Title:	**Balanced Fire Protection in Buildings**
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Subject:	Fire & Safety
Keywords:	Code Compliance Fire Safety
Publication Date:	2014
Original Publication:	CTBUH 2014 Shanghai Conference Proceedings
Paper Type:	1. Book chapter/Part chapter 2. Journal paper 3. **Conference proceeding** 4. Unpublished conference paper 5. Magazine article 6. Unpublished

Balanced Fire Protection in Buildings
建筑中的平衡式防火技术


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Abstract

The paper will focus on fire protection techniques used to establish a balanced fire protection scheme consisting of passive and active components. A history of and overview of Installation Code and product standard requirements used in Western Construction will be covered. Additionally, the dependence on product standards and third party certification will be explained. Specific emphasis will be on passive fire protection testing requirements of Spray-applied Fire Resistive Coatings, Fire Doors and Fire-rated Assemblies – walls, floors, etc.

Keywords: Fire Protection, Codes, Fire-Rated, Balanced

摘要

本文将着重介绍用于兼顾主动式防火和被动式防火的的平衡式防火技术。将对西方建筑中广为采用的安装法规和产品标准做一个历史回顾和总结。此外，还会解释对产品标准和第三方认证的相互联系。强调的重点是基于被动式防火理念的喷涂式的耐火涂层、防火门和防火相关的组件，比如墙和地板等等。

关键词: 防火，法规，耐火，平衡式

Balanced Fire Protection in Buildings

Today it is common for U.S. based architects and designers to be involved in global projects. Their projects incorporate materials (steel building component members, gypsum walls, glass curtains, wall finishes, etc.) and methods regularly used in North American construction projects. Along with following North American construction methods, architects and designers provide balanced fire protection in buildings through the use of a mixture passive and active construction methods and systems. The goal of balanced fire protection within high-rise structures is to provide life safety solutions for the building's inhabitants and property protection. These are top of mind necessities for building owners, occupants and investors.

History of Fire Protection

There is a history of fires in buildings using combustible materials and finishes. Large cities like London and Chicago had major fires that destroyed major portions of the cities. These fires burned down thousands of buildings and killed hundreds of people. The property damage and loss of life in these fires was attributed to several factors – including the use of combustible building materials, poor city planning, and inadequate water supply.

平衡式的建筑防火

当今，美国的建筑师和设计师广泛的参与国际项目是很常见的。这些项目中会涉及到北美建设项目中经常使用的材料 (钢质结构构件、石膏墙、玻璃幕墙、外墙饰面等) 和方法。结合下列北美的建筑施工方法，建筑师和设计师们通过使用主动防火和被动防火相结合的结构和系统来实现平衡式建筑防火。在高层建筑内采用衡式防火的目标在于提供有效的解决方案来最大程度上减少生命和财产的损失。这些都是建筑业主、住户和投资者最为关注的需求。

防火的历史

历史上有很多很多被大火烧毁的建筑中均采用了大量的可燃材料和内部装潢，比如伦敦和芝加哥这样的大城市都曾发生过重大火灾，烧毁了成千上万的建筑并且夺走了数百人的生命。造成这些重大的生命财产损失因素包括可燃材料的使用、城市规划的不合理以及供水不足。

在城市重建和建立新的多层建筑时，建筑师和设计师们把重点放在如何将更有效的防火和生命安全防护措施融入到建筑当中。例如，自动水喷淋系统，可追溯到19世纪初的伦敦。在美国，早在19世纪末期就安装了消防喷头来保护那些经常会发生火灾的工厂。第一个喷水灭火系统由多孔管组成，后来开发出了类似于现在使用的带可熔元件的喷头。

As cities rebuilt and multi-story buildings were erected, architects and designers focused on the ways of incorporating more effective fire and life safety protection into buildings. For example, fire sprinkler systems date back to the early 1800's in London. In the United States, fire sprinklers were installed in the late 1800s to protect factories that routinely had fires. The first fire sprinkler system consisted of perforated pipes, later sprinklers heads with fusible elements were developed similar to the ones in use today.

