation Education Institute.

• This project is now administered by the Preservation Education Institute, Historic Windsor, Inc. Windsor, Vermont.

• For Information: www.preservationworks.org
Funding

• This publication was developed by a grant from the National Center for Preservation Technology and Training, a unit of the National Park Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training (NCPTT).
Some times the term “Fire Safety” means different things to different people. The term “Fire Protection” is also used but to many that is an activity distinct from “Fire Prevention”. So, when we say Fire Safety we are including both fire protection and fire prevention.

The top part of the Fire Safety Concepts Tree that we will talk more about later, shows the logic of how fire safety can be achieved by either preventing fire from occurring or by managing the impact of a fire if it does occur.

In the property insurance industry, fire safety is sometimes considered equivalent to life safety and does not cover their primary interest in protecting property. As we shall see, the box labeled “Manage Fire Impact” in the Fire Safety Concepts Tree, has a broad connotation. It covers the impact of fire on people as well as on property and other assets that may be threatened by a fire such as cultural heritage and the environment.
Teaching Modules on Fire Safety for Historic Properties

- Fire safety is sometimes overlooked by preservationists.
- In order to protect cultural resources against natural and human threat of fire, five teaching modules have been developed for delivery or distribution to preservation conferences and academic institutions.
- Each module is compiled electronically for optimum dissemination and presentation technology and includes notes for instructors.

This presentation is one of five parts to the NCPTT fire safety program for historic properties.
Teaching Modules on Fire Safety for Historic Properties

1. Fire Prevention
2. Working with Code Requirements
3. Fire Safe Construction
4. Fire Detection and Suppression
5. Fire Safe Renovation

The five parts are:
1. Fire Prevention

Avoiding the occurrence of fire is the most desirable approach to fire safety. This module discusses conventional approaches and specific features for historic buildings with emphasis on awareness and management.

The first module deals with preventing the occurrence of fire.
2. *Working with Code Requirements*

An evolving new generation of fire safety codes and standards allows more flexibility and specifically addresses historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, performance-based evaluation and fire risk analysis.

In this second module we look at interactions of code requirements and historic preservation.
Certain features of building construction have a significant role in fire safety and often are usually underlying factors in major fire losses.

3. Fire Safe Construction

Building code objectives for means-of-egress and containment of fire can be met without significant intrusion on the fabric or architecture of a historic building. Fire resistance of archaic materials and evaluating inherent and necessary fire safety are part of this module.
Many fire safety deficiencies can be offset with appropriate fire systems.
Any work done at an historic site introduces factors that make it more vulnerable to fire.
We begin our discussion by identifying what it is we are trying to achieve by fire safety. There are 3 principal objectives of fire safety in historic buildings: Life Safety, Property Protection, and Preservation of Cultural Heritage.
Life safety is most often achieved through the application of fire safety codes and standards. The primary purpose of a building code is to protect the occupants from harm. In most situations the legal requirements for life safety from fire also contribute to the other objectives of fire safety.
Property Protection

Property protection refers to the protection of physical assets that are at risk of loss to fire. Most often we quantify the potential loss by considering the financial value of the assets. These would include both the building and its contents.
Preservation of Cultural Heritage

To the extent that structural features and artifacts are of significant historic value, protecting them falls into the category of preserving cultural heritage.
Other Fire Safety Objectives

- Mission Continuity
- Environmental Protection

**Mission continuity** may be important in a historic building that is dependent on its use to produce income.

**Environmental concerns** associated with fire include large amounts of smoke and toxic products of combustion that are harmful to the environment. Also, water used in fire fighting can become contaminated and run-off may cause environmental damage.
Preservation Goal

- Preservation from deterioration
- Preservation from fire

Most often preservationists focus on ways to control the effects of time and weather on a building.

However, a fire can destroy in minutes what could take nature centuries.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
The Fire Safety Concepts Tree is a logic diagram as described in the document NFPA 550. It is a convenient, concise, graphical representation of all the ways there are to achieve fire safety.

Fire Safety Concepts Tree

• Helps gain understanding of relationships of different fire safety strategies.

• Diagrammatic logic structure of all possible ways that fire safety can be achieved.

• NFPA 550, Guide to the Fire Safety Concepts Tree
These are the major branches of the Fire Safety Concepts Tree. The circle with the + in the middle is an “OR gate” indicating that the box or concept above it can be achieved by either of the concepts below it.

For example, the box “MANAGE FIRE IMPACT” can be achieved by managing the fire or protecting assets from exposure to fire, such as by evacuation.
This portion of the Fire Safety Concepts Tree shows all the ways that we can manage a fire if it does occur.

- There are very few ways we can control the combustion process in most historic buildings.
- Suppressing fire is the topic of the next module in this series.
- In this module we focus on controlling fire by construction.
In this third module we look at types of construction that were used in the past and how they can be evaluated or adapted to meet modern regulatory requirements with minimal compromise of historic integrity.
Module 3 – Fire-Safe Construction

*Learning Objectives*

The participant will know how or be able to do:

- Describe the elements of fire-safe building construction.
- List fire-safe features that are commonly found in historic buildings.
- Compare and contrast some common historic materials, methods, and systems in the context of fire safety.
- Apply contemporary fire safe building evacuation procedures to historic buildings.

This program will not make you a fire-safety expert but will help you to understand the role of building construction in fire safety, particularly as applied to historic buildings.
In this module we will look at the evolution of fire-safe building construction and modern code requirements in relation to historic buildings.
The First Structures

- Caves
- Pits
- Adobe / mud

Use of readily available and free or inexpensive building materials for construction: housing/shelter, public markets and other gathering materials

[Cliff Palace, Mesa Verde, AZ]
Stone was the favored building material for security for those who could afford it.

These Scottish castles are: Left, Glamis (pronounced glalms), and upper-right, Edinburgh (pronounced ed-in-boro, not ed-in-burg).

However the interiors were wood frame and many ruins, following fire, have only their exterior walls remaining, e.g., Balvenie Castle, lower right.
In the US there was less affluence and an abundant supply of wood.
As construction evolved, some aspects were recognized as fire hazards.

Thatched roofs were economical, as were chimneys of mortar and wood.

Population expansion brought these fire hazards into unacceptable proximity and the increased number of fires led to restrictions.
The Fireproof Building, a National Historic Landmark, was the most fire-protected building at the time of its construction in 1827. It is characteristic of the work of Robert Mills, the first native-born American to be trained as an architect, and a Charleston native.

Seemingly carved from a solid block of stone, the building consists primarily of solid masonry, with window sashes and shutters of iron.
A fire destroyed much of the upper floor of the “Fireproof” Building

The lessons were;

1) Contents of a fireproof building are not fire-proof
2) No building is “fireproof”

but the county records on the first floor were protected due to “fireproofing” measures.

National Historic Landmark
The term “fireproof” is not appropriate for construction.

"Fireproof" Building

- "Fireproof" is a 19th century architectural term that has been redacted as applicable to buildings.

- The term fireproofing is used today to refer to the coating of construction materials (steel) to make them fire-resistant (able to endure fire temperatures).
The Iroquois Theatre fire occurred on December 30, 1903, in Chicago. It is the deadliest single-building fire in United States history. At least 605 people died as a result of the fire but not all the deaths were reported, as some of the bodies were removed from the scene.

The building was touted as “fireproof”.

Iroquois Theatre

• “Fireproof”

• Fire 1905

• > 605 dead
In the latter half of the 19th century, the insurance industry began to classify buildings according to their response to fire.

**Fire Classification of Buildings**

- Fire Insurance Industry
- Later half of 19th century
- 5 categories of construction
- Based on structural components
Here are the structural components upon which we base a fire-safety classification of building construction types.
The 5 generic categories of construction are based on the relative fire safety of their structural components. We will look at each of them in more detail in this module.
Fire Classification of Buildings

Generic classifications correlate to codes:

• IBC – International Building Code

• NFPA 101 – Life Safety Code

Classifications of building construction are included in building and fire codes. The categories are similar to the generic classifications we use here.
The first and most common construction class is wood frame, which includes some forms of timber framing but is not to be confused with Heavy Timber – the 4th construction class.
Wood frame construction is the most prevalent in historic buildings.

Wood-Frame Construction

- Walls
- Floors
- Roof framing and covering
- Sheathing and siding
The earliest wood framing construction is called post and beam. Improved milling of small dimensioned lumber inspired balloon framing and later platform framing. Lumber dimensions have decreased over the years but there is an increase in timber framed residences that hark back to post & beam.
Balloon framing is a method of wood construction used primarily in Scandinavia, Canada and the United States (up until the mid-1950s). It utilizes long continuous vertical framing members (studs) that run from the sill plate to the top plate, with intermediate floor structures suspended from the walls. Once popular when long lumber was plentiful, balloon framing has been largely replaced by platform framing.

The stud channels create a path for fire to readily travel from floor to floor. This can be mitigated by the use of fire stops at each floor level.
Fire stops are designed to impede the spread of fire by filling (nogging) or blocking openings.

The photo on the right shows brick nogging in a wood frame wall cavity space.

A building identified as being balloon frame needs a thorough assessment of its fire stopping.
Platform framing begins with a floor box and joists making up the platform built on a supporting under structure and foundation. Once the boxed floor platform is in place, walls are built on top of that layer, then another platform (floor) atop that, and repeated floor by floor.

The platforms provide inherent fire stopping to prevent fire and flames from rapidly spreading floor to floor.
The concept of wood as a heating fuel is its “slow-burning”. This is seen in the difference between logs and kindling. Its slow burning affords a level of fire endurance.

With its larger dimensions, older wood frame buildings have inherently greater fire endurance than new construction. Also old growth lumber has finer grain than modern farmed lumber giving it greater density.

Older buildings are NOT “dried out”. After about 5 years the moisture level in lumber varies by ambient humidity, not age.

