Building Rehabilitation

- Explain why there are different requirements for new and existing buildings
- Distinguish between repair, renovation, modification, reconstruction, addition, and change in occupancy
- Determine when chapter 43 applies

Historic Fire

- First Interstate Bank

Existing Buildings

- Once approved buildings stays approved
  - Rare cases of retroactive requirements
- Odd chapters
  - Work done to building
  - Change of occupancy
- Not always practical to meet all requirements

追溯要求的罕见案例

Types of Rehabilitation Work

康复工作类别

- Repair
- Renovation
- Modification
- Reconstruction
- Change of use or occupancy classification
- Addition

修理
翻新
修改
重建
使用或占用分类的变更
附加

Chapter 4

- Existing buildings
  - Time for compliance: limited but reasonable, expenditure, disruption, degree of hazard
  - Additions same as new construction
  - Renovations as nearly as practical to new construction

翻新与新建工程尽可能接近

- Conditions for occupancy
  - Plan of correction
  - Occupancy classification does not change
  - No serious life safety hazard

Chapter 4

- Construction, repair, and improvement operations
  - Must have egress routes
- Changes of occupancy
- Maintenance and testing
  - Responsible persons
  - Applicable standards

Reconstruction

- Typically, 50% of building reconstructed = upgrade everywhere

通常，50%的建筑改建=到处升级

- Illumination and emergency lighting at level of new construction
- Supply smoke alarms in residential areas
- Sprinklers and standpipes throughout in some cases

Change of Occupancy

Hazard Category	Occupancy Classification
1 (highest hazard)	Industrial or storage occupancies with high hazard contents
2	Health care, detention and correctional, residential board and care
3	Assembly, educational, day care, ambulatory health care, residential, mercantile, business, general and special-purpose industrial, ordinary hazard storage
4 (lowest hazard)	Industrial or storage occupancies with

Historic Buildings

规范承认建筑物与其他建筑物不同

- Code recognize that buildings are unlike others
- Will usually require PBD
- Can fix with like
- Can leave means of egress with AHJ consent

经AHJ同意，可以离开出口通道

4.6.4.2* The provisions of this *Code* shall be permitted to be modified by the authority having jurisdiction for buildings or structures identified and classified as historic buildings or structures where it is evident that a reasonable degree of safety is provided.

Special Structures

- Identify special structures
- Describe the requirements for atriums
- Explain the requirements for high-rise buildings

识别特殊结构
描述中庭的要求
解释高层建筑的要求

Historic Fire

- Hartford Circus

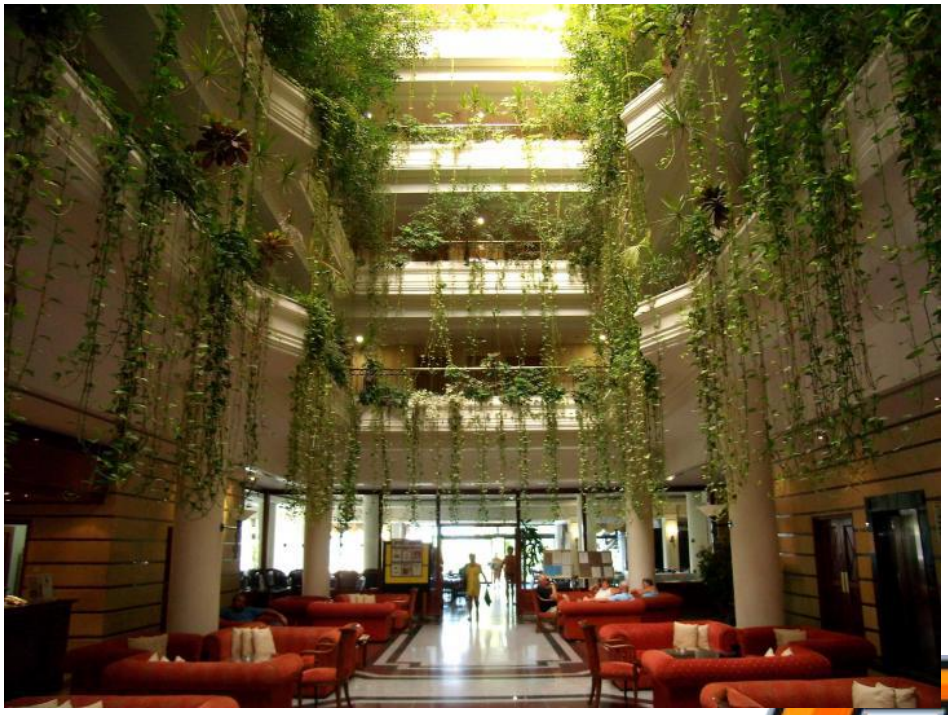
Special Structures

- Multiple occupancies
- Open structures
- Towers
- Water-surrounded structures
- Piers 码头
- Vehicles and vessels 车船
- Underground structures
- Permanent membrane structures 永久膜结构
- Temporary membrane structures
- Tents 帐篷

Chpater 11 and Chapter 8

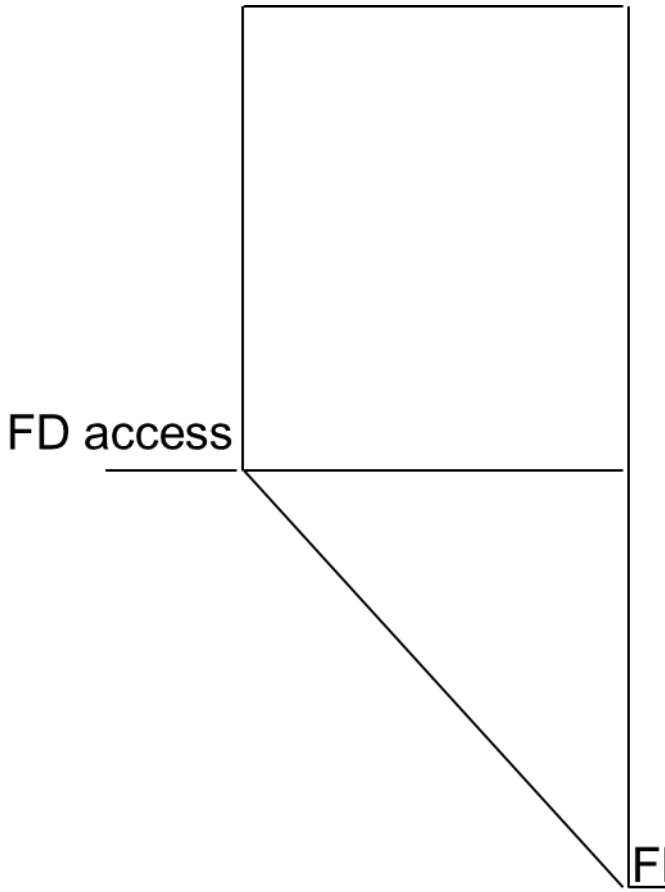
Atriums

- Separated
- Sprinklered throughout
- Smoke layer
  - Engineered design



High-Rise Buildings

- >75 ft above lowest level of fire department access
- Sprinklers and standpipes
- Voice alarm
- Two-way telephone for fire department use
- Additional emergency power requirements
- Emergency action plan
- Risk analysis

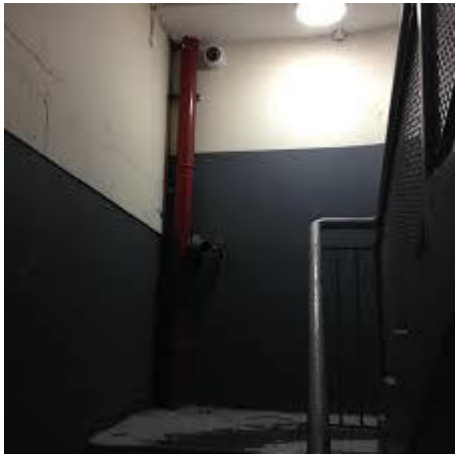


High-Rise Buildings

- Emergency command center
  - Status of fire protection systems
  - Elevator status 电梯状态
  - Emergency power status and control
  - Able to use voice alarm system
  - Two-way communication
  - Stairway video monitoring equipment

High-Rise in NFPA101

- Every 5th floor unlocked from ingress side 每五层从入口侧解锁一次
  - Minimum two re-entry doors 至少两个返回门
  - One door within top two stories 顶层两层内有一扇门
- Stairway video monitoring equipment
- Integrated testing
  - Initial
  - Every 10 years



High-Rise in IBC

- Remoteness of stairs
  - ¼ diagonal
  - 30 ft
- Additional stair
  - 420 ft
- 2-way communication every 5th floor if doors locked

International Building Code

- https://codes.iccsafe.org/content/IBC2021P1
- Describe the difference between a building code and the Life Safety Code
- Identify construction classifications
- Determine the separation requirement between different occupancies