The use of fire doors also dates back to the late 1800s. The first fire doors were constructed out of wood and later wood that was tin-clad. These were used to protect openings in factory walls that formed partitions between storage and office areas. These partitions formed "fire compartments" within buildings and helped limit the spread of fire through the building, thereby protecting life and property.

As architects began designing multi-story buildings, it quickly became evident that buildings needed to incorporate fire protection and life safety features. A good example of an early tragic fire of a high-rise building was the Triangle Shirtwaist Factory fire in 1911. The Triangle Shirtwaist Factory was in the upper floors of the 10 story Asch Building in New York City, New York and 146 lives were lost. The building height posed major problems for the New York Fire Department as their ladders were only capable of reaching the lower six floors. Additionally, there was a lack of fire detection and communications to warn workers of the imminent danger of the fire. This tragic fire not only changed workplace safety, but also emphasized the need for fire rated designs in multi-story buildings.

Types of Fire Protection Techniques

Passive fire protection, active fire protection and detection systems are the basic forms of fire protection found in industrial, commercial and residential occupancies. The following are examples of fire protection products and/or assemblies:

- Active Fire Protection – Sprinklers or Extinguishing Systems
- Passive Fire Protection – Fire rated walls and floors, Fire Doors, and Firestopping caulks, Intumescent coatings, Fire dampers
- Detection systems – Heat and smoke detectors, Pull stations, and Fire alarm panels

Passive fire protection designs and assemblies are construction systems which, when installed in a specific manner, will slow the spread of fire. Passive fire protection such as fire-resistance rated walls, floors and ceilings are commonly joined to form compartments to contain fire and smoke to the area of origin (i.e storage areas, mechanical rooms, etc.) . They also protect the means of egress system used for occupant evacuation and firefighting operations. Properly designed compartmentalized spaces can aide in containing fires and assist in the fire service response.

Active fire protection products and systems automatically sense and respond to fires without human intervention. Active fire protection is found in variety of different occupancies, including factories, residential occupancies, high risk areas within buildings, and in areas prone to fire like commercial cooking areas. Active systems can be very elaborate systems requiring the involvement of qualified professionals to specify the correct combination of system components. This is essential to providing a system that can accurately detect and respond to fires according to building space, occupancy and environment.

防火门的使用也可以追溯到19世纪末期。第一个防火门是采用木料制作的，再后来采用的是带锡包层的木料。它们被用来保护工厂中用于分隔储存区和办公区的墙板上的开口。这些隔墙构成了建筑内的"防火分区"，有助于限制火势在建筑内蔓延，从而达到保护生命和财产的目的。

建筑师开始设计多层建筑时，很快就意识到建筑需要融入防火和保障生命安全的功能。1911年的纽约三角内衣工厂 (Triangle Shirtwaist Factory) 大火就是早期高层建筑火灾悲剧的一个典型案例。该厂位于纽约州纽约市10层的阿希大厦 (Asch Building) 的顶层，在这场大火中有146人丧生。建筑的高度给纽约市消防局 (New York Fire Department) 造成了很大的麻烦，因为他们的消防梯只能到达较低的6层高度。此外，还缺乏火灾检测设施和通信设施，无法通知工人们迫在眉捷的火灾危险。这次悲剧性的火灾不仅改变了工作场所的安全，同时也让我们认识到多层建筑中必须有防火设计。

防火技术的类型

被动防火、主动防火和检测系统是工业、商业和居民房这些场所中常见的防火形式。以下是防火产品以及 / 或者防火组件的一些例子:

- 主动防火——喷淋或灭火系统
- 被动防火——耐火墙壁和地板、防火门、防火封堵剂、膨胀型防火涂料、防火闸
- 检测系统——感温和感烟探测器、火警自动报警器和火灾报警盘

被动防火设计和组件是以特殊方式安装时能够减缓火势蔓延的建筑系统。被动防火，如耐火墙壁、地板和吊顶，通常连接起来形成防火隔间，将火和烟隔挡在初始起火区域 (如: 储存区、机械室等) 。它们还可以保护用于人员疏散和消防作业的设施。合理设计的防火隔间有助于抑制火灾和协助消防部门有时间准备从而作出响应。

