9th annual cny engineering expo 2012

SFPE

Human Factors - Egress Analysis for High Hazard Occupancies

Presented by: Michael J. Klemenz, PE, SFPE

Group H

- Other SFPE presenters today discussed issues relevant to Group H
- This presentation addresses means of egress (MOE)
- Prescriptive and engineered methods

Group H Defined

- SECTION 307 HIGH-HAZARD GROUP H
- 307.1 High-Hazard Group H. High-hazard Group H occupancy includes, among others, the use of a building or structure, or a portion thereof, that involves the manufacturing, processing, generation or storage of materials that constitute a physical or health hazard in quantities in excess of those allowed in control areas constructed and located as required in Section 414…

Objectives

- Means of Egress (MOE) Concepts
- Prescriptive Code Requirements
- Example
- Performance-Based Alternatives
- Human Behavior in Fire Emergencies
- Q&A

MOE Defined

- *A continuous and unobstructed path of vertical and horizontal egress travel from any occupied portion of a building or structure to a public way.*

Alternate definition

- *Engineered building systems that permit protected travel from the interior of a building* [on fire] *to the relative safety of the exterior* [not on fire] *prior to the onset of untenable fire conditions.*

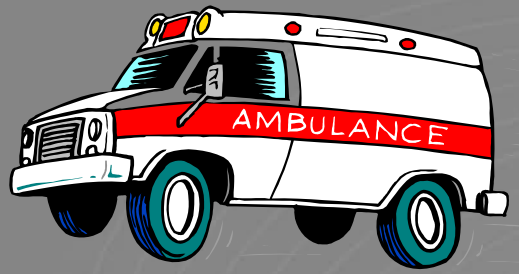
Components

- A passive fire protection system
- Consists of 3 parts:
  - Exit Access (“non-protected” path)
  - Exit (“protected” part)
  - Exit Discharge (safety)

Generally

- Codes normally prescribe at least two separate & remote egress paths
- Exit access travel distance limits apply
- Must be maintained for the life of the building

Two Directions



- Keep in mind…
- While occupants are exiting the building during a fire emergency…
- Emergency service providers are entering the building to render aid or mitigate the emergency (fire, EMS, Haz-Mat, etc.)

Objectives

- Means of Egress (MOE) Concepts
- Prescriptive Code Requirements
- Example
- Performance-Based Alternatives
- Human Behavior in Fire Emergencies
- Q&A

Codes & Standards

- NYS building code Chapter 10 "*Means of Egress*"
- IBC Chapter 10
- NFPA 101, "*Life Safety Code*"
- OSHA CFR 1910 Subpart E

Occupant Load

- *The number of persons for which the means of egress of a building or portion thereof is designed*

Gross Floor Area

- *The floor area within the inside perimeter of the exterior walls of the building under consideration, exclusive of vent shafts and courts, without deduction for corridors, stairways, closets, the thickness of interior walls, columns or other features. The floor area of a building, or portion thereof, not provided with surrounding exterior walls shall be the usable area under the horizontal projection of the roof or floor above. The gross floor area shall not include shafts with no openings or interior courts.*

Accessible Moe

- *A continuous and unobstructed way of egress travel from any accessible point in a building or facility to a public way.*

Exit Access

- *That portion of a means of egress system that leads from any occupied portion of a building or structure to an exit.*
- Normally no fire resistance rating

Exit

- *That portion of a means of egress system which is separated from other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives as required to provide a protected path of egress travel between the exit access and the exit discharge. Exits include exterior exit doors at ground level, exit enclosures, exit passageways, exterior exit stairs, exterior exit ramps and horizontal exits.*

Exit Discharge

- *That portion of a means of egress system between the termination of an exit and a public way.*

Public Way

- *A street, alley or other parcel of land open to the outside air leading to a street that has been deeded, dedicated or otherwise permanently appropriated to the public for public use and which has a clear width and height of not less than 10 feet*
- It is the final destination for occupants and is assumed to be safe from the emergency in the structure.