Historic Fire

- Cardington

International Building Code

- Non structural
  - Identify the occupancy classification
  - Determine if sprinklered
  - Determine construction type
    - Building height
    - Building area
  - Locate building on site
  - Determine special occupancy
  - Calculate occupant load
    - Compliance with means of egress

International Building Code

- Non structural
  - Identify rated components
  - Identify interior finishes
  - Identify building systems
  - Identify special features
  - Identify roof covering
  - Determine location of glazings
  - Determine accessibility

Pretty much like we look at before

International Building Code

- Structural
  - Determine material
    - Concrete
    - Aluminum
    - Masonry
    - Steel
    - Wood
  - Determine design loads
    - Live
    - Dead
    - Environmental

Organization

- First digit indicates the chapter
- First section of chapter is designated by "01“
  - The first section of chapter 3 is section 301
- Subsections paragraphs and subparagraphs are indicated by decimal points
  - For example, 302.1.1
- Heavy vertical lines in the margin is change
- Arrow in the margin is deletion
- Italicized terms are defined in Chapter 2

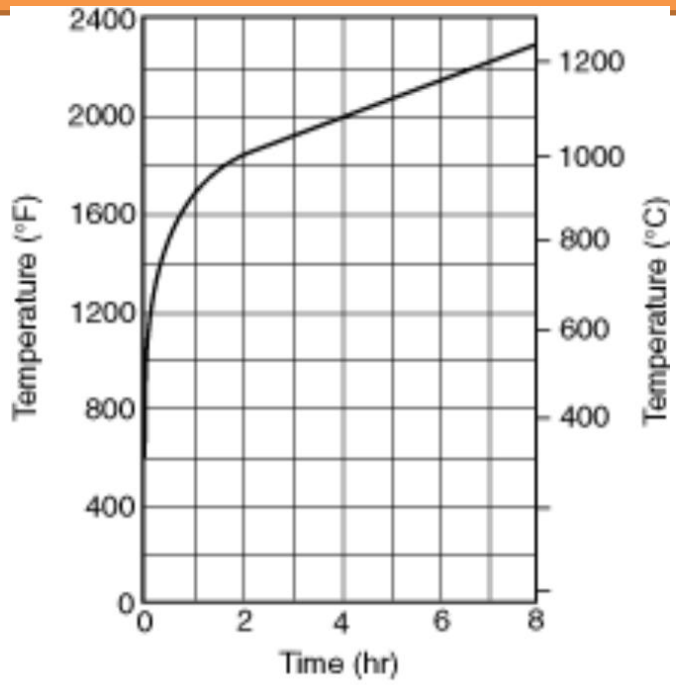
斜体字术语

Chapters

- Chapter 1
  - Basically Chapters 1 and 4 in NFPA 101
- Chapter 2
  - Basically Chapter 3 in NFPA 101
- Chapter 3
  - Basically Chapter 6 in NFPA 101
- Chapter 4
  - Basically Chapters 11-42 in NFPA 101
- Chapter 7
  - Basically Chapter 8 in NFPA 101 with additional design information
- Chapter 8
  - Basically Chapter 10 in NFPA 101
- Chapter 9
  - Basically Chapter 9 in NFPA 101
- Chapter 10
  - Basically Chapter 7 in NFPA 101

Fire Resistance Ratings

- Typically given in units of hours
  - Determined by nationally recognized testing laboratories
    - Example: Underwriters Laboratories
  - Standard time vs. temperature fire exposure



Note: The following are the points that determine the curve.

1000°F	(538°C)	at 5 minutes
1300°F	(704°C)	at 10 minutes
1550°F	(843°C)	at 30 minutes
1700°F	(927°C)	at 1 hour
1850°F	(1010°C)	at 2 hours
2000°F	(1093°C)	at 4 hours
2300°F	(1260°C)	at 8 hours or over

Fire Resistance Requirements

Find information on the code

- Fire walls typically 3 hour rated
- Fire barriers typically 2 hour rated
- Required fire resistance ratings for openings
  - Tables
  - In text

Comparison of Codes

NFPA	IBC
I (443)	
I (332)	I-A
II (222)	I-B
II (111)	II-A
II (000)	II-B
III (211)	III-A
III (200)	III-B
	IV-A
	IV-B
	IV-C
IV (2HH)	IV-HT
V (111)	V-A
V (000)	V-B

A is one hour rated, B is unrated

New Construction Classifications

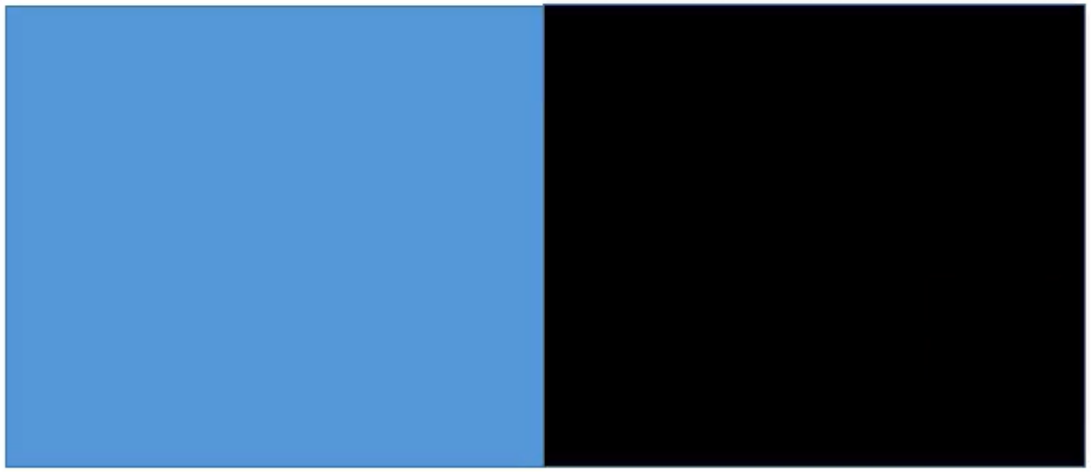
- Type IV has been redefined in the 2021 edition of the codes
  - Based on the results of testing
  - Allows for taller wood buildings
    - Fire resistance ratings required
  - New types
    - IV-A (fully protected by non combustible material)
    - IV-B (limited exposed interior members)
    - IV-C (increases for lower hazard occupancies)
  - NFPA 5000 no new categories, but allowed to follow Type II rules when having equivalent fire resistance and meeting other requirements

Separation

- For incidental accessory occupancy
  - (509 and Table 509) 附带附属设施占用
- Mixed occupancies
  - Accessary (508.2)
  - Nonseparated (508.3)
  - Separated (508.4 and Table 508.4)

Incidental Use

- Table 509



Half restaurant and half business
508.4, 2 hr rated wall between them
Area:50% assembly allowed area plus 50% business allowed area

0.5*9500+0.5*23000=4750+11500=16250 ft^2
5000/9500+5000/23000<1 ✓
5000/9500+12000/23000>1 ✗

Separated

- Table 508.4
- As of 2021 filling in both sides of the table
- Must use Table 506.2
- Options
  - No wall required
    - Use most restrictive
  - Rated wall required
  - Not allowed

International Building Code

- Apply the rules for height and areas of buildings
- Perform calculations related to adjustment factors

Historic Fire

- Cook County Office Building

TABLE 504.3 ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	50	40
	S13D	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60

Height and Area

- Sections 504 and 506
  - Sprinklers generally increase by 20 ft and 1 story for height
  - Sprinklers add 2 or 3 times original area

https://codes.iccsafe.org/content/IBC2018/chapter-5-general-building-heights-and-areas#IBC2018_Ch05_Sec504

Modifications of Area Limits

All the At and Is use non-sprinkler value

$$A_a = A_t + [A_t * I_f] + [A_t * I_s]$$

or

Both will have the same answer

Use 2 values on table

$$A_a = A_t + [NS * I_f]$$

Where:

A_a= Allowable area per floor

A_t= Allowable area from Table

I_f= Area factor increase due to frontage 建筑前面的空地面积

I_s= Area factor increase due to sprinklers

Area factor for sprinklers

- I_s=3 for buildings one story above ground
- I_s=2 for buildings more than one story above ground

Area Factor for Frontage

If not more than 0.75

$$I_f = \left[\frac{F}{P} - 0.25\right]\frac{W}{30}$$

Where:

I_f= Area factor increase due to frontage

F= Building perimeter with frontage (ft)

P= Total building perimeter (ft) 建筑总周长

W= Width of the frontage (ft)

Note: W/30 not permitted to exceed 1.0

W must be at least 20 ft

Area Factor for Frontage

- New table values in 2021

% of Perimeter	Open Space <20 ft	Open Space 20 to <25 ft	Open Space 25 to <30 ft	Open Space 30 ft or more
<25	0	0	0	0
25 to <50	0	0.17	0.21	0.25
50 to <75	0	0.33	0.42	0.50
75 or greater	0	0.50	0.63	0.75

- New values are at the lower end of each range
- Interpolation allowed
  - Client will want you to use linear interpolation
  - Old equation was linear interpolation
  - All values are still the same

Example 1

- What are the height and area limitations for a Group M occupancy in a building of Type III B construction?
- Solution: 2 Stories, 12,500 ft^2 per floor.