主动防火产品和系统可自动感应火灾并作出响应，无需人工干预。主动防火在各种不同的有人员活动的场所中很常见，包括工厂、住宅、建筑内的高风险区域、以及像商业烹饪区这种容易起火的区域内。主动防火系统是非常复杂的系统，需要有专业人士的参与，以确定系统组件的正确组合。基于建筑空间、建筑内人员情况和环境情况的分析来提供一个能够准确地探测和响应火灾的系统。

检测产品和系统的目的是提供早期的火灾预警。这些系统采用消防控制盘与感烟/感温传感器、水流传感器或其它装置相连接，以检测火情。控制盘依次向音频和视频设备发出信号，将火情通知建筑内的人员。消防控制盘还可以通知现场以外的监测设施或火灾应急调度中心。

隔断式被动系统建筑结合主动防火和图1所示的防火检测产品和系统，可提供一个平衡式的防火系统和隔断式建筑空间。事实证明，将平衡防火设计融入到商业、工业和住宅建筑中可保护建筑结构本身和其内部财产，更重要的是可为建筑内的人员提供生命安全保障。

Detection products and systems are intended to provide early warning of a fire event. These systems use a fire control panel connected to smoke and/or heat sensors, water flow sensors and/or other devices to detect the presence of fire. A control panel in turn sends out a signal to audio and visual devices to notify building occupants of a fire. The fire control panel may also notify off-site monitoring facilities and/or emergency dispatch centers of the fire.

Compartmentalized passive system construction in combination with active fire protection and fire detection products and systems as depicted in Figure 1 will provide a balanced fire protection system and compartmentalized building spaces. Incorporating balanced fire protection designs in commercial, industrial and residential buildings has proven to provide protection for the building's structure, its contents and more importantly provide life safety for the building's occupants.

Figure 1. Example of Balanced Fire Protection – Compartmentalized Office Spaces (Source: UL LLC)
图1 平衡式防火实例——分区式 办公空间 (来源: UL有限公司)

U.S. Building Codes and Standards

Codes such as the International Building Code published by International Code Council or the National Fire Protection Association's code, NFPA 1, Fire Code and product standards such as UL 10A, the Safety Standard for Tin-Clad Fire Doors or UL 263, the Standard for Fire Tests of Building Construction and Materials, have been recognized, adopted and enforced in the United States since the late 1800s. The evolution of United States codes and product standards requirements has often occurred to address fire safety problems connected with tragic fires. The following are examples of some major loss of life fires detailing their contributing factor to fire loss amd associated code and/or standard requirements that resulted:

1. The Iroquois Theater – 1903 Chicago, Illinois – 602 fatalities – The contributing factors to the fire and fatalities were combustible scenery in contact with lighting and blocked exit signs. The resultant changes to Code or Standard requirements were – Marked exits, flammability requirements for interior finishes, and fire curtains.
2. The Rhythm Nightclub – 1940 Natchez, MS – 200 fatalities – The contributing factors of the fire to fatalities were single operating exit doors and combustible material hanging from the ceiling rafters. The resultant Code or Standard requirements were – Increased number of exits provided in occupancies.
3. The Cocoanut Grove Night Club – 1942 Boston, Massachusetts – 492 fatalities – The contributing factors to fire and fatalities were a jammed main exit revolving door and the use of flammable interior finishes (fabric, artificial leather, etc.). The resultant new Code or Standard requirements were – Interior finishes flammability requirements and requirements for minimum collapsible force of revolving doors.
4. The MGM Grand Hotel – 1980 Las Vegas, Nevada – 85 fatalities – The contributing factors to the fire and fatalities were unprotected wall and floor penetrations in seismic joints and elevator shafts and faulty dampers allowed for rapid smoke migration. The resultant Code or Standard requirements were protection requirements for openings in fire rated constructions (walls and floors) and the use of fire suppression in hotel occupancies.