Exit Enclosure

- *An exit component that is separated from other interior spaces of a building or structure by fire resistance-rated construction and opening protectives, and provides for a protected path of egress travel in a vertical or horizontal direction to the exit discharge or the public way.*

Corridor

- *An enclosed exit access component that defines and provides a path of egress travel to an exit.*
- NOT the same as an exit passageway

Exit Passageway

- *An exit component that is separated from all other interior spaces of a building or structure by fire-resistance-rated construction and opening protectives, and provides for a protected path of egress travel in a horizontal direction to the exit discharge or the public way.*

Common Path Of Travel

- *That portion of exit access which the occupants are required to traverse before two separate and distinct paths of egress travel to two exits are available. Paths that merge are common paths of travel. Common paths of egress travel shall be included within the permitted travel distance.*

Exit Access Travel Distance

- *Exits shall be so located on each story such that the maximum length of exit access travel measured from the most remote point within a story to the entrance to an exit along the natural and unobstructed path of egress travel, shall not exceed the distances given in Table 1016.1.*

Measurement of Travel Distance

NFPA 101-7.6*.

7.6.1* The travel distance to an exit shall be measured on the floor or other walking surface as follows:

(1) Along the centerline of the natural path of travel, starting from the most remote point subject to occupancy

(2) Curving around any corners or obstructions, with a 12 in. clearance therefrom

(3) Terminating at (a) Center of the doorway, (b) Other point at which the exit begins or (c) exit discharge

Objectives

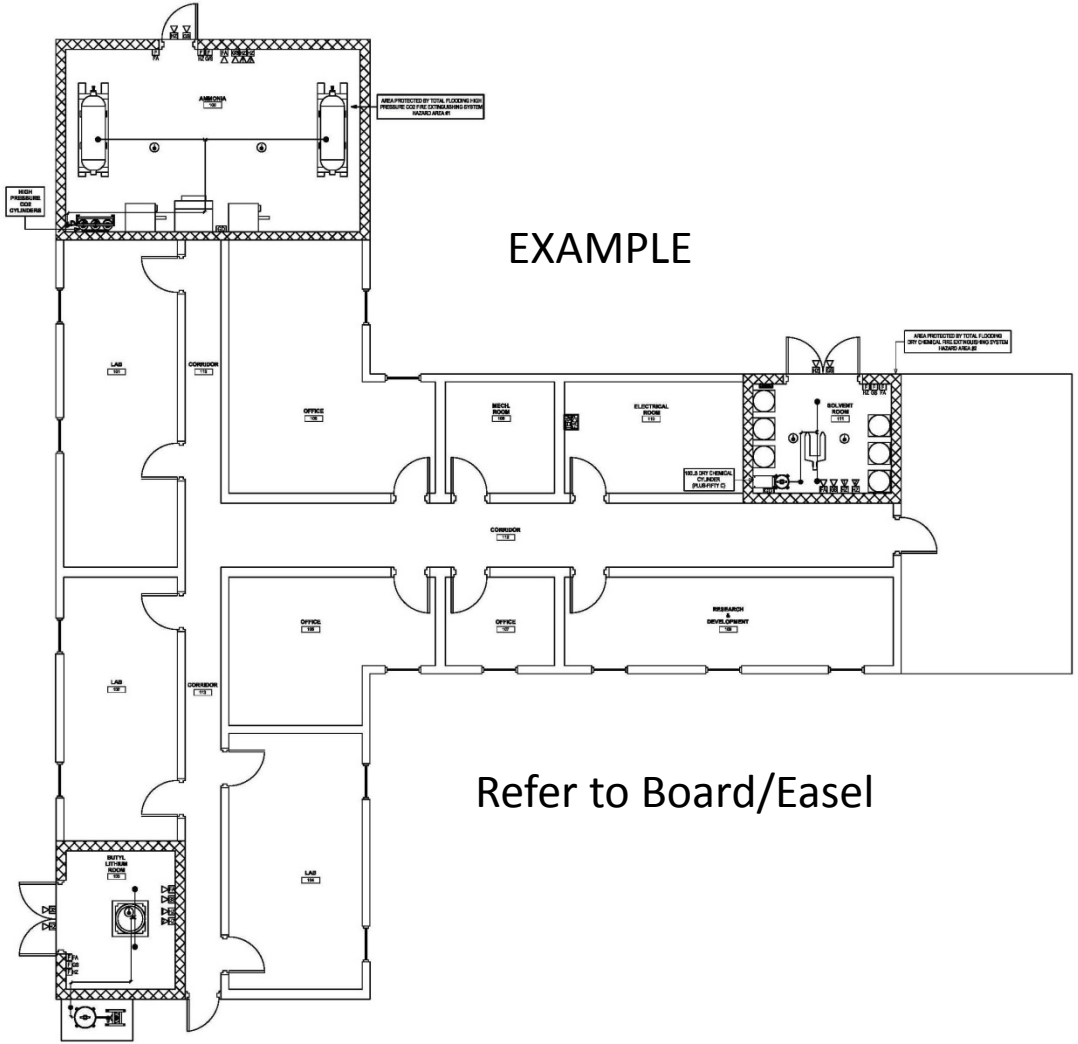
- Means of Egress (MOE) Concepts
- Prescriptive Code Requirements
- Example
- Performance-Based Alternatives
- Human Behavior in Fire Emergencies
- Q&A