	SM	UL	181,500	79,500	39,000	70,500	39,000	229,500	153,000	76,500
M	NS	UL	UL	21,500	12,500	18,500	12,500	61,500	41,000	26,625
	S1	UL	UL	86,000	50,000	74,000	50,000	246,000	164,000	102,500
	SM	UL	UL	64,500	37,500	55,500	37,500	184,500	123,000	76,875
	NS[d]									

	S	UL	6	4	3	4	3	9	6	4	4	2	2
M	NS	UL	11	4	2	4	2	4	4	4	4	3	1
	S	UL	12	5	3	5	3	12	8	6	5	4	2
	NS[d]	UL	11										

Example 2

- What are the height and area limitations for a library in an unprotected steel building without sprinklers?
- Solution: 2 Stories, 9,500 ft^2 per floor

A-1	NS	UL	5	3	2	3	2	3	3	3	3	2	1
	S	UL	6	4	3	4	3	9	6	4	4	3	2
A-2	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2
A-3	NS	UL	11	3	2	3	2	3	3	3	3	2	1
	S	UL	12	4	3	4	3	18	12	6	4	3	2

		A	B	A	B	A	B	A	B	C
A-1	NS	UL	UL	15,500	8,500	14,000	8,500	45,000	30,000	18,750
	S1	UL	UL	62,000	34,000	56,000	34,000	180,000	120,000	75,000
	SM	UL	UL	46,500	25,500	42,000	25,500	135,000	90,000	56,250
A-2	NS	UL	UL	15,500	9,500	14,000	9,500	45,000	30,000	18,750
	S1	UL	UL	62,000	38,000	56,000	38,000	180,000	120,000	75,000
	SM	UL	UL	46,500	28,500	42,000	28,500	135,000	90,000	56,250
A-3	NS	UL	UL	15,500	9,500	14,000	9,500	45,000	30,000	18,750
	S1	UL	UL	62,000	38,000	56,000	38,000	180,000	120,000	75,000

Example 3

- Are the height and area of the building acceptable?
  - Building is unsprinklered
  - Frontage on two adjacent sides 25 feet wide
  - 2 Stories
  - 110 ft x 100 ft
  - Type V-B Construction
  - Group B occupancy

两个相邻侧面的正面25英尺宽

Example 3

- Need 11,000 ft^2, 2 stories
- 9,000 ft^2, 2 stories
- Allowance for frontage:

$$I_f = \left[\frac{210}{420} - 0.25\right]\frac{25}{30} = 0.208$$

- Total area allowed:

A_a=9,000+[9,000*0.208]+[9,000*0]=10,875 ft^2

<11000 not allowed

Example 3

- Options
  - Just tell the owner no
  - Ask the owner to make their building smaller
  - Relocate building on site to increase frontage
  - Change to different construction type
    - Protect structural elements
    - Change material
  - Add sprinklers

Example 4

- Are the area and height acceptable if frontage 30 ft wide exists on all sides?
  - Sprinklered
  - 3 Stories
  - 130 ft x 360 ft
  - Group E Occupancy
  - Type II B Construction

Example 4

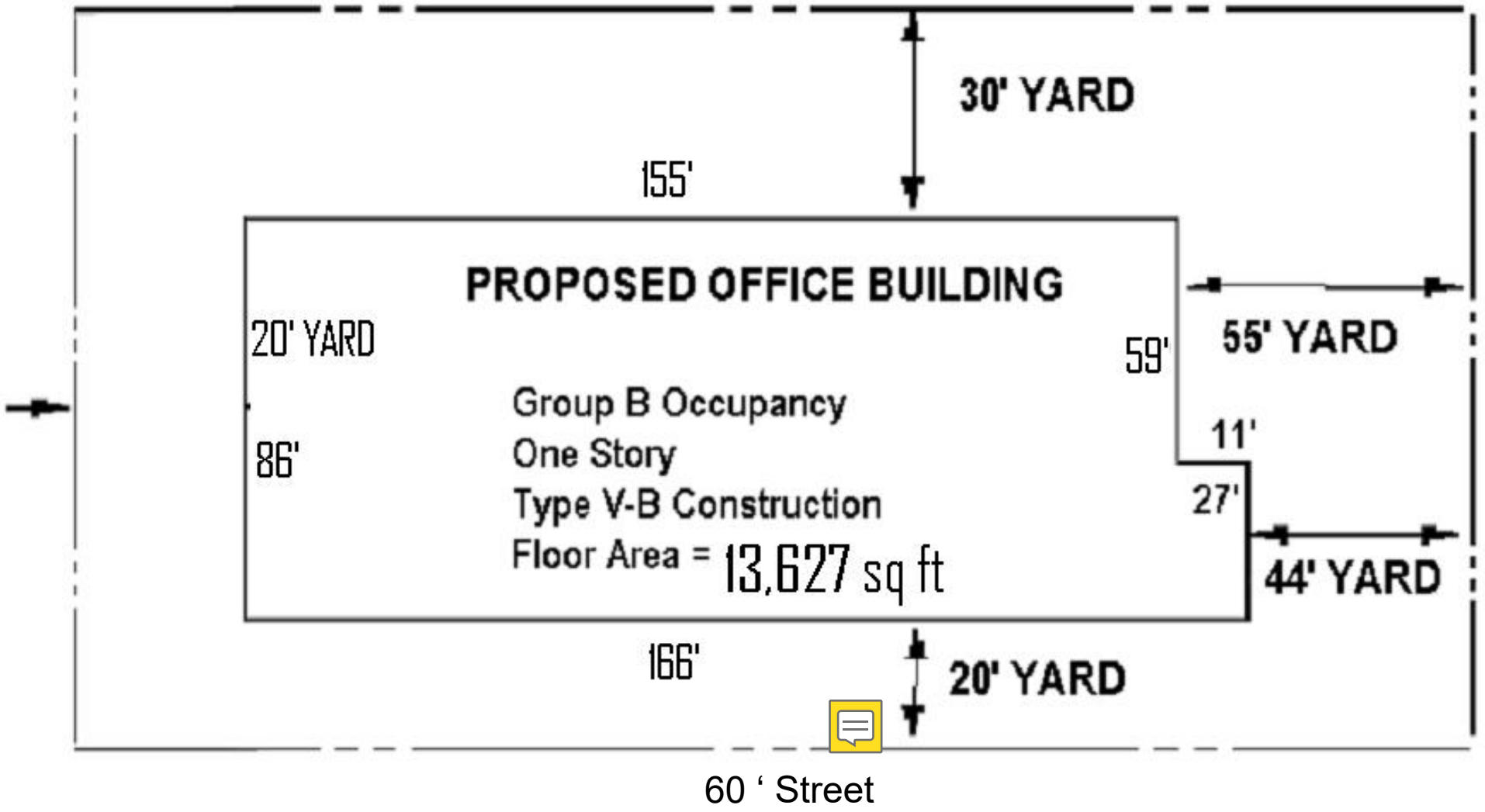
- Need 46,800 ft^2, 3 stories
- Nonsprinklered: 14,500 ft^2, 2 stories
- Sprinklers can increase to 3 stories
- Allowance for frontage:

$$I_f = \left[\frac{980}{980} - 0.25\right]\frac{30}{30} = 0.75$$

- Total area allowed:

A_a=14,500+[14,500*0.75]+[14,500*2]=54,375 ft^2

=43,500+[14,500*0.75]=54,375 ft^2



Using the information given, determine if the building may be of Type V-B Construction as proposed

Example 5

- Group B Occupancy, Type V-B: 9000 ft^2
- Varying frontage = check multiple configurations
  - Option 1: 20 ft frontage on all sides

$$I_f = \left[\frac{504}{504} - 0.25\right]\frac{20}{30} = 0.5$$

  - Option 2: 30 ft frontage on 83%

$$I_f = \left[\frac{418}{504} - 0.25\right]\frac{30}{30} = 0.579$$

  - Use Option 2
- Total area allowed:
- A_a=9,000+[9,000*0.579]+[9,000*0]=14,211 ft^2