There will be more on the fire endurance of wood later when we talk about Heavy Timber construction.
Wood framing components have evolved into standard dimensions that are significantly less than their generic designation. For example what is now called a 2x8 is actually 1-1/2 x 7-1/4, a decrease in mass of 32%.

The fire endurance of wood is directly proportional to its mass. So earlier wood construction has approximately 30% greater fire endurance than modern wood construction.
Timber framing and "post-and-beam" construction is a general term for building with larger timbers rather than "dimensional lumber" such as 2"x4"s. Traditional timber framing is the method of creating structures using heavy squared-off and carefully fitted and joined timbers with joints secured by large wooden pegs. It is commonplace in wooden buildings from the 19th century and earlier. The method comes from making things out of logs and tree trunks without modern high tech saws to cut lumber from the starting material stock.

Timber-frame structures benefit from the properties of large timbers, which char on the outside forming an insulated layer that protects the rest of the beam from burning. There is a very specific form of timber framing called heavy timber construction that was developed for fire safety and is the fourth classification of fire-safe construction that will be discussed in more detail later.
Modern rafters and trusses do not have the inherent fire endurance of larger dimensioned timbers and have evoked a concern among fire fighters that they can fail rapidly in a fire.

Thatch and wood shingles continue to be unacceptable roof coverings in terms of fire safety. They can be replicated by non-combustible materials with comparable appearance.
There are factors that influence the desirability of different types of sheathing and siding. In terms of fire safety we are primarily concerned with the potential of a nearby fire igniting the exterior of the structure. This is an acute problem for many national park sites located in what is referred to as the urban-wildland interface, a proximity to potential wildland fires that can spread to urban structures. In historic districts where buildings are closely spaced a fire can spread from one structure to another.

Some wood frame buildings have a masonry veneer that makes them look like brick buildings. But the supporting structure is wood framing.

Also, while stucco is most often applied to wood frame buildings, it has also been used on masonry walls, the next construction classification.
Fire Classification of Buildings

- Wood Frame
- MASONRY (ORDINARY)
- Non-combustible
- Heavy Timber (Mill)
- Fire-Resistive

Masonry construction introduces non-combustible, fire-resistant materials.
### MASONRY CONSTRUCTION

**“Ordinary”**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Properties</th>
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<tbody>
<tr>
<td>Brick</td>
<td>Compressive Strength</td>
</tr>
<tr>
<td>Stone</td>
<td>Thickness</td>
</tr>
<tr>
<td>Terra Cotta</td>
<td>Spalling</td>
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</table>

The designation “ordinary” construction is used for the very typical “main street” commercial building that had masonry walls and wood frame interior support of floors and roof. The insurance concept was that a fire may cause loss of interior structure but the masonry walls would remain standing thereby allowing rebuilding and reducing loss.

Masonry materials, typically brick, stone, concrete (or cinder) block, terra cotta, etc., do not burn. They have significant compressive strength but very little tensile strength which means they make good walls and pillars but not so good beams. While non-combustible, high temperatures may cause spalling and cracking.
Common features in older masonry walls are tie rods and fire cuts.
A pitched roof tends to push walls outward. Tie rods are sometimes used to pull opposite walls back toward each other.

As shown in this photo tie rods are also used to support fire damaged structures.
Spiders or wall plates or anchor plates are used on the outside ends of tie rods to “spread” the load across the surface. They may be decorative and/or functional. The difference is important because functional spreaders imply tie rods which fail early in a fire allowing the walls to fall outward.
A “fire cut” (left) is the angled end of a wood joist or beam in a brick wall. When a fire burns through the wood member it will collapse into the interior without causing damage to the wall. If there is no fire cut (right) the top corner of the beam will push up on the wall causing it to fall outward. This is another fire insurance inspired design to reduce damage from fire.
While most early masonry buildings are brick; terra cotta or hollow tile was also a popular fire-resistant building material in the late 19th and early 20th centuries. Being hollow, the blocks were lighter weight than brick and were used for walls and vaulted construction.
In 1895, Rafael Guastavino patented a “Tile Arch System” that is still in use today. It is a technique for constructing robust, self-supporting arches and architectural vaults using interlocking terracotta tiles following the curve of the roof. Guastavino arches are found in some of New York’s most prominent Beaux-Arts landmarks and in major buildings across the United States.

It is inherently a fire-safe structural system since it uses only non-combustible, fire-resistant material.
Tile vaulted construction was used for domes, doorways, and structural support systems. It is readily visible in many subway structures.
Heavy timber or mill construction is a fire classification that was developed by factory insurers to further reduce fire damage.
While wood will burn, larger sized of wood components, burn more slowly than smaller dimensional lumber and this is taken into account in design.

Heavy timber construction has long been recognized by the model building codes as fire resistant. To receive building code acceptance as "heavy timber," minimum dimensions of thickness are specified for all load carrying wood members.

The fact that large wood structural members provide a substantial degree of fire endurance was recognized as early as 1800 when heavy timber framing assumed importance in the design of factory buildings. When a group of cotton and woolen mill owners organized in 1835 for mutual protection of their property from damage by fire, this system of construction increased in prominence and became identified as "mill construction."
Cellulose is the main constituent of wood and as the temperature of wood is increased the cellulose begins to vaporize and decompose, or pyrolyze.

At approximately 450°F, and in the presence of a pilot flame, wood will ignite. However, at a thickness greater than approximately ½ inch wood cannot self-maintain combustion. This is why we need kindling to start a fire.

The onset of pyrolysis in wood is marked by darkening and the emission of volatile gases. The reaction becomes exothermic and the wood converts to a carbonized state we recognize as char which provides an insulating layer that blocks the incoming convective heat.

While the char has no structural capacity, it remains in place providing an insulation layer protecting the interior material.
In the combustion of wood, pyrolysates move to the surface and subsequent charring forms a boundary layer which quickly develops a steady-state where the rate of mass loss of wood becomes constant. This is referred to as the char rate.

The char which forms on timber during a fire is an effective insulator protecting the inner section of timber from the effects of heat.

At a distance of 3/4 inch from the edge of the char, the internal temperature of burning wood will only be about 175°F. At this temperature, a beam can retain 80% of its tension and compression strength, and 95% of its stiffness (modulus of elasticity).

The char depth in 30 minutes would be approximately 1 inch.

What all this amounts to is – the bigger the log, the slower it burns.
Chamfers are cuts to remove corners of wood members. Radiant heat energy from a fire focuses on sharp edges and corners. You can witness this by trying to ignite a piece of paper in the middle versus the edge. Although often thought of as simply decorative, on columns in heavy timber construction chamfers reduce the ignition propensity by making the corners less acute and thus less absorbent of radiant heat.

One of the most important characteristics of heavy timber construction is the absence of void or concealed spaces. There are no areas in the building construction where a fire can start and grow without being seen or detected.

Since all the interior spaces are open, automatic sprinklers are especially effective in controlling incipient fires.
Weaknesses of Heavy Timber

- Beams
  - Penetrated for conduit and pipes.
  - Long bolts and nuts are used.
  - Metal can create a path for heat to reach the interior.
  - Watch for spliced timber with overlapping joints and metal connectors.

Reuse of heavy timber buildings may compromise its fire safety. Enclosing structural members can create concealed spaces where fire can spread quickly.
Fire Classification of Buildings

- Wood Frame
- Masonry (Ordinary)
- Heavy Timber (Mill)
- **NON-COMBUSTIBLE**
- Fire-Resistive

The next category, non-combustible, refers to construction materials that do not ordinarily burn but lose structural strength when exposed to fire. These include historic cast iron and modern steel.
James Bogardus (1800-1874) was an American inventor and architect, the pioneer of American cast-iron architecture, for which he took out a patent in 1850. In the next two decades he demonstrated the use of cast-iron in the construction of building facades, in New York City and Washington, DC.
While cast iron is non-combustible, it can fail to perform its structural function in a fire.

CAST IRON
Material Properties

- High Carbon Alloy (1.7%-3.7% : brittle)
- Corrosion resistant (compared to steel)
- Strong in compression, weak in tension
- Subject to failure at elevated temperatures:
  - At 100% of design load: failure at 400°C
  - At 50% of design load: failure at 550°C
Cast iron was found to be a structural material that could significantly reduce the diameter of columns, allowing more visibility in public assembly areas. Yet it retained the characteristic of masonry columns as non-combustible.
Cast Iron Columns

• Functional, decorative & non-combustible

• Columns can be both functional and decorative

• Material has significant compressive strength but little tensile strength

• Can lose strength at fire temperatures and is not considered fire-resistant
This figure shows the use of cast iron and brick vault construction to create a fire-resistant floor assembly.
Steel

- Structurally efficient
- Non-combustible
- Loses strength rapidly when heated

Steel is our most efficient structural material. It has significant strength in both compression and tension.

Although it can oxidize very rapidly in fine form, e.g., powered or steel wool, it is considered non-combustible. (Steel wool in sufficient oxygen will burn with flames.)

While non-combustible in structural form, steel softens at fire temperatures resulting in loss of strength. Steel weakens dramatically as its temperature climbs above 450 degrees Fahrenheit, retaining only 10% of its strength at about 1380ºF.

Wood is more fire-resistant than unprotected steel.
All materials weaken with increasing temperature and steel is no exception. Strength loss for steel is generally accepted to begin at about 300°C (570°F) and increases rapidly after 400°C (750°F). By 550°C (1020°F) (a typical fire temperature) steel retains only approximately 60% of its room temperature yield strength, and 45% of its stiffness. Steel is also subject to significant thermal elongation at high temperatures which may lead to adverse impacts, especially if it is restrained. It follows that structural steelwork subjected to high temperatures exhibits distortion and buckling.
Steel & Wood in Fire

After-fire scene shows steel beams draped over wood beam.
The importance of the temperature effect on steel strength is greater when fire-rated assemblies are considered.

In this figure the temperature of a steel member exposed to a “standard” test fire is shown and a fire-endurance of $t_e$ is indicated. However, actual fire temperatures tend to get hotter faster than the standard test fire which means that a steel structural member will reach its critical temperature sooner.