Example Problem

- Single story, 4000 sf. building
- Non-separated uses consisting of labs, offices, storage, process and support spaces
- Construction type per Table 503
- NFPA 13 fire sprinkler system IAW 903.2.4.1

Group H Building

- Class 4 Oxidizers- quantity exceeds Table 307.1.1 for a control area
- 307.3 High-Hazard Group H-1. Buildings and structures containing materials that pose a detonation hazard

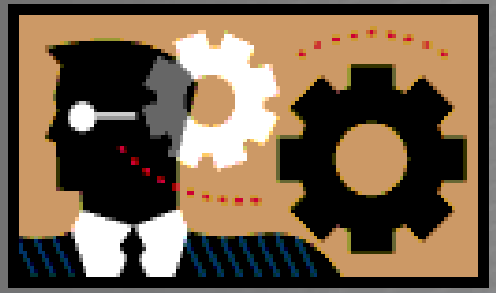


EXAMPLE

Refer to Board/Easel

Example

1. Calculate occupant load
2. Evaluate means of egress
3. Make necessary corrections



Example

1. Calculate occupant load
2. Evaluate means of egress
3. Make necessary corrections

Occupant Load

- Occupant load factors in Table 1004.1.1
  - Industrial areas: 100 gross
  - Accessory storage areas, mechanical equipment rooms: 300 gross
  - Business areas: 100 gross
- Where an intended use is not listed in Table 1004.1.1, the code enforcement official shall establish a use based on a listed use that most nearly resembles the intended use.

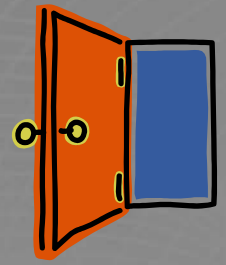
Also see NFPA 101 Table 7-3.1.2

Occupant Load

- Assume occupant load factor of 75 sf. gross per the AHJ
- Occupant load = 4000 sf. ÷ 75/sf. =53.3 ≈ 54 occupants

Example

1. Calculate occupant load
2. Evaluate means of egress
3. Make necessary corrections



Summary of Values for H-1

* Single exit H-1 not permitted by Table 1019.2

Feature	Value	Reference
Number of Exits	2	Table 1019.1*
Exit Access Travel Distance	75’	1016.1
Common Path of Travel	25’	1014.3
Dead End Corridor	20’	1017.3
Corridor Width	44” or per Table 1005.1	1017.2
Exit Remoteness	1/3 max. horizontal	1015.2.1
Corridor FRR	1 hr. w/ 20 min. door	Table 1017.1