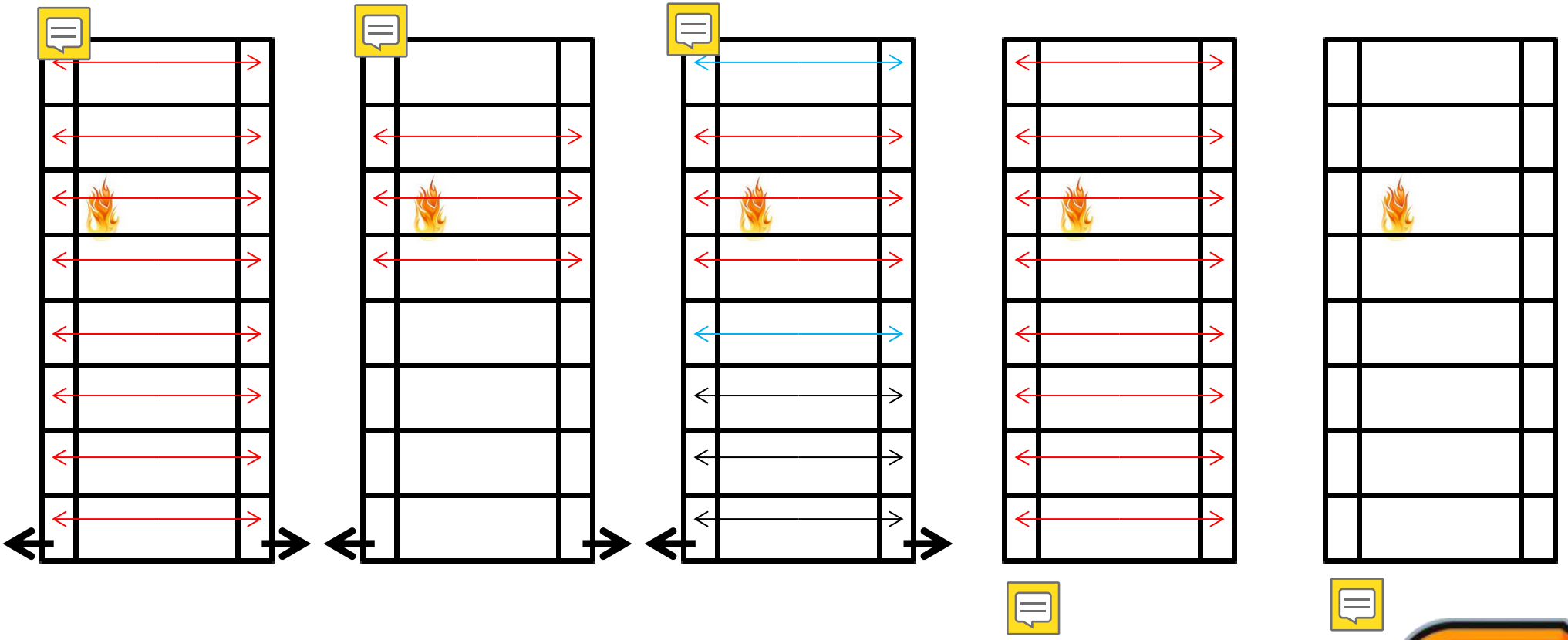
Building Evacuations

- Select the appropriate evacuation strategy for a building
- Determine when elevator evacuations are appropriate
- Identify the requirements for fire drills and emergency plans

Historic Fire

- 1993 World Trade Center

Evacuation Strategies

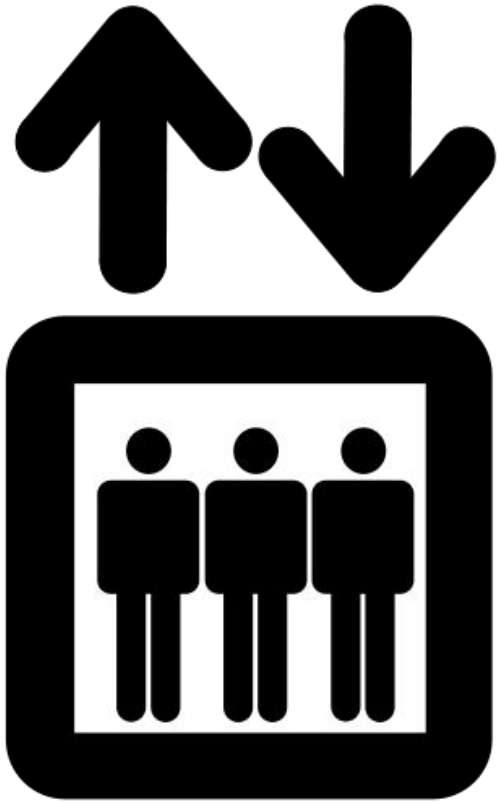


Hazardous Areas

- High-hazard
  - 75 ft
  - Means of egress from other codes
- Mechanical rooms
  - 50 ft (longer with sprinklers and other conditions)
- Normally unoccupied spaces
  - Less stringent requirements

Elevator Evacuation

- Advantages
- Problems
- Messages
  - Content
  - Templates



Emergency Stair Travel Devices

- Not required
- New installations to meet relevant standard

Fire Drills

- As required by chapters 11 through 42
- Announced or not
- Sufficient frequency
  - Familiarity
  - Identify problems
- All persons shall participate
  - Training
- Availability of exits
- Competent persons shall be responsible
- Order and discipline -- not speed
- Relocate to predetermined location
- Cry-wolf
- Lost productivity

Emergency Plan

- Procedures for reporting of emergencies
- Occupant and staff response to emergencies
- Evacuation procedures
- Appropriateness of the use of elevators
- Design and conduct of fire drills
- Type and coverage of fire protection systems
- Other items required by AHJ
- Shall be submitted to AHJ for review
  - AHJ sets frequency

Construction

- Explain the hazards during construction
- Discus how to effectively utilize site planning
- Determine the separation required between buildings

Historic Fire

- Notre Dame

Construction

- Greater fire risk than at other times
  - Incomplete or missing fire barriers
  - Limited water supplies
  - Extraordinary combustible sources 特殊可燃源
  - Limited ingress and egress routes
  - Extraordinary ignition sources
  - Extraordinary security conditions
- Earlier installation of fire protection systems could be beneficial

Construction

- Limited notification
- Human activities
  - Smoking
  - Housekeeping
  - Open flames
  - Intentional fires by unauthorized people

Construction

- Life safety
  - Stairway (temporary or permanent) required when construction exceeds 40 ft above lowest level of fire department access
  - Within one floor of the highest point of construction having secured decking or flooring
  - Means of egress must be maintained at all times

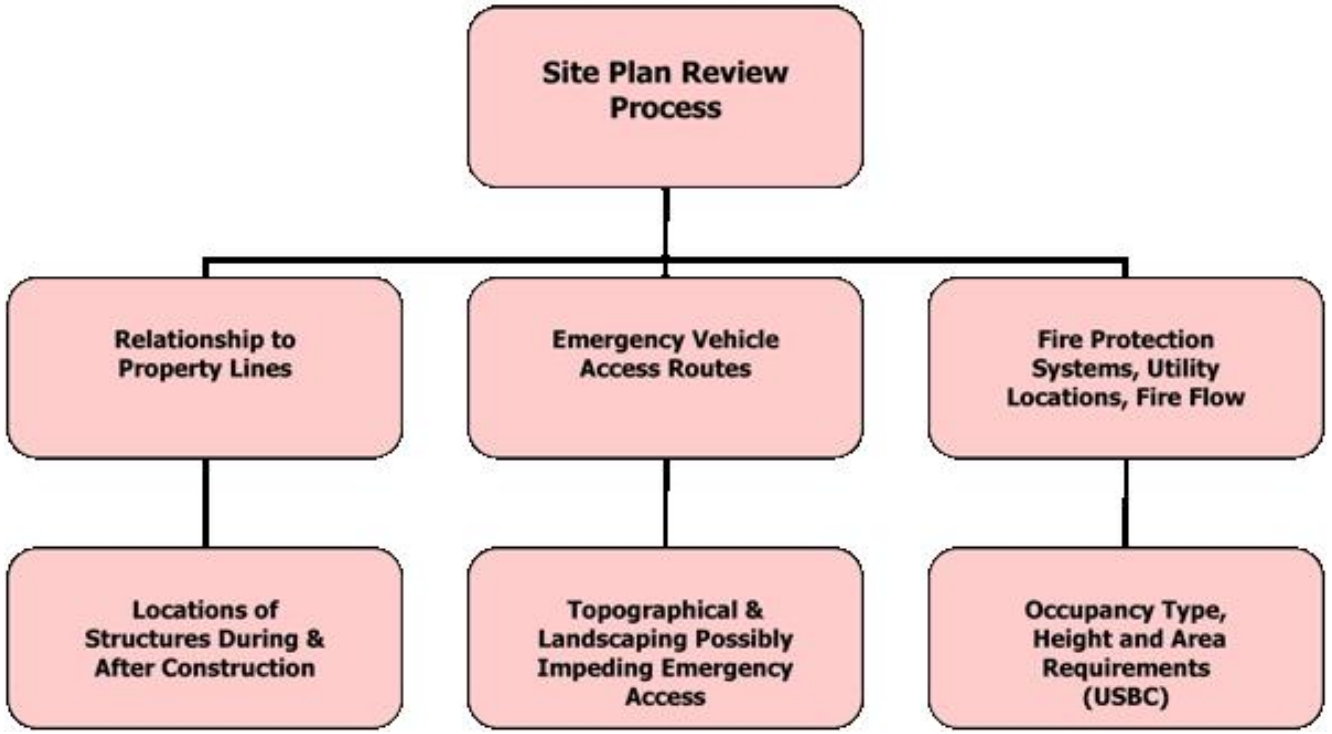
if the fire marshal happens to show up on site and see that mean of egress are being blocked.They're gonna shut down operations

Why Talk About Site Planning?