In one test a steel I-beam deflected 35 inches after 30 minutes exposure to a standard fire, the deflection could have been greater in a real fire.
Fire Classification of Buildings

- Wood Frame
- Masonry (Ordinary)
- Heavy Timber (Mill)
- Non-combustible
- **FIRE-RESISTIVE**

Not many historic buildings fall into the category of fire resistive.

Fire resistance rating is the amount of time a member can support its load without collapsing or spreading fire, either directly or indirectly through heat transfer. A one hour rating, for example, means that an assembly should be capable of supporting its full load without collapsing for at least one full hour after the fire starts.
The most common forms of fire-resistive construction are:

Reinforced concrete has steel rods or mesh embedded in it (reinforcement) to provide tensile strength and reduce spalling and cracking.

Structural steel members can be made fire-resistant by encasing them in non-combustible materials sometimes referred to as fireproofing. These materials include gypsum wall board, spray-on insulating substances (photo), and intumescent coatings.
Intumescent Coatings

• Intumescent coatings work by forming a layer of black carbonaceous char when subjected to heat.

• The substance intumesces or swells up into a foam that chars and solidifies, very much like the firework known as a “snake”.

• This puffed-up foam contains millions of tiny, closed, fire-resistant cells that insulate the surface from the heat of a fire.

• An intumescent is a substance that swells as a result of heat exposure, thus increasing in volume and decreasing in density.
• The paint and coatings industry has developed numerous formulations for fire safety applications.
• Applied to structural steel, intumescent coatings provide insulation for fire endurance.
• Applied to combustibles surfaces they reduce the flame spread.
• However, intumescent coatings can also be applied to combustible structural materials to provide fire endurance.
Fire resistance is commonly defined as the ability of a construction element to withstand the effects of fire for a specified period of time without the loss of its fire separating or load-bearing functions or both.

In the late 19th Century the building construction industry was in need of rational, quantified, and repeatable assessment of building materials and structures subject to heating during fire. Subsequently, a procedure was adopted whereby the fire resistance of a given building element is determined by subjecting a specimen of the assembly to a “standard fire test”, which follows a “standard time-temperature curve”. The standard fire resistance test has not changed significantly since the 1920s and thus reflects context of knowledge available at that time.

While many modern construction assemblies are tested and listed by commercial services such as Underwriters Laboratories, the cost of full scale testing is significant. In addition, as we discussed in regard to behavior of steel in fire, the standard fire test is not representative of real fire scenarios.

Analytical methods have been developed as an alternative to the full-scale fire tests. They allow an engineering design for fire resistance instead of conducting full-scale tests. These techniques draw on computer simulation and mathematical modeling, thermodynamics, and heat-flow analysis to predict the fire resistance of building elements.

Even with such calculations there are variables of material properties that can affect fire endurance. Most significant is the moisture content but different chemical compounds can behave differently in fire.
While many modern construction assemblies are tested and listed by commercial services such as Underwriters Laboratories, older buildings often contain materials and assemblies that are fire safe but not listed in current fire ratings sources. The HUD Guideline on Fire Ratings of Archaic Materials and Assemblies is a compilation of fire ratings from earlier sources for a wide variety of materials and assemblies found in buildings from the nineteenth to the mid-twentieth centuries.

One significant theoretical method for non-listed assemblies is known as “Harmathy’s Rules”. They provide a foundation for extending available data to analyze or upgrade current as well as archaic building materials and assemblies. For example: Rule #1 asserts that the minimum performance of an untested assembly can be estimated from the fire endurance of the individual components.
Unlike new buildings that can be readily designed to meet modern code requirements for means of egress, historic building may have to adapt construction features to meet the intent of safe evacuation in case of fire or other emergency.

The basic egress requirements are for adequacy to evacuate all the occupants quickly and reliability that the means of egress will be properly used and protected during evacuation.

These requirements are based on a categorization of the occupancy and use of the building.
Occupancy classification is based on the size of the building which is translated into a number of occupants, and on capability of the occupants to evacuate in a timely manner. For example, occupants may be asleep in a residential occupancy but are expected to be awake in a business occupancy. Patients in health care institutions will have a range of capabilities, mental and physical.

Certain hazardous operations may be categorized separately but these will not generally be characteristic of historic buildings.

The three most common occupancy classifications for historic buildings are residential, e.g., homes, apartments, hotels, B&Bs, etc.; Business, e.g., retail establishments, offices, house museums, etc.; and Assembly, e.g., larger museums, libraries, galleries, places of worship, theatres, etc.
Egress adequacy refers to the time it will take to evacuate a building, sometimes referred to as the Required Safe Egress Time (RSET). It is a function of the number of people (occupant-load-factor based on square-footage of the floor space). This in turn is used to determine the number or exits required and their width (although there are also minimum widths specified). Then the travel distance indicates how long it will take for occupants to reach an exit.
Egress Reliability

- Minimum of 2 remote exits
- Fire resistance of means of egress
- Limiting flame spread on wall, floor, and ceiling surfaces

While capacity of egress is the first priority, there are also code requirements intended to assure the exits can be used properly.
Some historic buildings have only one exit or the exits are not remote. For example a small church may have 2 doors in the front but no others. Although the concept of remoteness is not well defined, this would typically be an unacceptable condition.

In buildings with a lot of people, more than two exits may be required.
Egress Reliability

*Fire Resistance Rating of Means of Egress*

1-3 stories – 1 hr
> 3 stories – 2 hr

• Walls
• Doors
• Stairwells

Required fire resistance ratings may be difficult to achieve in historic buildings.

In general ratings for components must be 1 hr in 1-3 story buildings and 2 hr in taller buildings.

• Walls may achieve the required rating based on fire resistance of archaic assemblies.

• Doors can be more problematic but several treatments are available as alternatives to replacement. Another issue occurs with corridors where the doors have transoms.

• Stairwells often present the greatest problem in historic buildings and may need research into compliance alternatives.
Flame spread is a measure of how fast fire will travel on a combustible surface. These surfaces include walls, ceilings, and floors. There are 3 basic controls:

- Non-combustible = 0
- Combustible materials have a range of flame spread ratings, typically A, B, or C
- Flame-resistant or fire-retardant coatings can be applied to combustible materials to reduce their flame spread rating.

Non-combustible materials such as tile, brick, or concrete, will not have any flame spread.

Limited-combustible materials may burn but not fast enough to create a problem. There is a significant difference as to whether the material is on the floor, walls, or ceiling. Floor coverings such as carpet may be safe on the floor but may be a severe hazard if mounted on the wall.

Flame-resistant coatings, such as intumescents, can sometimes be applied to combustible surfaces to meet flame spread requirements.
Egress Reliability

- Dead-end/Common path of travel
- Door swing
- Stair details
  - riser height
  - tread width
  - handrail height
- Lighting & Signage [identification and directional]

Egress reliability also includes code requirements that are intended to assure best usage of exits by the occupants.

Length of dead ends, or in code language, common path of travel, is limited so that occupants will not be excessively delayed if they make a wrong turn.

Doors are required to swing in the direction of travel to make egress easier.

Stair dimensions are specified to avoid tripping and falling while descending.

Signs and lighting are necessary for occupants to find the exits.
Alternative Means of Egress

- Horizontal exits
- Area of refuge
- Means of escape
- Elevators

Sometimes alternative configurations can be used to provide adequate egress.

Horizontal exits are passages through interior fire walls that allow occupants to move to another part of the building in which they are protected from the fire while exiting.

Areas of refuge have been devised primarily to protect disabled persons until they can be rescued.

Exterior fire escapes are not permitted on new construction but can be designed for existing buildings.

Elevators have traditionally not been used as exits but they can be made fire safe.
The next module covers fire detection and suppression systems. Automatic sprinklers can alleviate some of the construction requirements that might be difficult to comply with in an historic building.
NFPA publishes a handbook for the Life Safety Code. This document is useful to find exceptions and alternatives that are applicable to historic buildings.
Summary

- Evolution of construction methods and materials

- Fire Safe construction classifications
  - Wood, Masonry, Heavy Timber, Non-combustible, Fire Resistive

- Code construction requirements for emergency egress
  - Adequacy and Reliability

These are the basic construction issues that influence fire safety in historic buildings.
Questions and Answers

Thank you for your participation.

We now have time for questions.
Resources


These documents provide more information on the principles presented in this module.
Module 4

Fire Detection and Suppression
Fire Detection and Suppression

Part 4 of Fire Safety for Historic Properties

This is Part 4 of 5 teaching modules on Fire Safety for Historic Properties.
This Project

• This project was developed by the Fire Safety Institute, Middlebury, Vermont with the assistance of Preservation Architecture and the Preservation Education Institute.

• This project is now administered by the Preservation Education Institute, Historic Windsor, Inc. Windsor, Vermont.

• For Information: www.preservationworks.org
Funding

• This publication was developed by a grant from the National Center for Preservation Technology and Training, a unit of the National Park Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training (NCPTT).
Some times the term “Fire Safety” means different things to different people. The term “Fire Protection” is also used but to many that is an activity distinct from “Fire Prevention”. So, when we say Fire Safety we are including both fire protection and fire prevention.

The top part of the Fire Safety Concepts Tree that we will talk more about later. shows the logic of how fire safety can be achieved by either preventing fire from occurring or by managing the impact of a fire if it does occur.

In the property insurance industry, fire safety is sometimes considered equivalent to life safe and does not cover their primary interest in protecting property. As we shall see, the box labeled “Manage Fire Impact” in the Fire Safety Concepts Tree, has a broad connotation. It covers the impact of fire on people as well as on property and other assets that may be threatened by a fire such as cultural heritage and the environment.
This presentation is one of 5 parts to the NCPTT fire safety program for historic properties.