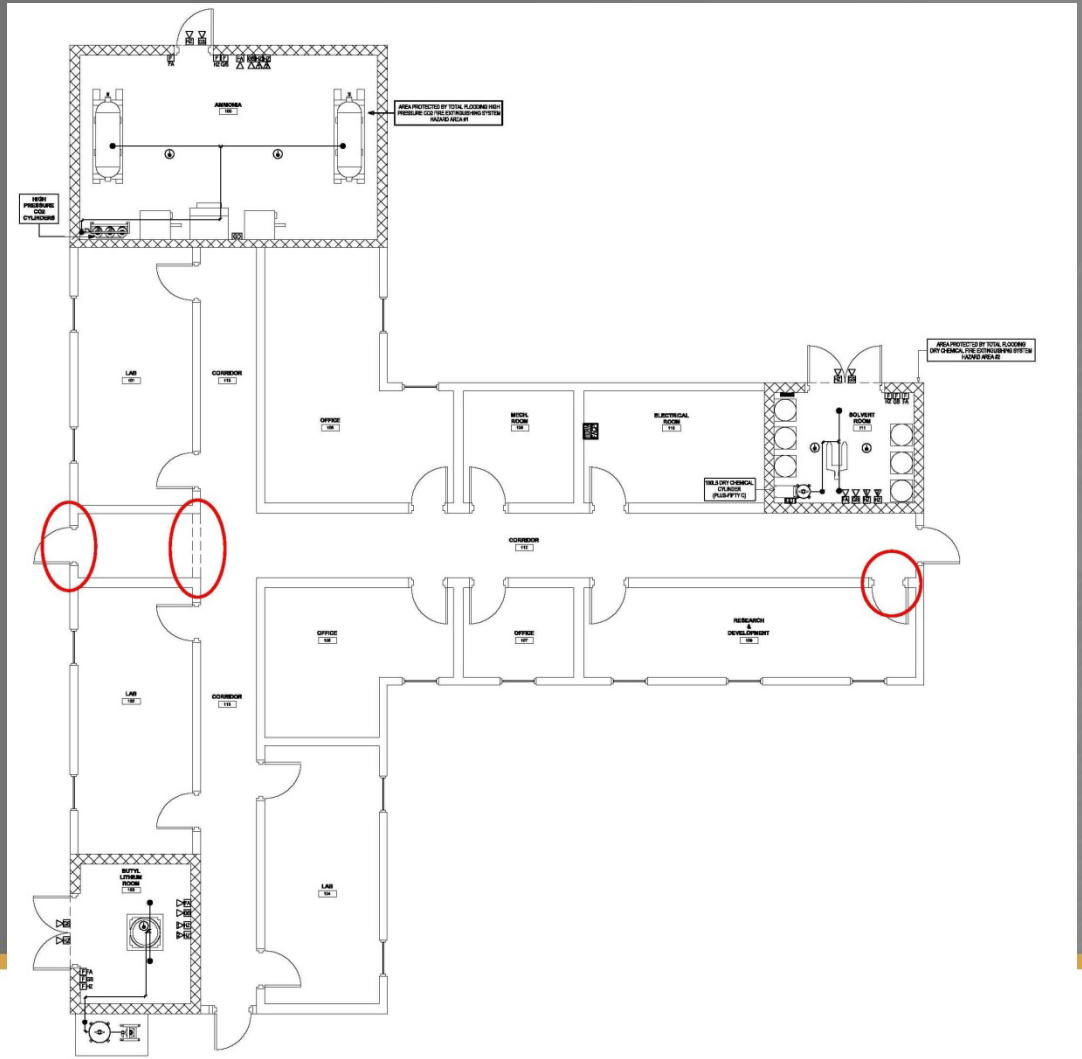
Example

TABLE 1005.1
EGRESS WIDTH PER OCCUPANT SERVED

Occupancy	No Sprinklers		With Sprinklers	
	Stairway (in. per occupant)	Other egress components (in. per occupant)	Stairway (in. per occupant)	Other egress components (in. per occupant)
Other than listed below	0.3	0.2	0.2	0.15
Hazardous: H-1, H-2, H-3 & H-4	0.7	0.4	0.3	0.2
Institutional: I-2	NA	NA	0.3	0.2

Example

1. Calculate occupant load
2. Evaluate means of egress
3. Make necessary corrections


AMMONIA
AREA PROTECTED BY TOTAL FLOODING HIGH PRESSURE CO2 FIRE EXTINGUISHING SYSTEM HAZARD AREA #1
HIGH PRESSURE CO2 CYLINDERS
LAB
CORRIDOR
OFFICE
MECH. ROOM
ELECTRICAL ROOM
AREA PROTECTED BY TOTAL FLOODING DRY CHEMICAL FIRE EXTINGUISHING SYSTEM HAZARD AREA #2
SOLVENT ROOM
150LB DRY CHEMICAL CYLINDER (PUSH-PITY'D)
EXIT
CORRIDOR
OFFICE
OFFICE
RESEARCH & DEVELOPMENT
LAB
CORRIDOR
BUTYL LITHIUM ROOM
LAB

Ceiling Height & Lighting

- 1003.2 Ceiling height. The means of egress shall have a ceiling height of not less than 7’-6”
- 1006.2 Illumination level. MOE illumination level shall not be < 1 foot-candle (11 lux) at the walking surface level. Power shall be from the premises' electrical supply. Provide E-power (90 minutes) in MOE components.