- Important issues affect:
  - Value and usability to the owner
  - Life safety of occupants
  - Cost
  - Effects upon neighboring properties

    对邻近财产的影响

Site Planning



Interior Layout

- Relative use of doors, walls and other elements of compartmentation
- Relative complexity
  - Circulation patterns are important in emergency evacuation
- Building height
  - Ladder trucks only reach about 7 floors
  - Interior evacuation above the 7th floor
- Security features

Transportation

- How accessible is the building?
- Time is vital for fire department
  - How quickly can the fire department arrive
  - What traffic issues could delay arrival

Accessibility for Fire Department Operations

- Access to the building
  - Fire lanes
  - Windowless areas
  - Concealed spaces
  - Interior access

消防车道
无窗区域
隐蔽空间
内部通道

Water Supply

- Critical issues
  - Residual pressure
  - Volume
  - Reliability
- High-rise pressure requirements
- Number of sprinklers that might activate
- Location of hydrants

Exposure Protection

- Fire in another building a threat
  - Radiation
  - Flame impingement
  - Flying debris
- Requirements in IBC

Exposure Protection

$A/a+A_a/a_a \leq 1.0$

Three examples

Where:

A=Area of protected openings

a=Allowable area of protected openings

A_a=Area of unprotected openings

a_a=Allowable area of unprotected openings

Separation Distance (ft)								
	< 3	3 to <5	5 to <10	10 to <15	15 to <20	20 to <25	25 to <30	30+
UPNS	NP	NP	10 %	15 %	25 %	45 %	70 %	UL
UPS	NP	15 %	25 %	45%	75 %	UL	UL	UL
P	NP	15 %	25 %	45 %	75 %	UL	UL	UL

Exposure Protection

$$A_e = A + (A_f * F_{eo})$$

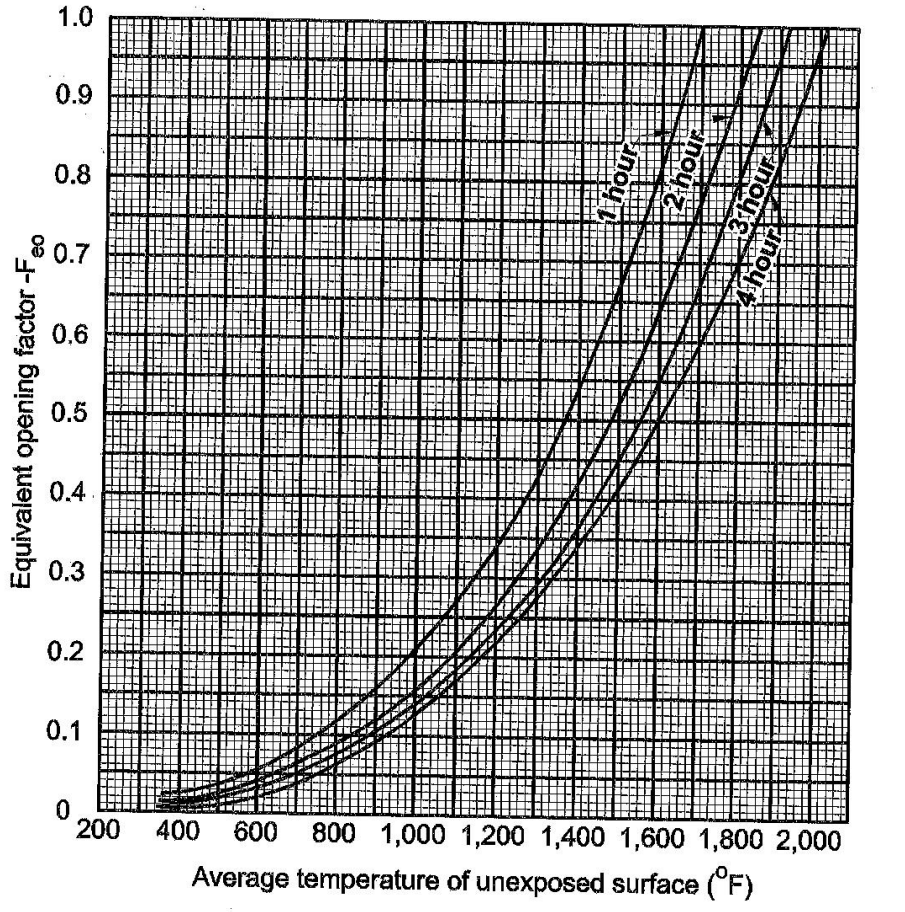
Where:

A_e=Equivalent area

A=Area of protected openings

A_f=Area of wall surface excluding openings

F_{eo}=Equivalent opening factor



Design of the Building

- Compartmentation
- Detection, alarms, and communications
- Automatic fire suppression
- Egress systems
- Ventilation systems

Occupant Behavioral Scenarios

- Explain the PBD process
- Select appropriate evacuation scenarios
- Identify appropriate fire scenarios

Historic Fire

- Cocoanut Grove

There was one room particular fire started fake palm trees and lots of other things to make it look like it was a floral tropical type of place but the fire started because well within all that insulation. Obviously they have lights and other things and in a back corner. Apparently there was one guess to was with his. girlfriend at the time.Wanted a little bit more dark in that corner of the room for whatever reason and so went and unscrewed the light bulb there to make it dark in that back corner. First boy later on was was told to go back there and fix the light So we went there but because it's dark.you see the lighter so he could see what he was doing and the process of the hot material from light bulb or his lighter caught some of that foam plastic into your finish on fire which then led to very rapid fire spread

有一个房间是由假棕榈树和其他很多东西引起的，使它看起来像是一个热带花卉类型的地方，但火灾是在所有的隔热层内发生的。很明显，他们有灯光和其他东西，在后面的角落里。显然有一个猜测是关于他的。当时的女朋友。不管什么原因，她想在房间的那个角落再暗一点，于是去拧下那个角落的灯泡，让后面的那个角落变暗。第一个男孩后来被告知回到那里修理灯，所以我们去了那里，但因为天很黑。你看到打火机，这样他就可以看到他在做什么，从灯泡或他的打火机的高温材料的过程中，一些泡沫塑料在你的饰面上着火，然后导致火势迅速蔓延

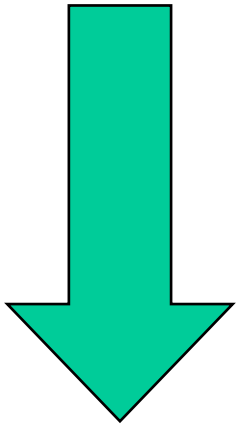
Performance Based Option

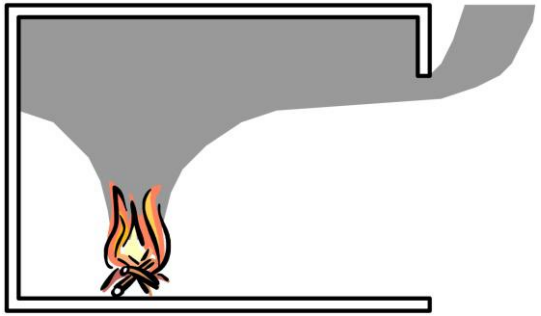
- Chapter 5 of NFPA101
- No rules
  - Goals and objectives
  - Some prescriptive rules stay
- All stakeholders
  - Assumptions
  - Agreement
- Establish performance criteria

Safety Assessment

Performance based design

Required Safe Escape Time (RSET) < Available Safe Escape Time (ASET)





Safe

Occupant Scenarios

- Characteristics
  - Physical
  - Cognitive
- Number
  - High density
  - Low density
- Location
- Activities
  - Actions
  - Decisions
- Trained staff
- Building life cycle
- Off-site conditions

Prescribed Occupant Scenarios

so you can't really go to chapter 5 NFPA 101 for this one you're gonna have to consider different variables. What's important to that space? Why is it important you come up with the scenarios accordingly?