Teaching Modules on Fire Safety for Historic Properties

• Fire safety is sometimes overlooked by preservationists.
• In order to protect cultural resources against natural and human threat of fire, five teaching modules have been developed for delivery or distribution to preservation conferences and academic institutions.
• Each module is compiled electronically for optimum dissemination and presentation technology and includes notes for instructors.
Teaching Modules on Fire Safety for Historic Properties

1. Fire Prevention
2. Working with Code Requirements
3. Fire Safe Construction
4. Fire Detection and Suppression
5. Fire Safe Renovation

The five parts are:
1. Fire Prevention

Avoiding the occurrence of fire is the most desirable approach to fire safety. This module discusses conventional approaches and specific features for historic buildings with emphasis on awareness and management.

The first module deals with preventing the occurrence of fire.
In the second module we look at interactions of code requirements and historic preservation.

2. Working with Code Requirements

An evolving new generation of fire safety codes and standards allows more flexibility and specifically addresses historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, performance-based evaluation and fire risk analysis.
3. Fire Safe Construction

Building code objectives for means-of-egress and containment of fire can be met without significant intrusion on the fabric or architecture of a historic building. Fire resistance of archaic materials and evaluating inherent and necessary fire safety are part of this module.

Features of building construction are usually underlying factors in major fire losses.
4. Fire Detection and Suppression

Modern fire safety technology can address many issues in both code compliance and protecting historic buildings from damage or destruction by fire. New types of fire detection and suppression systems have the capability to protect from fire while avoiding physical and esthetic impact on significant and sensitive historic materials and features.

Many fire safety deficiencies can be offset with appropriate fire systems.
5. Fire Safe Renovation

A high proportion of fires in historic buildings occur during renovation or preservation activities. This module covers fire precautions needed during the construction phase of a rehabilitation or restoration project.

Any work done at an historic site introduces factors that make it more vulnerable to fire.
We begin our discussion by identifying what it is we are trying to achieve by fire safety. There are 3 principal objectives of fire safety in historic buildings: Life Safety, Property Protection, and Preservation of Cultural Heritage.
Life safety is most often achieved through the application of fire safety codes and standards. The primary purpose of a building code is to protect the occupants from harm. In most situations the legal requirements for life safety from fire also contribute to the other objectives of fire safety.
Property protection refers to the protection of physical assets that are at risk of loss to fire. Most often we quantify the potential loss by considering the financial value of the assets. These would include both the building and its contents.
To the extent that structural features and artifacts are of significant historic value, protecting them falls into the category of preserving cultural heritage.
Other Fire Safety Objectives

- Mission Continuity

- Environmental Protection

**Mission continuity** may be important in a historic building that is dependent on its use to produce income.

**Environmental concerns** associated with fire include large amounts of smoke and toxic products of combustion that are harmful to the environment. Also, water used in fire fighting can become contaminated and run off inappropriately damaging local environment.
Most often preservationists focus on ways to control the effects of time and weather on a building.

However, a fire can destroy in minutes what could take nature centuries.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
Fire Safety Concepts Tree

- Helps gain understanding of relationships of different fire safety strategies.

- Diagrammatic logic structure of all possible ways that fire safety can be achieved.

- NFPA 550, *Guide to the Fire Safety Concepts Tree*

The Fire Safety Concepts Tree is a logic diagram as described in the document NFPA 550. It is a convenient, concise, graphical representation of all the ways there are to achieve fire safety.
These are the major branches of the Fire Safety Concepts Tree. The circle with the + in the middle is an “OR gate” indicating that the box or concept above it can be achieved by either of the concepts below it.
We can achieve our fire safety objectives by preventing the fire from occurring or, if it does occur, by controlling the impact it has on a building and its contents, including occupants and our cultural heritage.
This part of the Fire Safety Concepts Tree shows the logic of how objectives of fire safety can be met by either preventing fire from occurring or by controlling and managing a fire if it does occur. The plus sign in the small circle is called an “or gate” and refers to the logic that the concept in the box at the top, fire safety, can be achieved by either of the boxes below.
In this module we are primarily concerned with the box in lower middle, that is SUPPRESS FIRE. This is one means used to MANAGE FIRE which in turn is one way to MANAGE FIRE IMPACT when we cannot PREVENT FIRE IGNITION. Note however that fire detection and alarm are also part of MANAGE EXPOSED which refers to evacuation of occupants.
This module describes the two best hardware approaches to meeting fire safety objectives.
Module 4 – Fire Detection & Suppression

Learning Objectives

The participant will know how or be able to do:

• Recognize principles of fire signatures and how to detect them.
• List common components of fire detection systems.
• Consider the typical developmental stages of fire in one’s work.
• Compare and contrast fire detection and suppression systems.

In this module you will learn basic principles of fire detection and suppression to help decide on installation and need for periodic maintenance.
Culture Shock

- Download and watch the video: “Culture Shock: Fire Protection for Historic and Cultural Property”

This video identifies the importance of fire detection and suppression in historic buildings and introduces technical aspects of fire detection and suppression systems.

Note the video was produced in 1995. 20 years on there have been technological advances in fire detection and suppression. However the basic information is applicable to historic buildings in 2015.
In this module we look at 2 fire safety technologies: fire detection and alarm systems and fire suppression systems.
PART I
Fire Detection & Alarm

• Objectives
• Functions
• System Components
• System Configurations
• Design & Installation
• Reliability

These are the characteristics of fire detection and alarm systems covered in this module.
Fire detection and alarm systems can meet or contribute to many fire safety objectives.

Fire Detection and Alarm

Objectives

• Life Safety
• Building Protection
• Content Protection
• Mission Continuity
• Security
There are several ways that fire detection and alarm systems function to meet fire safety objectives.
Fire Detection and Alarm

System Components

- Initiation
- Notification
- Control Panel
- Building System Interface
- Central Station Monitoring

A fire detection and alarm system consists primarily of initiation (detection) and notification (alarm). These are connected in a control panel. In addition to notification, the control panel may also activate other fire safety system components such as smoke control and special fire suppression systems.
This figure shows the interconnection of fire detection and alarm system components.
Fire signatures are distinctive products of combustion in the form of energy and mass.

Energy is felt as thermal convection and radiant flames.

Mass products of combustion are smoke, which refers to particulate matter both visible and invisible, and gasses such as carbon dioxide and water vapor as well as toxic gases such as carbon monoxide.
We detect fires by analyzing fire signatures.

In general, initiation devices imitate human senses.
Fires begin small. Detection in the early or incipient stage means the fire can be controlled or extinguished before there is extensive damage.
There are several different types of fire detection devices. The most common are ionization and photoelectric smoke detectors.
Thermal/Heat Detectors

- Set off alarm when temperature reaches set point
- Fusible link, bimetallic strip, or rate-of-rise
- Least expensive
- Least sensitive
- Alarms only after fire well established

Fusible link melts } at particular temperature set point,
Bimetallic strip distorts } setting off alarm

Rate-of-rise -- sounds alarm when temperature rise exceeds about 15°F a minute.

Useful in kitchens, other places with many ambient particulates in the air, or unheated areas where low temperatures can delay activation in other types of detectors, but relatively slow in response. Fire is well established before you know there is a problem.
Small quantity of radioactive material ionizes air in the chamber making it electrically conductive and allowing an electric charge to flow between two electrodes.

When smoke particles enter the chamber they attach to the charged ions reducing the flow of electric current which activates a signal to sound the alarm.

Dual chamber devices have a reference chamber to eliminate influence of environmental changes, such as temperature, humidity.

Ionization detectors respond faster to open flaming fires that produce large quantities of very small invisible smoke particles, than to smoldering fires whose particles tend to be larger.
Module 5

Fire Safe Renovation
Photoelectric Detectors

- Operate on light scattering principle
- Good at detection of smoldering fires with large smoke particles

Detector contains a light source and photocell arranged so it cannot see the light.

When large smoke particles enter they cause the light to scatter and some of it strikes the photoelectric cell which activates a circuit to set off the alarm.

Some smoke detectors combine both ionization and photoelectric detection principles.
Flame Detectors

- Respond to visible or invisible radiant energy (UV or IR)
- OR
- Video analysis of flame color and motion
- Special applications

IR -- filters out unwanted wavelengths of light, focusing the incoming energy on a photoelectric cell which generates an alarm when light typical of fire is detected.

UV -- detection tube is focused at the potential source of fire and is triggered by the presence of UV light

These devices sense flames within milliseconds but once flaming combustion starts fire spread is rapid. So they don’t provide much advance notice of incipient fires but are used in locations where smoldering fires aren’t likely such as conservation labs or garages.
Aspiration Detection

- High sensitivity, early warning detection system
- Expensive

Also called air-sampling detectors

Samples of air in the building are sucked (aspirated) into a cloud chamber or laser light that can detect tiny particles produced by combustion.
Detection Geometries

- Spot – Thermal/Smoke
- Linear - Thermal and Optical Cable
- Projected Beam – Smoke
- Area – Aspiration Smoke and Flame

Different types of detectors are configured to cover points (spot detectors) lines (linear and beam detectors) or spatial volumes (aspiration and flame detectors)
Detector Selection Issues

- Occupant characteristics – number, physical ability, location
- Value of building, contents, mission
- Combustibility of contents, building fire resistance, (compartmentation), fire suppression, smoke control
- Environmental factors – ambient temperatures, air pollution, dust, ambient lighting
- Geographic location – distance to fire department
- Cost

There are many factors that can influence the type of detection to be used.
The type of fire expected can determine the best detector to use.

### Selecting Detectors

<table>
<thead>
<tr>
<th>Material</th>
<th>Ionization</th>
<th>Photoelectric</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Good</td>
<td>Fair</td>
<td>Excellent</td>
</tr>
<tr>
<td>Wood, smoldering</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Wood, flaming</td>
<td>Very good</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Fabric</td>
<td>Fair</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Paint</td>
<td>Very good</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Electrical wire insulation</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>
The detector signal is transmitted to the control panel where it is processed and the appropriate notifications are activated.