美国建筑规范与标准

自19世纪末期起，美国诸多建筑规范和标准都陆续被认可、采纳并作为美国国标强制执行。诸如国际建筑规范委员会颁布的《国际建筑法规》(International Building Code)，美国消防协会(National Fire Protection Association) 标准NFPA 1，以及消防规范和产品标准 如钢制门防火标准UL 10A，建筑结构和建筑材料防火测试的标准UL 263。美国建筑规范与产品标准的制定通常都是为了应对一些悲剧性火灾事件中发现的安全隐患。以下是一些由重大火灾事故而生成的建筑规范和标准的实例:

1. 易洛魁剧院 (Iroquois Theater) ——1903年，伊利诺伊州芝加哥——602人死亡——火灾及人员死亡的促成因素是可燃的舞台幕布被聚光灯点燃而出口标志也被挡住。因此对规范或标准提出了对应的要求——安全出口的标识、内部装饰的可燃性要求以及防火帘布的应用。
2. 节奏夜总会 (Rhythm nightclub) ——1940年，马萨诸塞州纳切兹——200人死亡——火灾之所以导致大量人员死亡，是由于整个建筑内仅有一个出口并且屋顶椽子上悬挂了很多易燃材料。因此对规范或标准提出了对应的要求——增加室内出口的数量。
3. 椰林夜总会 (Cocoanut Grove Night Club) ——1942年，马萨诸塞州波士顿——492人死亡——火灾及人员死亡的促成因素是主要出口旋转门卡住且室内使用了较多的诸如布、人造革等的可燃装饰材料。因此对规范或标准提出了对应的要求——有内部装饰的可燃性要求和旋转门的最低可折叠力要求。
4. 米高梅大酒店 (MGM Grand Hotel) ——1980年，内华达州拉斯维加斯——85人死亡——造成火灾及人员死亡的主要因素是高层建筑的墙壁和地板中没有防火封堵保护的抗震缝，电梯井以及未能关闭的防火阀形成了允许烟雾迅速蔓延的通道。因此对规范或标准提出了对应的要求是防火级结构 (墙壁和地板) 中开口处的防火要求和在酒店内采用灭火装置。
5. 杜邦广场酒店 (DuPont Plaza Hotel) ——1986年，波多黎各圣胡安——97人死亡——造成火灾及人员死亡的主要因素是出口门被锁上和未采用灭火装置。因此对规范或标准要求进行了修改——修改了酒店入住安全政策和酒店入住灭火要求。

5. The DuPont Plaza Hotel – 1986 San Juan, Puerto Rico – 97 Fatalities – The contributing factors to the fire and fatalities were locked exit doors and no fire suppression protection used. The resultant Codes or Standards requirements were changes in hotel occupancy security policies and fire suppression requirements in hotel occupancies.
6. The Station Night Club – 2003 Warwick, Rhode Island – 100 fatalities – The contributing factors to the fire and fatalities were the use of pyrotechnics (fireworks) in contact with combustible interior finish (foam). The resultant Code or Standard requirements were flammability requirements for interior finishes and mandatory automatic sprinkler protection.

Since their publication, U.S. codes and standards have relied on industry experts to advance requirements. Industry experts come from various sectors – insurance, manufacturing, consulting, building trades, code authorities, testing laboratories, universities, design engineers, and others. This approach has been successful at maintaining codes and standards, advancing technology and safety, thus being relevant and recognized around the global.

U.S. codes and standards incorporate a mixture of prescriptive and performance based fire protection requirements and methods. Performance based fire protection requirements involve a combination of predictive modeling and actual systems/product/design testing. Prescriptive requirements on the other hand relate to the use of evaluated products, materials or design assemblies which have fire protective or resistive properties.

NFPA 1 for example, includes Chapter 5 – Performance Based Options to demonstrate compliance. Chapter 5 permits authorities having jurisdiction (AHJ), enforcers of the code, to consider accepting data from qualified individuals (i.e material consultants, testing organizations, etc.) that detail fire and life safety scenarios and strategies. The data will typically include fire modeling and calculations of how the proposed design will provide fire and life protection to satisfy the AHJ's concerns.