Potential Occupant Scenarios: Characteristics

- Sensibility
- Reactivity
- Mobility
- Susceptibility

敏感性
反应性
流动性
敏感性

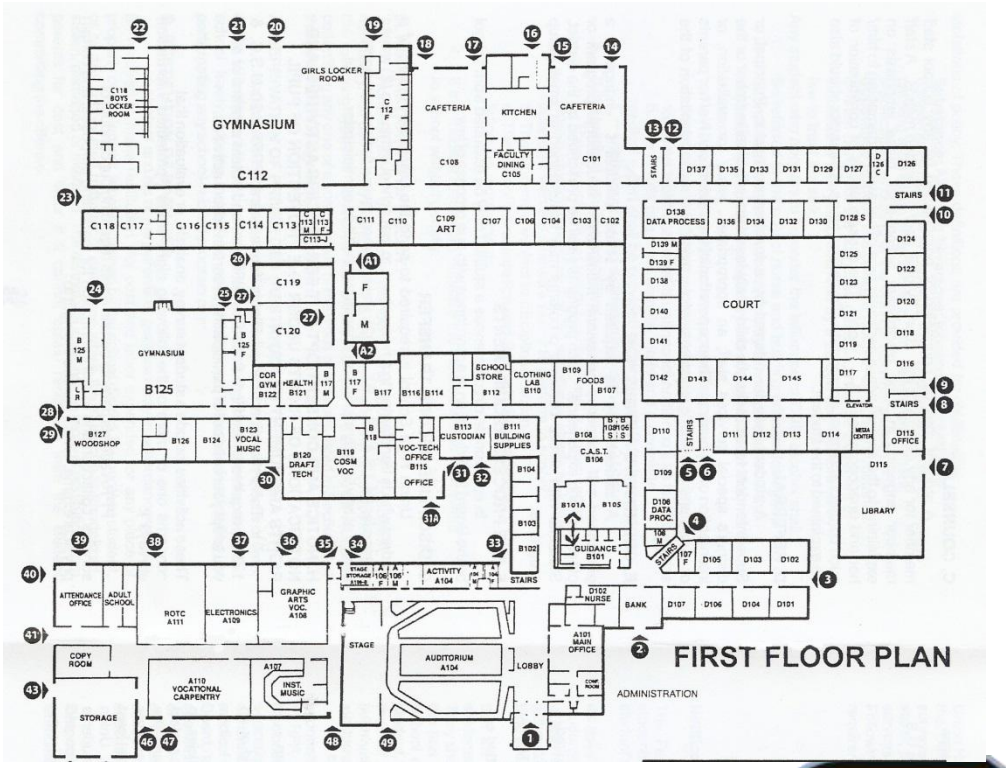
- Normal conditions
- Elderly
- Children
- Disabled

正常条件
老年人
儿童
残废

We need to count worst case realistic scenario

Potential Occupant Scenarios: Number and Location

- Normal conditions
- Maximum occupant load
  - All occupied rooms
  - Average density
  - Special occasion
- Low occupant load



Potential Occupant Scenarios: Activities and Staff

潜在占用场景：活动和员工

- Normal conditions
- Delays
  - Role
  - Familiarity
  - Actions
  - Decisions
- Staff assistance
- Emergency response personnel

Potential Occupant Scenarios Building and Off-Site Conditions

建筑物和场外条件下的潜在占用场景

- Post-construction
- Off-site

what's happening outside the building can make a big difference.

Fire Scenario Considerations

- Identify the specific fire safety challenges
- Location of the fire
- Type of fire
- Potential complicating hazards leading to other fire scenarios
- Systems and features impacting the fire
- Occupant actions impacting the fire

Prescribed Fire Scenarios

主要出口的超快火力

- Occupancy specific typical fire

特定占用的典型火灾

- Ultrafast fire in primary means of egress

OKLAHOMA STATE UNIVERSITY

Prescribed Fire Scenarios

- Starts in normally unoccupied room with large number of people in another area
- Concealed space fire adjacent to a large room

靠近大房间的隐蔽空间火灾

fire starts somewhere where there's not many people because of that people's response is delayed and then the fire gets much larger as people delayed

Prescribed Fire Scenarios

- Slow fire shielded from systems near high occupancy

- Severe fire characteristic of the building

Prescribed Fire Scenarios

- Outside exposure fire

- Ordinary combustibles fire without passive fire protection system functioning
- Ordinary combustibles fire without active fire protection system functioning

We don't have to assume the worst case because the worst case is the massive fire, shielded from the system and passive system fails and and and it's just an ordinary combustible part

Scenario Selection

- Must address all potential scenarios
  - Realistic
  - Do not have to model all
- Results must be documented

Analysis

- Deterministic vs. Probabilistic 确定性与概率性
- Sensitivity analysis 敏感性分析

Wayfinding

- Explain the difference between emergency lighting and means of egress lighting
- Determine how to use signage effectively
- Specify the appropriate guidance for the means of egress

Historic Fire

- Haunted Castle

Illumination

- People need to find ways to exits
  - Lighted means of egress at all times
  - Designated portions of exit access and exit discharge
- Can use natural or artificial light
  - Will the building ever be used after dark?
- Cannot use batteries 不能使用电池
- Can use motion sensors 可以使用运动传感器

Lighting

- Normal
  - 10 ft-candle on stairs
  - 1 ft-candle normal
  - 0.2 ft-candle in assembly occupancy during performance
  - 0.2 ft-candle if failure

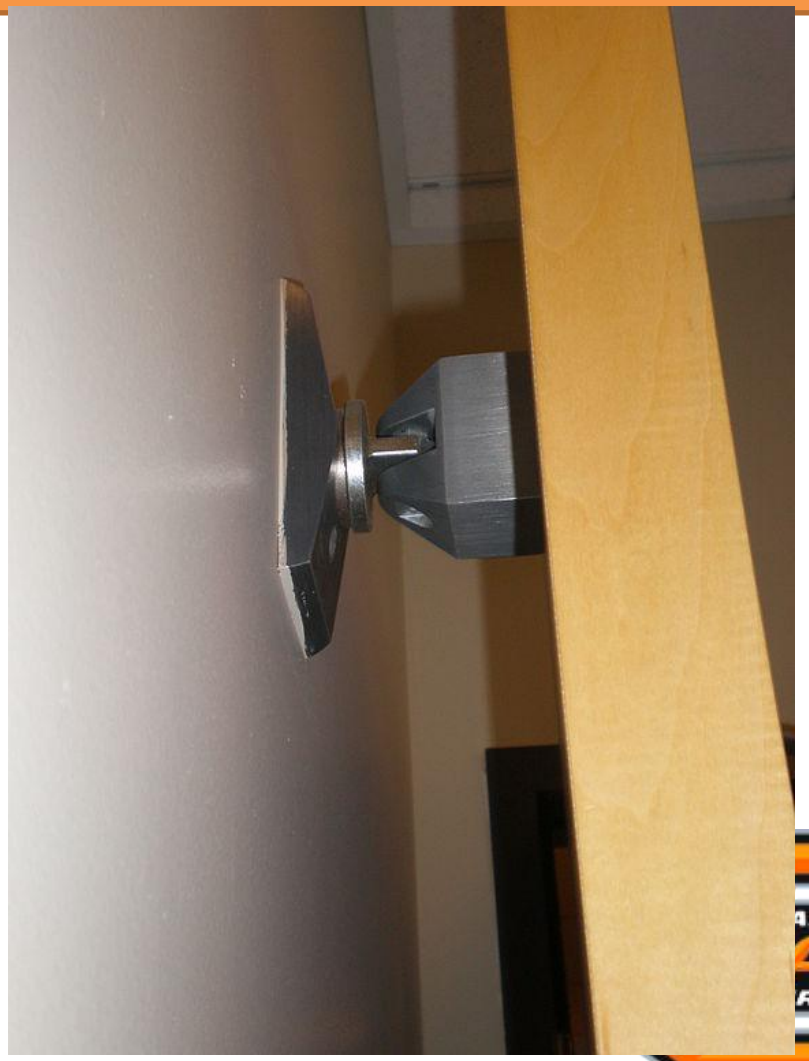
楼梯上的10英尺烛光
1英尺烛光正常
演出期间，装配占用0.2英尺烛光
如果发生故障，则为0.2英尺烛光

Emergency Power

- Purpose of emergency power
- Systems required to be on emergency power

Means of Egress

- Automatically closing doors fail closed
- Electronic locks fail open



Emergency Lighting

- 10 s max
- 1.5 hr required
- Monthly test (30 s)
- Annual test (1.5 hr)