The current industry standard is known as an addressable system whereby when any device detects fire the system identifies the specific device allowing detailed identification of the fire location
In addition to alerting occupants, fire notification may connect with other responding functions.

There are different mechanisms to alert occupants and other responses.
Building System Interface

- Fire Doors Closure
- Fire Dampers Closure
- HVAC Fan Shut Down
- Electrical Shutdown
- Elevator Recall
- Smoke Control Fan Operation
Fire doors that will close automatically upon activation of the smoke detectors above them.
Central Station Monitoring

• Commercial security company
• Staffed 24 hrs./day, 7 days/week
• Certified according to national standards
• Receives fire notifications via telephone lines
• Alerts principals, fire department, police

UL approved and periodically inspected and recertified by UL to comply with NFPA 72, National Fire Alarm and Signaling Code.
Smoke detectors can accumulate dust and insects which will interfere with their operation. In-house inspection and testing of detectors helps ensure they will function when needed.

Annual ITM by a licensed commercial service firm is required in some jurisdictions.

NFPA 72 covers the application, installation, location, performance, inspection, testing, and maintenance of fire alarm systems and their components.
These are the aspects of fire suppression systems covered in this module.

PART II
Fire Suppression Systems

• Types of Systems
• Automatic Fire Sprinklers
• System Components
• Water Mist Systems
• Clean Agents
• Reliability
Types of Suppression Systems

- Manual Suppression
- Automatic Sprinklers
- Water Mist Sprinklers
- Gaseous Agents

This module will emphasize automatic sprinklers but cover other types of systems as well.
Manual Suppression

- Fire extinguishers
- Occupant use hose systems
- Fire department standpipe systems

Fire extinguishers will be covered in more detail in the next module.

Occupant use hose systems are more dangerous than useful in most non-military facilities.

Fire department standpipe systems are primarily for high-rise buildings where fire-fighters cannot quickly carry hose.
Despite what you see in movies and TV, sprinklers only operate in the space where they are activated by the heat from a developing fire. They cannot be activated by a cigarette or pulling a fire alarm.

As opposed to fire department operations, sprinklers apply relatively little water. The application is more effective because they operate relatively early in the fire development and only on the fire.
In 1991 a fire occurred in Windsor Castle
“It was a blessing in disguise that the Castle was not fitted with a sprinkler system. That would have done more damage to the fabric and the artifacts”

UK Heritage Minister
Sunday Mail
22 November 1992

This response from the UK Heritage Minister at the time sends the wrong message.
This is the damage to the Great Hall in Windsor Castle after the fire. Hard to imagine how it could have been worse…
A sprinkler system consists of these component parts.

- Water supply
- Distribution piping
- Sprinklers
- Control and alarm
  - Water valve
  - Water flow sensor
  - Connection to fire alarm panel
Water supply is critical to put enough water on a fire to control it.

Rural areas do not have the ready supply of water that is available in urban water systems. This can be a limitation as the cost of an adequate water supply may be prohibitive.

Regrettably, most authorities do not recognize the fire safety potential of limited water supply sprinklers.
Sprinklers at the end of the piping system are activated by heat from a fire. Water discharges only from the sprinklers directly exposed to the heat.

- Fusible style head -- link, held closed with solder that has a specified melting point.

- Frangible style head -- glass bulb partially filled with liquid. With heated the liquid expands, breaking the bulb.
When the heat-sensitive element breaks (2) a cap it held in place is released (3) allowing water to flow and be dispersed by the deflector (4).
Sprinklers are manufactured for installation in a variety of configurations.
Most sprinkler piping is black iron pipe (steel).

Plastic piping is becoming more popular as it is less expensive and easier to install.
The most common sprinkler system is “wet pipe”.

In areas subject to freezing a dry pipe system can be used.

Other types of automatic fire sprinkler systems include preaction, deluge, on/off, and water mist.
Piping contains water under pressure at all times.

When a sprinkler is activated, water is released onto the fire.

Only the sprinklers activated by the heat of the fire release water.
More than 9 out of 10 sprinkler systems are wet pipe

Wet Pipe Sprinkler Systems

• Most widely used system
• Appropriate for most applications
• Generally least expensive to install and maintain
• Greatest number of component and design options
• Not suited for freezing environments
Dry Pipe Sprinkler Systems

- Used where pipe may encounter freezing conditions
- Less design flexibility and fewer component options than wet systems
- 10%-20% higher installation and maintenance costs
- Components must be selected to minimize corrosion

Dry pipe systems add complexity thereby reducing reliability and increasing installation and maintenance costs.
Piping is filled with compressed air above the valve.

When a sprinkler is activated by the heat of a fire, air is released, the valve opens, and water fills pipes.

Water is released from the activated sprinkler, other sprinklers are now in the condition of a wet pipe system.
Pre-Action Sprinkler Systems

- Two actions required to initiate sprinkler discharge – automatic detector and sprinkler head operation
- Used for high value areas
- Higher aesthetic impact
- Less design flexibility than wet systems
- 35%-50% higher installation and maintenance costs

Offers an additional level of protection from inadvertent water damage.

- Piping pressurized with air or nitrogen
- Smoke detectors sense fire before sprinklers activate opening the “preaction valve”
- When preaction valve opens, gas pressure is released allowing water to fill pipes
- Heat from fire activates sprinkler to release water

But, system more complex to maintain:

- Introduces more potential points of failure
- If charges with air there more chance of corrosion
There are significant installation cost differences among these standards.

Regrettably, authorities do not generally recognize that a residence converted to an office building or historic house museum has significantly lower fire hazards associated with the occupancy (no sleeping, less cooking, less clutter, fewer ignition sources, greater likelihood of staff emergency training, etc.).
Water Mist Systems

- Water under very high pressure, creating very small droplets
- Reduces heat, prevents materials from igniting
- Very low quantities of water used

Water in fine mist is more effective at conducting heat from a fire and wetting surfaces to prevent fire spread.

Fires can be extinguished with less than half that required by sprinklers.

Water mist floods the entire enclosed space including areas under tables that could shield water from conventional sprinklers.

Water must be filtered and stainless steel piping used to avoid corrosion that could plug the very small nozzle openings.
Installation cost is estimated based on the square feet of floor space in the protected area.

While this is primarily a capital outlay there is also an ongoing operational cost.

Sprinkler piping and sprinklers are most often exposed which makes the high level of fire safety readily observable.

Piping can be painted to match its surroundings. Sprinklers come in a limited number of colors but can be painted by special order.

Concealing sprinkler piping can intrude on the historic fabric of a building. “Concealed” sprinklers (see slide 62, lower right) can also be painted by special order.
Annual ITM by a licensed commercial service firm is required in some jurisdictions.

NFPA 25 covers the application, installation, location, performance, inspection, testing, and maintenance of water-based fire suppression systems and their components.
Gaseous fire suppression avoids water damage but is seldom cost-effective in other than special applications.
There are 2 basic types of gaseous fire suppression agents

Gas Agent Types

- Halocarbons
- Inert gases
Haloncarbons are the most effective gas fire suppression agents because they do much more than just smother the fire, they efficiently absorb heat and interact with the fire’s chemical process. Halon 1301 was widely used and effective but ceased production due to environmental impact. There are many newer gases that are less ozone depleting.

Haloncarbons are the most effective gas fire suppression agents because they do much more than just smother the fire, they efficiently absorb heat and interact with the combustion process in flames.

Some of the newer halocarbons include: FM-200, FE-13, and others.
Inert gaseous fire suppression agents require a greater concentration than halocarbons.

Fire is similar to the oxidation of blood that takes place in humans in that there are minimum levels needed to exist (12-14%). Some inert gas mixtures attempt to control combustion while not endangering humans.
The components of a gaseous suppression system are similar to a water sprinkler system except for the storage containers.

Because of less efficient suppression, inert gases require more agent storage than halocarbons.
A gaseous fire suppression system requires more engineering than a water sprinkler system. Much of this is focused on maintaining the necessary concentration of gas in the protected space.

• Room must be completely sealed to maintain agent concentration
• Occupants must be trained to QUICKLY evacuate in case of alarm
• Discharge may cause thermal shock and condensation
• High discharge pressures may move and shift objects
Detection and Suppression System Design Criteria

- Desired point of operation
- Expected type of fire (design fire)
- Room geometry – height, width, configuration, physical characteristics
- Aesthetic characteristics
- Ambient conditions
- Ventilation – natural and building system
- Installation factors - aesthetic and fabric impact
- Cost – installation and maintenance

There numerous criteria that must be considered in both detection and suppression systems.
Design and Installation Documentation

- Technical Specifications and Design Requirements
- Approvals and acceptance requirements and procedures
- Inspection, Testing, & Maintenance

Documentation of any detection or suppression system should include these 3 basic categories of information
A fire detection or suppression system is a significant investment to meet fire safety objectives.

This investment, like, for example, an automobile should be protected by regular maintenance.

Inspection, testing, and maintenance helps maximize system integrity to avoid failure and ensure fast, effective response in a fire emergency.
Specific information you may need for your particular building can be hard to find. It is important to consult with qualified and knowledgeable people who can help answer the many questions that arise with individual and unique historic properties. A good approach is to network with other owners or operators of similar historic properties who have dealt with installation and maintenance of fire detection and suppression systems.

Help

- Fire detection and suppression systems are technically sophisticated
- They are not the jobs of electricians or plumbers, but of specially trained designers, technicians, and installers
- The information in this module is to help you understand enough to ask informed questions as part of a team:
  - Owner, operator, fire official, insurance representative, fire safety consultant
## Summary

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<td>• Reliability</td>
<td>• Reliability</td>
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</tbody>
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This module covered the fire safety technologies of fire detection and alarm and automatic fire suppression.
Questions and Answers

Thank you for your participation.