Building code prescriptive requirements are well defined. The requirements are tied to the type of construction materials used, building heights, floor areas and types of occupancy. For example, Chapters 3, 4 and 5 of the International Building Code define occupancy types, hazards and allowable building heights and areas based on types of construction materials used – noncombustible or combustible. Chapters 6 and 7 establish required hourly fire ratings and lays out compartmental concepts by detailing fire and smoke protection requirements for walls, doors, structural members, shafts, etc. Active Fire Protection is covered in various parts of Fire Codes, but specifically for example, NFPA 1, Chapter 20 outlines minimum sprinkler requirements provided in various occupancies and exceptions to the installation of sprinkler systems.

Fire resistance ratings may be determined using prescriptive requirements for designs and assemblies as outlined throughout Chapter 7. Optionally, fire resistance can be determined through testing contained in specified referenced standards. The referenced standards are either ASTM E 119, Test Methods for Fire Tests of Building Construction and Materials or UL 263, Standard for Fire Tests of Building Construction and Materials. Both standards are nearly identical and vary only editorially. The test methods described in the standards require building elements (walls, doors, structural members, etc.)

6. 车站夜总会 (Station Night Club) ——2003年，罗得岛沃里克——100人死亡——造成火灾及人员死亡的主要因素是可燃的室内装饰材料 (泡沫) 被焰火 (烟花) 。因此对规范或标准提出了对应的要求——内部装饰的可燃性要求和强制使用自动喷水灭火装置。

美国的这些规范和标准自发布以来一直依靠业内专家来不断完善各种要求。业内专家来自于不同的行业——保险、制造、咨询、建筑业、规范权威机构、测试实验室、大学、设计工程师等。这种方法在维护规范与标准、推动技术和安全方面取得了巨大成功，因而受到全世界的普遍认同，意义重大。

美国规范与标准综合纳入了指令性和基于性能的防火要求和方法。基于性能的防火要求涉及到预测模型和实际系统 / 产品 / 设计测试的结合。另一方面，指令性要求涉及经过评估的具有消防防护或耐火性能的产品、材料或设计组件的使用。

例如，NFPA 1，包括第5章——基于性能的选择以符合要求。第5章允许有司法权的主管机关 (AHJ) 和规范执行者考虑接受来自被授权的人员 (即: 材料顾问、检测机构等) 的详细说明消防和生命安全方案及策略的数据。数据一般包括针对提出的设计能够提供何种火灾和人员安全保护的火灾模拟和计算，以满足AHJ的要求。

建筑规范指令性要求都有明确的定义。这些要求取决于所使用的建材类型、建筑高度、建筑面积和使用类型。例如，《国际建筑规范》的第3章、第4章和第5章根据所使用的建材可燃与否定义了使用类型、危害及允许建筑高度和面积。第6章和第7章规定了以耐火时间划分的耐火等级，并通过详细介绍墙壁、门、结构件、井道等的防火防烟要求提出了隔断概念。《防火规范》的诸多章节里面都涉及到了主动防火，但具体举例来说，NFPA 1第20章根据不同的居住使用情况提出了最低的水喷淋保护的要求以及水喷淋系统安装的一些例外情况。

耐火等级可以使用第7章中所述的指令性设计与组件防火要求来确定。或者，耐火性能可以通过指定参考标准中的测试来确定。参考标准既可以是ASTM E 119"建筑结构与材料的防火试验方法"，也可以是UL 263"建筑结构与材料的防火试验标准"。这两种标准几乎是相同的，只是在编辑风格上有所不同。这两种标准中所述的试验方法要求建筑元素 (墙壁、门、结构件等) 按照图2所示的时间温度曲线暴露于火中。可接受的试验结果包括: 不允许有能通过火焰的穿孔 (防火墙) 、将温度保持在低于规定范围 (如被保护钢柱上的平均温度为1000°F) 和支持额定负荷 (防火层) 。

认证组织所扮演的角色

规范和产品安全标准详细规定了施工与测试要求。有了合适的测试设备和设施，制造商或AHJ就可以进行自己的测试了。然而，美国的监管系统依赖于独立的被认可的第三方机构来评估产品和系统，并证明其是否符合产品安全标准。美国的司法管辖部门没有足够的预算用于建造测试实验室并进行自己的测试。相反，有意在美国市场销售的制造商们将必要的测试承包给专门从事产品评估的第三方认证机构。