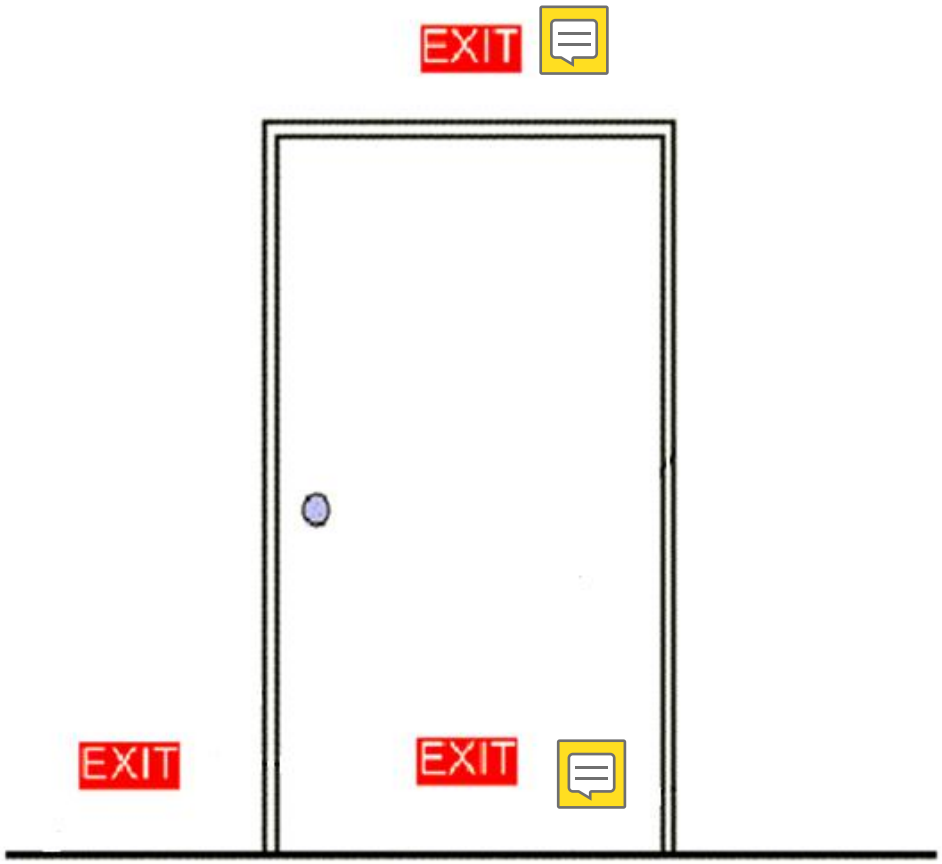
- 1 ft-candle at any point
- 0.1 ft-candle at floor level
- Cannot drop below 0.6 and 0.06 ft-candle after 1.5 hr
- Maximum-to-minimum no greater than 40 to 1

Activation of Emergency Power

- Failure of public utility 公用事业的失败
- Opening of circuit breaker or fuse 断路器或保险丝断开
- Manual acts
  - Turning off the normal lights

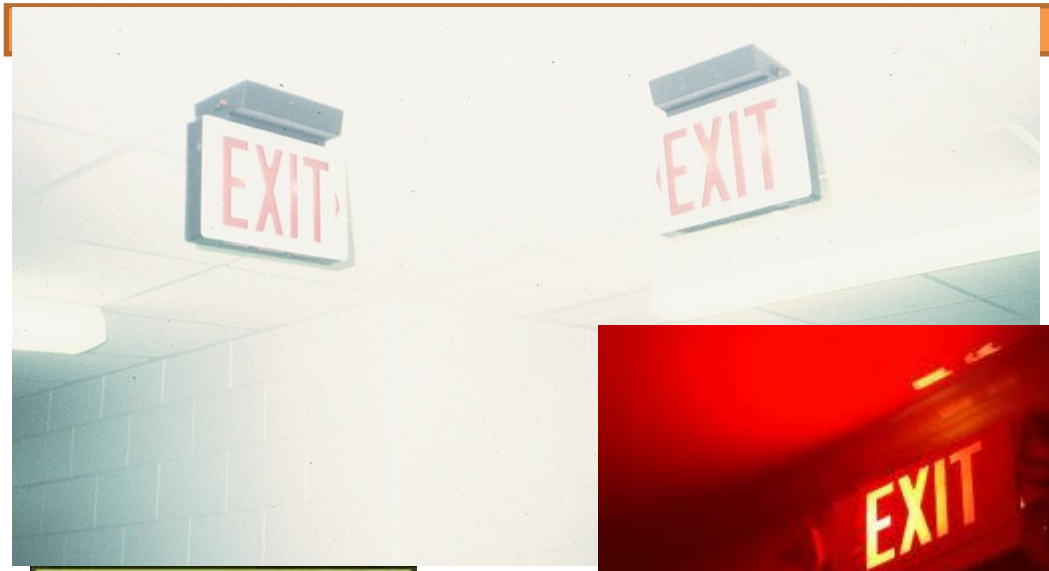
Illumination and Placement of Signage

EXIT



OKLAHOMA STATE UNIVERSITY

Signs


EXIT
EXIT

EXIT


EXIT
EXIT
EXIT
EXIT


SALIDA DE
EMERGENCIA


SALIDA


CH'É'ÉTIIN


OKLAHOMA
STATE
UNIVERSITY

Sign Requirements

- Tactile 触觉的
- 100’
- 5 ft-candles
- Monthly inspections
- Other signs

Not an Exit

- Purpose
- Requirements

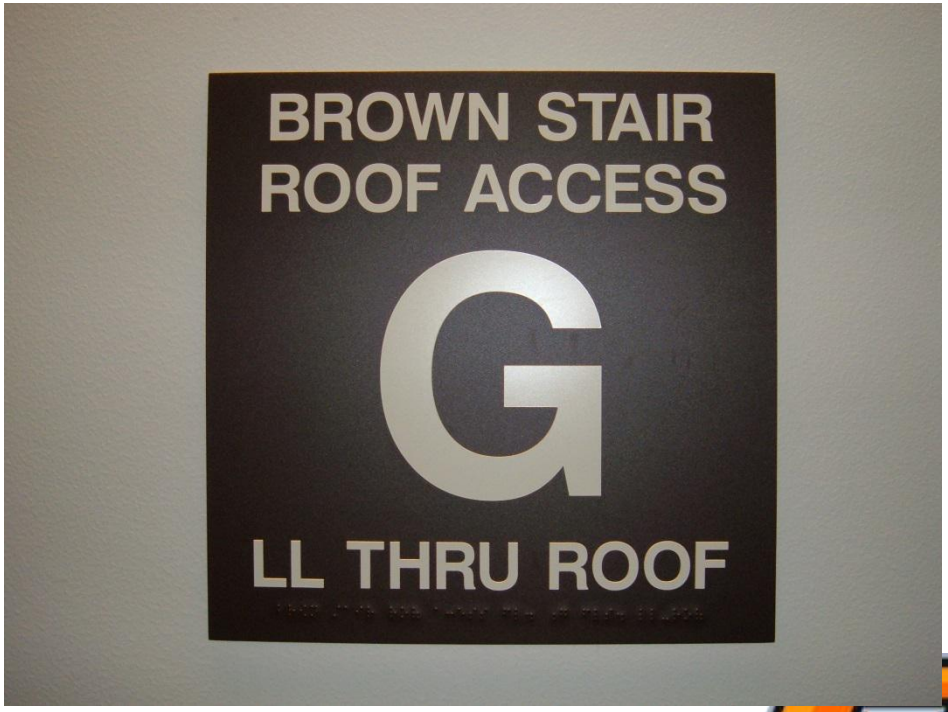
NO
EXIT

NO
EXIT

NFPA101 permit

Exit Stair Signage

- Connecting 3 stories
- Requirements
  - Every floor
  - Floor level
  - Top/bottom
  - Stair identification
  - 48 to 84 in above floor
  - Visible when door open
  - Tactile
  - NO ROOF ACCESS
  - Re-entry locations indicated



Occupant Load

- Occupancy specific
- Conspicuous 引人注目的
  - Near main exit/exit access

3.3.170.2 ***Occupant Load.*** The total number of persons that might occupy a building or portion thereof at any one time. (SAF-MEA)

Accessibility

- Area of refuge 避难区
  - Two-way communication system
- Exterior area for assisted rescue
  - IBC

Delayed Egress Doors

- Must have signage
  - Action
  - Alarm
  - Time

Static vs. Dynamic

- Intent to raise situational awareness 提高态势感知的意图
- Traditionally static
- Dynamic has advantages
  - Cost
  - Information

Characteristics of "Good" Alarm System

- Exploit learned/natural expectations 利用学到的/自然的期望
- 2-stage signal if complex information is being provided
  - 1st: Attention-getting signal
  - 2nd: Information signal: provide distinct information
- Distinguishability from ambient noises & other alarms
- Provide only essential information
- Provide same signal at all times
- Multiple senses