We now have time for questions.
Resources


Note the first resource is a publically available pdf
Fire Safety During Renovation

Part 5 of Fire Safety for Historic Properties

This is Part 5 of 5 teaching modules on Fire Safety for Historic Properties primarily sponsored by NCPTT.
Some times the term “Fire Safety” means different things to different people. The term “Fire Protection” is also used but to many that is an activity distinct from “Fire Prevention”. So, when we say Fire Safety we are including both fire protection and fire prevention.

The top part of the Fire Safety Concepts Tree that we will talk more about later. shows the logic of how fire safety can be achieved by either preventing fire from occurring or by managing the impact of a fire if it does occur.

In the property insurance industry, fire safety is sometimes considered equivalent to life safe and does not cover their primary interest in protecting property. As we shall see, the box labeled “Manage Fire Impact” in the Fire Safety Concepts Tree, has a broad connotation. It covers the impact of fire on people as well as on property and other assets that may be threatened by a fire such as cultural heritage and the environment.
This Project

This project was developed by the Fire Safety Institute, Middlebury, Vermont with the assistance of Preservation Architecture and the Preservation Education Institute. This project is now administered by the Preservation Education Institute, Historic Windsor, Inc. Windsor, Vermont. For Information: www.preservationworks.org
Teaching Modules on Fire Safety for Historic Properties

• In order to protect cultural resources against natural and human threat of fire, five teaching modules have been developed for delivery or distribution to preservation and fire safety conferences and academic institutions.
• Each module is compiled electronically for optimum dissemination and presentation technology and includes notes for instructors.

This presentation is one of 5 parts to the fire safety program for historic properties developed with funding from the National Center for Preservation Technology and Training.
Teaching Modules on Fire Safety for Historic Properties

1. Fire Prevention
2. Working with Code Requirements
3. Fire Safe Construction
4. Fire Detection and Suppression
5. Fire Safe Renovation

The five parts of the series are listed on this slide. They are:
1. *Fire Prevention*

Avoiding the occurrence of fire is the most desirable approach to fire safety. This module discusses conventional approaches and specific features for historic buildings with emphasis on awareness and management.

The first module deals with preventing the occurrence of fire.
2. Working with Code Requirements

An evolving new generation of fire safety codes and standards allows more flexibility and specifically address historic buildings. This module elaborates on alternatives to prescriptive requirements including equivalency, indexing, performance-based evaluation and fire risk analysis.

In this second module we look at interactions of code requirements and historic preservation.
3. Fire Safe Construction

Building code objectives for means-of-egress and containment of fire can be met without significant intrusion on the fabric or architecture of a historic building. Fire resistance of archaic materials and evaluating inherent and necessary fire safety are part of this module.

Features of building construction are usually underlying factors in major fire losses.
4. Fire Detection and Suppression

Modern fire safety technology can address many issues in both code compliance and protecting historic buildings from damage or destruction by fire. New types of fire detection and suppression systems have the capability to protect from fire while avoiding physical and esthetic impact on significant and sensitive historic materials and features.

Many fire safety deficiencies can be offset with appropriate fire systems.
5. Fire Safe Renovation

A high proportion of fires in historic buildings occur during renovation or preservation activities. This module covers fire precautions needed during the construction phase of a rehabilitation or restoration project.

Any work done at an historic site introduces factors that make it more vulnerable to fire.
Primary Fire Safety Objectives

- Life Safety
- Property Protection
- Preservation of Cultural Heritage

We begin our discussion by identifying what it is we are trying to achieve by fire safety. There are 3 principal objectives of fire safety in historic buildings: Life Safety, Property Protection, and Preservation of Cultural Heritage.
Life safety is most often achieved through the application of fire safety codes and standards. The primary purpose of a building code is to protect the occupants from harm. In most situations the legal requirements for life safety from fire also contribute to the other objectives of fire safety.
Property protection refers to the protection of physical assets that are at risk of loss to fire. Most often we quantify the potential loss by considering the financial value of the assets. These would include both the building and its contents.
To the extent that structural features and artifacts are of significant historic value, protecting them falls into the category of preserving cultural heritage.
Other Fire Safety Objectives

- Mission Continuity
- Environmental Protection

**Mission continuity** may be important in a historic building that is dependent on its use to produce income.

**Environmental concerns** associated with fire include large amounts of smoke and toxic products of combustion that are harmful to the environment. Also, water used in fire fighting can become contaminated and run off inappropriately damaging local environment.
Most often preservationists focus on ways to control the effects of time and weather on a building.

However, a fire can destroy in minutes what could take nature centuries.
Thus, there is significant overlap in the goals of fire safety and historic preservation.
Fire Safety Concepts Tree

- Helps gain understanding of relationships of different fire safety strategies.

- Diagrammatic logic structure of all possible ways that fire safety can be achieved.

- NFPA 550, *Guide to the Fire Safety Concepts Tree*

The Fire Safety Concepts Tree is a logic diagram as described in the document NFPA 550. It is a convenient, concise, graphical representation of all the ways there are to achieve fire safety.
These are the major branches of the Fire Safety Concepts Tree. The circle with the + in the middle is an “OR gate” indicating that the box or concept above it can be achieved by either of the concepts below it.
Achieving Fire Safety Objectives

- Prevent Fire Ignition
- Manage Fire Impact

We can achieve our fire safety objectives by preventing the fire from occurring or, if it does occur, by controlling the impact it has on a building and its contents, including occupants and our cultural heritage.
Achieving Objectives

This part of the Fire Safety Concepts Tree shows the logic of how objectives of fire safety can be met by either preventing fire from occurring or by controlling and managing a fire if it does occur. The plus sign in the small circle is called an “or gate” and refers to the logic that the concept in the box at the top, fire safety, can be achieved by either of the boxes below.
Almost without failure, fires in historic buildings occur when there is some sort of renovation activity going on. Often this is intended as preservation but can end up as destruction.

Fire risk management involves ways to deal with the fire risk from renovation/rehabilitation projects and other fire threats.
**Fire Safety for Historic Buildings**

**Module 5**  
Fire Safety During Renovation

**Learning Objectives:** The participant will know how or be able to

- List four common causes of increased fire risk during renovation, rehabilitation or preservation activity.
- List four sources of increased fire ignition.
- Use check lists for fire risk mitigation.
- Include risk analysis and fire scenario assessment in construction
  site management recommendations and protocols.

While the focus of this module is on renovation/rehabilitation, the fire risk
management principles presented also apply to the ongoing function of an historic
building.
Fire Safety During Renovation

- Renovation fires
- Increased Fire Risk During Rehabilitation Projects
- Fire Risk Assessment
- Fire Risk Check Lists for Rehabilitation or Renovation
- Fire Risk Indexing
- Fire Risk Management

We will start with discussion of the conditions that account for fires in historic buildings occurring when there is some sort of renovation activity going on. Then we describe processes for identifying and managing the ensuing fire risk.
Renovation Fires
(Colleges & Universities)

• Ball State University, Muncie, Indiana
• University of Kentucky, Louisville, Kentucky
• Longwood College, Farmville, Virginia

Although fires during renovation occur in all types of buildings, college and university campuses cover a wide range of occupancies from museums to chemical labs. Following are just 3 examples of destructive fires attributable to construction activities.
Fire During Renovation
Extensive damage to third floor, some smoke and heat damage to artwork on 2nd floor when Fire Dept. arrived – said they had become used to the false alarms!

Presenter can illustrate with local fires in historic buildings.
Presenter can illustrate with local fires in historic buildings.
Historic Ruffner Hall, Longwood College – Farmville, Virginia
April, 2001

Fire During Renovation
Sprinklers Turned Off Due to Construction Work.
Sprinklers in Other Buildings Stopped Fire Spread

Presenter can illustrate with local fires in historic buildings.
Renovation Fires

- \textit{Wirt Dexter Building, Chicago} - Designed by renowned architect Louis Sullivan, the building was destroyed by fire caused by scrap workers cutting apart a boiler in the basement.

- \textit{Old State Capitol, Iowa City} - At the time of the blaze, which caused $5.6$ million in damage, workers were using torches to strip paint as part of an restoration of the dome and exterior.

- \textit{Chatham County Courthouse, Pittsboro, NC} - Restoration of the courthouse derailed when a fire broke out in the 1882 structure. Investigators announced the cause as a soldering iron that a construction worker was using to repair the gutters.

- \textit{St. Peter’s School, Kingston, N.Y.} - The century-old school was under renovation, thanks to a $2.15$ million state grant when a fire occurred. The roof of the 18,000-square-foot building was destroyed, and all three floors sustained water damage.

Here are just a few of the many news items describing fires in historic buildings that occurred during rehabilitation/renovation. And there are many times the number of such fires in buildings of lesser significance including “main street” store fronts and private homes.
A fire in an historic building was featured on the Cover of *Preservation* magazine, published by the National Trust for Historic Preservation.
There are four principal reasons that fires in historic buildings occur so often when there is restoration, rehabilitation, exhibit renovation, major maintenance, or other structural changes going on. Each of these will be discussed.

Increased Fire Risk During Rehabilitation Projects

- Increase in Ignition Sources
- Increase in Combustible Materials
- Increase in Potential Fire Spread
- Decrease in Security
Rehabilitation processes inherently bring in additional potential sources of fires. These can be in many forms. The first step in fire prevention is to acknowledge that these conditions will occur.
Construction activities introduce additional combustible materials to the site. These can be in very different forms and at many locations that would not ordinarily have such combustibles openly present.
Increased Hazards During Construction & Renovation

Increased Potential for Fire Spread

- Temporarily Opened Floors and Walls
- Temporarily Removed Doors and Fire Barriers
- Temporary Disablement of Fire Protection Systems

Construction activities also cause temporary changes that significantly increase the means of a small fire spreading and becoming a very large fire. Construction features that inherently or by design limit fire spread are compromised. Investment in fire detection and suppression systems is endangered when they need to be turned off.
The nature of a work site is one of diminished security. Typical security systems are bypassed and more people have access to secured areas.
In most properties, most areas of the building are susceptible to arson. However while fires are frequently set in restrooms, cafeterias, storage rooms, and lobbies; vacant buildings and construction sites are the most common targets.
Given the increased risk of fire during rehabilitation, we seek ways to assess this risk in terms that can identify means of controlling it or managing it. These are shown in order of increasing availability or complexity. The last refers to fire modeling of potential consequences and the statistical calculation of expected loss. This is beyond our scope but insurers often make these estimates.
Chapter 13 of NFPA 914, *Code for Fire Protection of Historic Buildings*, is an excellent description of the fire hazards and controls in a rehab project.