并非所有美国的第三方认证机构都是相同的。有些只是测试和认证产品，而其它机构还会额外投资进行消防研究活动和编制产品标准。例如UL，它拥有专门的研发人员与AHJ和消防服务人员密切合作，以更好地掌握火灾现场发生的问题。UL的研究成果被用来改善产品标准，更新和完善安装规范和标准，并协助消防服务部门发展更为先进的消防战术。

be exposed to fire following the time temperature curve shown in Figure 2. Acceptable tests results include not allowing the passage of flames (fire rated walls), maintaining temperatures below specified limits (such as 1000°F average on protected steel columns) and supporting rated loads (fire rated floors).

Role of Certification Organizations

Codes and product safety standards detail construction and testing requirements. With the proper test equipment and facilities some manufacturers or AHJs could actually conduct their own testing. However, the U.S. regulatory system relies on independent, accredited third party organizations to evaluate products and systems and certify their compliance with product safety standards. U.S. jurisdictions do not have sufficient budgets to construct test labs and conduct their own testing. Instead manufacturers interested in selling in the U.S. market contract for the necessary tests with recognized third party certification organizations that specialize in product evaluations.

Not all U.S. third party certification organizations are the same. Some only test and certify products, while other organizations additionally invest in fire research activities and product standard development. UL for example has dedicated research staff that work closely with AHJs and the fire service staff to better understand field issues. The results of UL research are used to refine product standards, update and improve installation codes and standards, and assist fire services in developing improved firefighting tactics.

Besides research activities, UL also maintains over 1500 product standards, hundreds of which are adopted by reference in installation codes. In fact several UL Standards are the de facto standard recognized by the fire industry to evaluate fire protection products and systems.

Summary

Architects, and/or Fire Protection Engineers/Consultants design installations to comply with U.S. installation codes, and these designs rely on third party certified active fire protection, passive fire protection and detection systems to provide a code compliant, balanced fire safety installation. Besides prescriptive requirements, architects and designers can use the performance options of U.S. codes to cover cutting edge designs and use of the latest construction materials and systems. However, if there are any doubts in material/product properties or performance, U.S. recognized third party certification organizations have the expertise to conduct research, develop test methods and test innovative safety solutions.

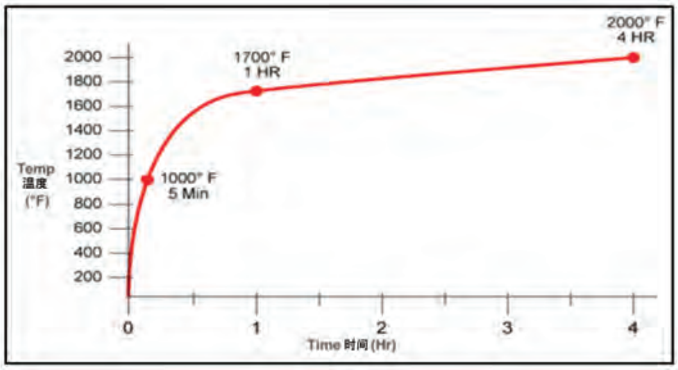

Figure 2. UL 263 Time –Temperature Curve (Source:UL LLC)
图2 UL 263 时间/温度曲线 (来源: UL有限公司)

除研究活动外，UL还维护1500多种产品标准，其中数百个标准被安装规范所援引和采纳。事实上，许多UL标准都是消防行业所公认的用于评估防火产品和系统的事实标准。

总结

建筑师／消防工程师／顾问设计出符合美国安装规范的安装设计，而这些设计依赖于第三方认证的主动防火、被动防火和检测系统，从而提供符合规范的、平衡式的消防安全整体解决方案。除了指令性要求，建筑师和设计师可以使用美国规范中所定义的性能选择来进行尖端的设计并使用最新的建筑材料和系统。然而，如果对材料／产品的特性或性能有任何疑问，美国认可的第三方认证机构会有专家进行研究，开发测试方法并测试创新的安全解决方案。