ASET

- Predict time to incapacitation 预测丧失能力的时间
- Calculate the available egress time

NFPA 101 anyone not intimate with ignition shall be kept safe from the fire.So how long do you have to keep them safe

Historic Fire

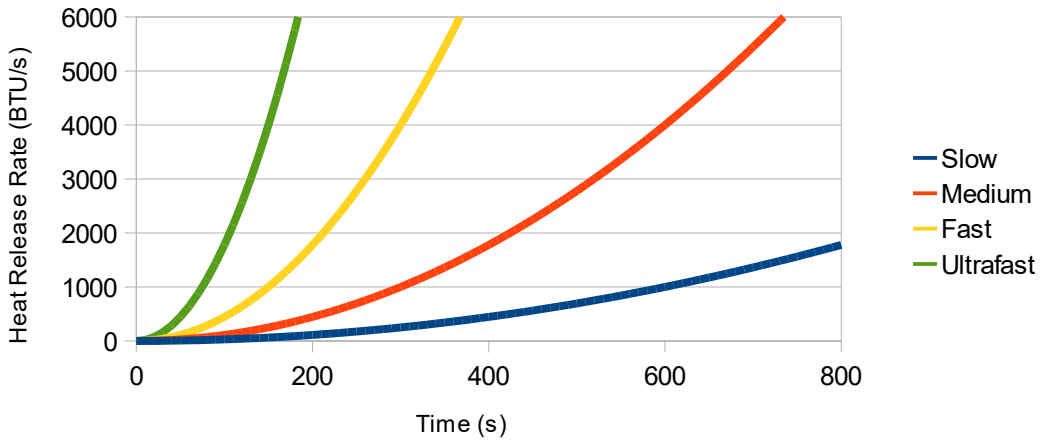
- DuPont Plaza Hotel

ASET

- Meaning of acronym
- Times included 

Fire Growth

- t^2
  - Based on reaching 1000 Btu/s (1055 kW)
    - Slow: $0.28*10^{-2}$ Btu/s^3, τ=600s
    - Medium: $1.11*10^{-2}$ Btu/s^3, τ=300s
    - Fast: $4.44*10^{-2}$ Btu/s^3, τ=150 s
    - Ultrafast: $17.78*10^{-2}$ Btu/s^3, τ=75 s



Smoke Plume

$$T_p = \frac{\dot{Q}_c}{\dot{m} \cdot c_p} + T_0$$

Where:

T_p=Smoke plume temperature

$\dot{Q}_c$=Convective heat release rate

$\dot{m}$=Mass entrainment rate

C_p=Specific heat

T_0=Ambient temperature

Smoke Plume

$$\dot{V} = \dot{m} \cdot \frac{(T_p + 273)}{353}$$

Where:

$\dot{V}$=Volumetric flow rate (m^3/s)

T_p=Smoke plume temperature (°C)

$\dot{m}$=Mass entrainment rate (kg/sec)

Smoke Production

$$\dot{m} = 0.071 \cdot k^{2/3} \cdot \left(\dot{Q}_c\right)^{1/3} \cdot z^{5/3} + 0.0018 \cdot \dot{Q}_c$$

Where:

$\dot{m}$= Mass flow in plume at height z (kg/s)

k= Wall factor

$\dot{Q}_c$= Convective heat release rate of fire (kW)

z= Height above top of fuel (m)

Ceiling Jet

$$\Delta T = 5.38 \cdot \frac{\left(\frac{\dot{Q}}{r}\right)^{2/3}}{H}$$

Where:

r/H>0.18

ΔT=Temperature change (°C)

$\dot{Q}$=Total heat release rate (kW)

H=Height (m)

r=Distance from center of plume (m)

Ceiling Jet

$$U_{cj} = 0.195 \cdot \frac{\dot{Q}^{1/3} \cdot H^{1/2}}{\left(\frac{r}{H}\right)^{5/6}}$$

Where:

r/H>0.15

U_{cj}=Velocity (m/s)

$\dot{Q}$=Total heat release rate (kW)

H=Height (m)

r=Distance from center of plume (m)

Activation Times 激活时间

$$T_d = \sum \left(T_{d,i-1} + \frac{\left(U_{cj}\right)^{1/2} \cdot \left(T_{cj} - T_{d,i-1}\right)}{RTI \cdot \Delta t} \right)$$

Where:

T_d=Temperature of detector (°C)

U_{cj}=Velocity (m/s)

T_{cj}=Temperature of ceiling jet (°C)

RTI= Response Time Index ($m^{0.5}*s^{0.5}$)

Δt= Time step (s)

Smoke

$$\%COHb = 3.32 \cdot 10^{-5} \cdot CO^{1.036} \cdot RMV \cdot t$$

Where:

CO=concentration (ppm)

RMV=breathing rate (L/min)

$$FED = \sum\sum \frac{C_i}{Ct_i} \cdot \Delta t$$

Where:

C_i=Concentration at given time

Ct_i=Dose at endpoint

t=1 min, 1000 ppm
t=2 min, 4000 ppm
t=3 min, 9000 ppm
t=4 min, 16,000 ppm
t=5 min, 25,000 ppm

Endpoint 35,000 ppm-min
1 min time steps

Time (min)	CO (ppm)	Dose (ppm-min)	Exposure (ppm-min)
1	1000	1000	1000
2	4000	4000	5000
3	9000	9000	14,000
4	16000	16000	30,000

Tenability 容受度

$$F_{IN}=((F_{ICO}+F_{ICN}+FLC_{irr})*VCO_2+FED_{IO})$$

- See 3-130 or 6-18 in NFPA Handbook for details
- Irritants can cause incapacitation 刺激物可导致丧失工作能力
  - See FEC equation (6-24)

Visibility

- Incapacitation when not able to see exits
  - 2 ft (0.6 m) cannot see own hand
  - 16.4 ft (5 m) visibility where familiar
  - 49 ft (15 m) visibility where unfamiliar
- $Vis = 0.43 \cdot \frac{K}{D}$

Where:

Vis=Visibility distance (m)

K=Constant

D=Optical density (m^{-1})

Heat

- Skin burns 皮肤烧伤
  - Skin temperature 113 °F (44.8 °C)
  - 2.5 kW/m^2
  - 392 °F (200 °C)
- Respiratory burns 呼吸道烧伤
  - 140 °F (60 °C)
- Hyperthermia 热疗
  - 248 °F (121 °C)
  - 150 °F (66 °C)

Heat

$$t_{I,rad} = r \cdot \left(\dot{q}''\right)^{-1.33}$$

Where:

辐射致残时间(最小)

$t_{I,rad}$=Time to incapacitation from radiation (min)

r=Radiant heat exposure dose at endpoint (1.33 for pain, 10 for incapacitation from serious injury)

$\dot{q}''$=Heat flux (kW/m^2)

r=终点辐射热暴露剂量（疼痛为1.33，重伤致残为10）

$$t_{I,conv} = 5 \cdot 10^7 \cdot T^{-3.4}$$

Where:

由于对流而丧失行动能力的时间(MJ)

$t_{I,conv}$=Time to incapacitation from convection (min)

T=Temperature at skin surface (°C)

Crowd Management

- Explain crowd response
- Apply FIST to crowd management
- Determine solutions to crowd events

Historic Event

- Who Concert

Crowd Management

- Crowd control
- Crowd management
- Locations

Crowd Characteristics

- Ambulatory: moving in and out of venue
- Disability/movement limited: restrictions in movement
- Cohesive/spectator: watching activities
- Expressive/reveler: emotional release
- Participatory: mass involvement in activity
- Aggressive/hostile: disregarding authority
- Demonstrator: some organization with leader
- Escaping/trampling: attempting to flee
- Dense/suffocating: individual movement lost
- Rushing: purpose to obtain
- Violent: Attacking

Crowd Factors

- Organization: planned or spontaneous
- Leadership: who is in charge
- Cohesiveness: individuals bonds
- Unity of purpose: goals
- Common motives for action: responding to same threat
- Emotional intensity: may not notice external cues
- Volatility: boiling point
- Individuality: how much self control and concern for others

Crowd Response 人群反应

- Panic
  - Scarce resource
  - Contagion
  - Selfish
  - Irrational behavior

稀缺资源
传染病
自私的
非理性行为

- Collective behavior
  - Emergent norm theory
  - Reorganization during emergency
  - Social affiliation
  - Group size

涌现规范理论
紧急情况下的重组
社会关系
组大小

Risk Factors

- Flight response
- Craze
- Festival seating
- Escalator
- Transportation

飞行反应
狂热
节日座位
自动扶梯
运输

Solution of this is in reading

FIST

- F
- I
- S
- T

Force information space and time

Solutions

we can do metering where we limit the flow in and out that also encounter things like that bridge going over to the station, so we spread people out in terms of a space type issue there of only giving enough space to handle the crowd More information, more easy to control