NFPA 241 is often cited by local jurisdiction fire and building codes.
Simple checklists are one of the most effective means of reducing risk. Hospital OR staff often use checklists, recognizing their training is best implemented if they have an easy way to apply what they know.

The most readily available checklist is the table of contents of an applicable code or standard. There are many available checklists that can be used or adapted found in appendices or annexes of codes and standards and other publications. Insurers can often provide appropriate checklists.

We will look at some check list items appropriate to fire safety in rehabilitation projects.
Example Checklists for Fire Safety During Renovation

- Planning
- Oversight
- Evaluation

Here is a list of applicable checklist topics. There are 3 stages that need to be considered: before work is begun, what is expected during the work, and daily evaluation of the effectiveness of fire precautions.
One of the most significant means of achieving fire safety during rehab projects is to make sure ahead of time that contractors realize the need for extra precautions to preserve the cultural value of the facility from loss by fire. The main purpose is to instill an awareness and sensitivity of the importance of fire safety on the particular project.

Check List #1

Introductory Meeting With Contractors

- Identify precautions and steps they will take to protect the building and contents
- Advise them of special concerns
- Review security & fire protection procedures
Check List #2
Oversight of Construction Work by Owner or Institution (Part 1)

☐ Site security and monitoring of contractors & visitors
☐ Isolation of construction from the existing building, contents and collections
☐ Limitation of impairments to existing protection systems
☐ Monitoring location & handling of flammable liquids & gasses

Checklist #2 is a list of 9 basic items that need to be considered in daily operations during rehab. It is in 2 parts and each item has its own checklist for fire safety, 2a – 2i.
Checklist #2(a) 
Security for Job Site

- Fencing / Barriers
- Lighting
- Access Control & Identification of Contractors
- Guard Service Extended to Construction Areas
- Emergency Notification Procedures & Equipment

During the daily fluctuations of the rehabilitation project it is difficult to maintain the normal security measures, including the full operability of security and fire protection equipment. In part this is due to the introduction of temporary workers and processes that cause constant changes in the type, scale, and location of hazards.

The contractor should closely supervise all activity and traffic on the site and orderly work and storage areas. To prevent theft, vandalism, and arson only authorized personnel should be allowed within the construction area. If a location has experienced labor management difficulty or has sustained a set fire or other vandalism, it is established as a target for arson and additional security is needed.
To the extent possible it is desirable to separate the construction activity and its associated fire hazards from other parts of the building.

“Access to Fire Protection System Components” refers to such as control panels and shut-off valves.
Existing fire detection and alarm systems should be maintained in operating order wherever possible. The smoke detectors that are deemed necessary within the construction area must be protected from dust, dirt, and extreme temperatures during construction. When construction has finished for the day, a security guard or other authorized person should be instructed to remove the covering from any of the smoke detectors in the construction area to avoid delayed alarms during nonworking hours. Care should be taken to avoid disabling the fire alarm system or causing false alarms during the rehabilitation work.

In buildings where sprinkler protection existed prior to the rehabilitation project, the system should be kept in service as long as possible during the rehabilitation work to provide continuous protection to the building.

A fire watch is a trained person hired to monitor work areas when they are not occupied.
Storage and use of flammable liquids during rehabilitation operations should be carefully controlled and monitored. Potential sources of ignitions should be identified and safeguarded whenever operations involving flammable liquids are to be conducted. Ventilation should be provided for operations involving the use or application of materials containing flammable liquids. Flammable liquids storage requirements are specified in fire prevention codes.

Checklist #2(d)
Control Location & Handling of Flammable Liquids & Gasses

- Limit quantities within building to 1 day supply
- Protect containers from damage & exposure to heat
- Lock-up materials at the end of the day to prevent access by vandals
- Store in approved storage cabinet or 50’ from main construction project or building
- **DO NOT** allow gasoline engines, fuel storage, flammable gas storage or service areas within existing building
- Prohibit on-site recharging of gas cylinders
Check List #2
Oversight of Construction Work by Owner or Institution (Part 2)

- Removal of rubbish & combustibles
- Supervision of hot-work and other sources of ignition
- Acceptance testing of fire protection systems
- Provision of portable extinguishers
- Restrictions on smoking

This is the second part of the list of checklists for construction oversight. Each of these will be represented by checklists 2(e) through 2(i).
Good site control and housekeeping procedures can minimize the amount of combustible material readily available to fuel a fire.

Check List #2(e)
Control of Combustible Waste

- Daily removal from site of:
  - Deconstruction debris
  - Packaging and wrapping
- Use non-combustible containers such as steel bins
- Alternative is to wet down debris piles
Although often treated the same in codes and standards, so called “hot work” presents different forms of ignition hazards

1. Open flames and High surface temperatures from such as soldering, heat guns, and heated adhesives can ignite combustibles that are in direct contact.
2. Mechanical sparks from grinding and similar metal work can travel 10ft from the source but are small enough to lose heat rapidly
3. Sparks, slag, and hot particles will travel as much as 30 feet from the operation while retaining their ignition potential

Heat gun
Mechanical sparks – grinding, drilling, sawing,
Vs.
Hot particles
Production of sparks and especially particles from such as thermal cutting and welding.
Cutting and welding operations on the job site should require a permit that is under the supervision of the designated person in charge of fire protection. Any such operations should be carried out in accordance with the requirements of local fire prevention codes.

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**Check List #2(f) Hot Work Supervision**

- **DO NOT permit hot work in or near existing premises, unless there is no other viable alternative**
- Remove combustibles / Isolate area with fireproof tarps or partitions
- Station a fire-watch nearby with fire extinguisher
- Curtail any work involving flammable liquids
- Monitor area for at least 3 hours after work is finished
Check List #2(g)

Fire Protection Systems

- To the extent possible, installed fire protection systems should be made operational as soon as possible
  - Fire detectors are susceptible to dust contamination and need to be covered in a dusty environment
  - Automatic fire sprinklers may be subject to mechanical damage or spray painting
- Remove protective covers as soon as possible
- Turn on automatic sprinklers when not endangered by construction activities (at night)

If automatic sprinkler protection is to be provided, the installation should be placed in service as soon as possible.

Temporary fire protection may also be provided.
Water supply for either temporary or permanent fire protection, should be made available as soon as construction begins and combustible material accumulates. The local fire authority should be contacted regarding adequacy of water supply for hose lines. Where underground water mains are to be provided as part of the construction project, they should be installed, completed, and in service with hydrants or standpipes located as directed by the local fire authority prior to construction work.

Should a temporary fire detection system with some form of connection to the fire department be installed, this system should only include heat detectors and manual fire alarm boxes with smoke detectors installed in areas that are not affected by the construction.
Portable fire extinguishers should be provided and maintained in an accessible location for every building operation, including those occurring in a tool house, storeroom, or other structure located in or adjacent to the building under rehabilitation, or within a room or space used for storage, workshop, or employee changing. At least one approved fire extinguisher should also be provided in plain sight on each floor at each useable stairway.

Check List #2(h)
Portable Fire Extinguishers

☐ Provide all-purpose fire extinguishers (ABC) throughout job site –

☐ Pay Special Attention To:
  ☐ Nearby access points & stairways
  ☐ Areas where hot work is in process
  ☐ Construction offices or trailers
  ☐ Areas where combustibles are located
  ☐ Train staff on locations and proper use
  ☐ Check locations and condition daily

Portable fire extinguishers should be provided and maintained in an accessible location for every building operation, including those occurring in a tool house, storeroom, or other structure located in or adjacent to the building under rehabilitation, or within a room or space used for storage, workshop, or employee changing. At least one approved fire extinguisher should also be provided in plain sight on each floor at each useable stairway.
Many construction workers will be smokers. It is better to accept this fact than try to prohibit all smoking which can lead to surreptitious smoking and dangerous disposal of cigarette butts.

Smoking should be prohibited or restricted to designated areas. Smoking areas should be selected on the basis of their remoteness from exposed combustible materials, the low degree of danger that an incipient fire could spread rapidly, and the availability of fire protection equipment and personnel. Receptacles for spent smoking materials should be provided in the smoking area, and housekeeping should be exemplary. Stringent restrictions on smoking also serve to promote general consciousness of the need for fire safety. Surreptitious smoking should be dealt with severely.

Check List #2(i)
Smoking Policy

>>> Smoking will occur on the job site! <<<

- Identify areas where smoking is permitted that are convenient enough to not encourage surreptitious smoking
- Provide containers for effective disposal of smoking materials
- Check smoking areas daily
Check List #2
Oversight of Construction Work by Owner or Institution

Many of these concepts are specified in local codes and ordinances.

More details on the items in checklist #2 can be found in codes and standards such as the NFPA Fire Prevention Code.
Most fires at construction sites start out as slow smoldering fires, which could be manually extinguished if caught at an early stage. Other hazards can also be identified: equipment not shut off, shorting electrical systems, flammable liquids left out, etc.

Check List #3
Evaluation

- Simplest,
- Most effective, and
- Least cost

means of detecting and extinguishing the majority of fires is to

walk the construction site 1 hour after contractors have left for the day
On this form the left-hand column lists the construction site hazards and safety features previously discussed. The second column indicates if the item is applicable to the particular project (checking N/A indicates the item is not applicable). The right-most columns identify the conditions of the items as either safe or unsafe. If an applicable item is designated unsafe corrective action is necessary.

Depending on the nature of the project, a checklist such as this could be implemented as often as two or even three times a day to insure continued fire safe practices on the site, including the walk-through after the work day has ended.
The primary limitations of codes and checklists are:

1. There is no or little acknowledgement of how fire safety attributes may interact. For example elevators and emergency egress, which is now being studied.

2. Codes prescribe levels but do not acknowledge the value of a better situation. For example, a code may specify a maximum building height of 3 stories but does not recognize that a one story building is inherently much safer.

3. We do not know what the level of risk is. Statistics are one measure of overall fire safety but we cannot say how much safer one building is than another.
The limitations of codes leads us to consider alternative methods of fire risk assessment. Fire risk indexing is specified as an option in building and life safety odes.
Fire Risk Indexing

- Model of fire safety that analyzes and scores hazards and other attributes to produce a rapid and simple estimate of relative fire risk

- Establishes system equivalency by assessment of a building to determine if it meets the intent or level of safety provided by a code

- FRI is analogous to wind-chill factor that uses 2 attributes, temperature and wind-speed to produce a measure of how cold it is.

- Codes acknowledge the appropriateness of equivalent fire safety. This is one way to establish that equivalency.
We established in Module 2 of this series that building codes include fire risk indexing approaches as specified in


- Compliance Alternatives in Chapter 14 of the International Existing Building Code.

An additional option is the Historic Fire Risk Index (HFRI) developed with support from NCPTT.
**Historic Risk Fire Index**

HFRI

- “Clean Sheet” Development

- Multi-attribute Decision Analysis

The HFRI (Historic Fire Risk Index) is a project funded by National Center for Preservation Technology and Training that produced a prototype fire risk index specifically for a class of historic buildings. It does not adapt existing indexes such as the NFPA FSES but starts fresh to look at what fire safety attributes are appropriated to such facilities. The development was structured using concepts of management science such as MADA (Multi-attribute Decision Analysis).
Historic Risk Fire Index

HFRI

• Historic House Museums

• Eleven Fire Safety Attributes

The prototype fire risk index is specifically for historic house museums.

An historic house museum is defined as a structure with recognized historic designation, or apparent historic significance, that is open to the public to display the building and its contents.

Thus the 11 fire safety attributes are focused on this type of occupancy.
Attributes are major fire hazard and safety elements that can be numerically evaluated.

The term attribute is primarily used in decision analysis which is also the source of risk indexing theory. In most fire risk indexing systems the attributes are referred to as parameters.
These are the 11 fire safety parameters (attributes) used in the HFRI.

Associated with each parameter is a weight or measure of importance derived by reverse engineering from existing fire risk index systems.
Building and fire codes generally identify minimum levels of attributes and do not recognize any additional safety of a better than required condition. For example, codes typically specify a minimum of 2 exits or means of egress but do not acknowledge the superior situation of having more than 2 exits.

By assigning weights and grades to fire safety attributes, a fire risk index can balance deficient values of some attributes with the additional safety provided by better than minimum values of other attributes. For example, where a code might require enclosure of vertical openings (e.g., stairwells) this might be offset by a greater number of exits than specified in the code.

### Fire Safety Attributes

- Codes specify minimum requirements with no credit for superior conditions
- FRI balances weak and strong attributes
This is the grading sheet for the HFRI. Note that in some sense it looks like a check list. However instead of yes-no check mark, an ordinal assessment or evaluation (the Parameter Grade) is determined for each attribute and entered in the third column (A). The Total fire safety score is then the sum of each parameter grade multiplied by its respective weight.
There are three steps to implementing the HFRI.

1) A survey of building is made to identify specific fire safety features that contribute to the attributes. The survey instrument is a form of checklist.
2) Using decision tables, the list of features is converted to a grade for each attribute (parameter). The parameter grades represent the...
A FRI is much easier to use than a code. It is a simple structured checklist that assigns numerical values.

The underlying decision theory of risk indexing provides a robustness that is not found in codes or checklists.

Because a FRI has values associated with fire safety attributes, costs can be assigned and a “best” solution found.

There are more extensive and detailed methods of fire risk assessment but they can be time consuming and expensive as illustrated on the next slide.
This figure illustrates that a complex quantitative risk analysis (QRA) as shown in curve (A) can define risk precisely, but at a significant cost for the analysis. Such analysis, typically an expected value calculation, might be applicable for special cases such as iconic buildings.

On the other hand, simple (C) and detailed (B) risk indexing does not provide the precision in defining risk but can be implemented with much less investment.
Limitations

Fire Risk Indexing

- Level of detail
- Level of comfort

Some people are concerned that FRI does not always include the level of detail that is in some building codes. However, an FRI can be constructed or modified to whatever level of detail is desirable.

Another concern is that an FRI is a much different structure than building codes. Code officials may not be comfortable with the simpler format.
A fire risk index is a tabular tool for analyzing and scoring hazards and other risk parameters that describe various building features or systems related to fire safety.

Numerical values assigned to these parameters are arithmetically manipulated to create a single mathematical expression for the overall level of fire safety provided by the building.

This last refers to fire modeling of potential consequences and the statistical calculation of expected loss. This is a mathematical engineering approach that will be discussed only briefly.
An expected loss calculation is the engineering estimate of risk based on the probability and consequence of a hazard or scenario. Fire scenarios are easier to identify than hazards.
Most fire safety engineers think in terms of fire scenarios. These are sets of possible fires, including their likelihood and consequences.

**Fire Scenarios**

- Detailed description of the conditions related to a hazardous event a facility may experience.

- Typically includes Ignition, fuel, fire spread, and threat to people and assets.
Calculating the expected loss from fire involves examining all possible fire scenarios and averaging the total loss based on the likelihood of each. While this equation is not complex, identifying the scenarios and determining their probabilities and consequences is a very involved process that typically employs computer fire modeling and inferential statistics.

\[
E.L. = \sum_{\text{scenarios}} (P_i \times \text{Loss}_i)
\]
What happens next with this information?

Knowing what the hazards and risks are we can evaluate them and deal with them using managerial expertise.
Another way to look at the scope of fire risk management is to break it into the parts shown in this figure.

We have looked at fire risk assessment which needs to be evaluated by the fire risk manager. Unacceptable risks need some form of risk treatment.
The principles of risk management apply to all areas of potential loss or damage. This is also referred to as fire risk treatment.

**Risk Management Principles**

- Eliminate hazards – avoid heat sources and combustibles
- Minimize exposure – separate hazards from significant historic elements.
- Provide protection – fire detection and suppression systems
- Transfer risk – This is the principle of insurance. Insurers can help identify and control hazards.
- Limit loss – Emergency response
Fire Risk Treatment

—*Risk Avoidance* - eliminating fire hazards
—*Risk Mitigation* - reducing risk by minimizing adverse effects
—*Risk Transfer* – economically laying off risk to other parties

Fire risk treatment involves activities performed to prevent fire and creating ways to meet fire losses that are not preventable or that occur despite preventive measures. We will look at each of the three principal categories.
The best treatment is to make the hazard go away. Consider every heat source and potential fuel and ask if there is an alternative. For example, a master power switch that shuts off all non-essential electrical service when the building is not occupied.

**Risk Avoidance**

- It is not possible to avoid all fire risk, but it is the most certain way of controlling loss

- It is possible to eliminate some fire hazards through design and fire prevention activities and to thereby avoid their associated risk

- Eliminate hazards – avoid heat sources and combustibles
Not all fires are preventable and there are ways that potential loss can be controlled when a fire does occur. This is the “Manage Fire Impact” branch of the Fire Safety Concepts Tree.
Achieving Objectives

The very top of the Fire Safety Concepts Tree shows the logic of how objectives of fire safety can be met by either preventing fire from occurring or by controlling and managing a fire if it does occur.
Risk Mitigation

• **Administrative** - Guidelines, policies, and procedures such as fire safety SOPs
• **Engineering** – Specially designed systems to remove or limit fire hazards
• **Object Protection** – Barriers, containment, encapsulation, etc. to protect assets (“exposed”)
• **Emergency Response** – In-house and public or contracted service

• Minimize exposure – separate hazards from significant historic elements.
• Provide protection – fire detection and suppression systems
• Limit loss – Emergency response
Transfer of risk is the principle of insurance. Insurers can help identify and control hazards.

**Risk Transfer**

- The transfer of risk to an insurance company is a necessary risk management alternative.
- Large deductibles can reduce costs while helping to cope with a catastrophic loss.
- The financial options of risk transfer are myriad and require careful analysis.
Risk Acceptance

• Acceptable risk is an elusive term that requires some hard decision making.
• The important thing about accepted or retained risk is that it be identified as such.
• Accepting risk is very different from ignoring risk, either intentionally or through ignorance. Ignoring risk is managerially unacceptable.

Some risks will be found acceptable, at least within economic constraints. The decision-making involved is not easy.
Risk acceptance includes both the risks we are know about and are willing to deal with as well as those that we do not anticipate. Nothing is risk free and there will always be some residual risk that is so remote we implicitly accept it.

**Residual Risk**

Difficult to Eliminate Risk from:

- Determined Arsonist
- Hidden Electricals
- Equipment Malfunction
- Human Error
- Exposure Fires
SUMMARY

- Historic building restoration projects are especially vulnerable to fire given the presence of combustible construction systems and materials. Most fires during construction can be avoided by carefully selecting and trained construction personnel, by selecting non-hazardous construction materials and processes, by maintaining full control over the site and personnel, and by ensuring that fire protection features and systems are in place and operational.
- Fire risk assessment and management can help organize protection during rehabilitation or renovation as well as during normal operation.

A high proportion of fires in historic buildings occur during a renovation or preservation activity. This module covered fire risk management with emphasis on precautions needed during the construction phase of a rehabilitation or restoration project.
Questions and Answers

Thank you for your participation.

We now have time for questions.
RESOURCES


Additional information on fire safety during construction activities in historic buildings may be found in the cited references