1006.4 contains detailed photometric and performance requirements

Objectives

- Means of Egress (MOE) Concepts
- Prescriptive Code Requirements
- Example
- Performance-Based Alternatives
- Human Behavior in Fire Emergencies
- Q&A

Alternate Methods

Egress Time < Hazardous conditions time

- Apply where compliance with prescriptive parameters may not be possible or practical
- Use FP engineering principles and computer modeling to simulate fire development and compare to calculated egress time from a building

Fire Modeling

One side of the equation

- ASET (Available Safe Egress Time) is a program for calculating the temperature and position of the hot smoke layer in a single room with closed doors and windows.
- Used to determine the time to the onset of hazardous conditions for both people and property.

Fire Modeling

- DETACT (DETector ACTuation-Time squared) is a program for calculating the actuation time of thermal devices
- Used to predict the actuation time of fixed-temperature and rate-of-rise heat detectors and of sprinkler heads subject to a user-specified fire that grows as the square of time.

Fire Modeling

- CFAST (Consolidated Model of Fire Growth and Smoke Transport) is a multi-room fire model that predicts the conditions resulting from a user-specified fire within a structure

Fire Modeling

- FDS (Fire Dynamics Simulator) predicts the transport of heat and smoke from a fire.
- BREAK1 estimates time until glass breaks
- FPEtool is a multi-purpose modeling tool

CFAST Input Parameters

- Geometrical data describing the rooms and connections
- Thermophysical properties of the ceiling, walls, and floors
- Fire as a rate of mass loss
- Generation rates of the products of combustion

CFAST Output

- Temperature, species concentrations and thickness of the hot upper layer and the cooler lower layer in each compartment
- Surface temperatures, heat transfer, and mass flow rates

Total Egress Time

The other side of the equation

- Time to Notification
- Reaction Time
- Pre-evacuation Activity Time
- Travel or Movement Time

Time to Notification

- Fire detection or discovery
- Signal processing
- Alert signal or message to occupants
- Received by occupants?

NFPA 72, National Fire Alarm Code

Reaction Time

- Time it takes an occupant to perceive the alarm or fire cue and then decide what action to take
- Depends on what the occupant perceives
- Immediate danger?

Pre-evacuation Activity Time

- Time that elapses while the occupant is preparing to leave or seek refuge
- Safely shut down plant operations?
- Make phone calls?
- Alert others?
- Secure sensitive files & information?

Travel or Movement Time

- Time to move to a location of safety
- Includes horizontal and vertical travel
- 250 ft/min average speed* for occupants with no impairments?
- Significant speed reduction for occupants with disabilities

Successful MOE Design

- Time to the onset of hazardous conditions for occupants
- Total egress time
- Egress Time < Hazardous conditions time

Objectives

- Means of Egress (MOE) Concepts
- Prescriptive Code Requirements
- Example
- Performance-Based Alternatives
- Human Behavior in Fire Emergencies
- Q&A

Human Behavior

- The way a person reacts to a fire emergency is dependent on many complex and interrelated factors
- Occupant actions are influenced by the perceived fire threat and observed behavior in others

Evacuation Studies

- The earliest documented studies on human behavior in the United States involved capacity counts of the velocity of pedestrian movement for the New York City design of the Hudson Terminal Building in 1901
- The first edition of the National Fire Protection Association's *Building Exits Code in 1927 (which eventually evolved into NFPA 101®, Life Safety Code®)* was developed from evacuation studies conducted during the decade since 1917.

Occupant Interviews

- Scientific, post-fire interviews with people have revealed a great deal of data on occupants' actions during the fire
- Experiments were performed to observe subjects reactions to fire cues

An Interesting Experiment

- College students
- While the students were completing a written questionnaire, the experimenter introduced smoke into the room through a small vent in the wall
- If the students left the room and reported the smoke, the experiment was terminated.

People's Inhibition of Smoke Cues (Source: B. Latane and J. M. Darley, "Group Inhibition of Bystander Intervention in Emergencies," *Journal of Personality and Social Psychology, Vol. 10, No. 3, 1968, p. 218)*

An Interesting Experiment

People's Inhibition of Smoke Cues (Source: B. Latane and J. M. Darley, "Group Inhibition of Bystander Intervention in Emergencies," *Journal of Personality and Social Psychology, Vol. 10, No. 3, 1968, p. 218)*

- If the students did not report the presence of the smoke within 6 minutes from the time they first noticed it, the experiment was considered complete.
- Students alone in the room reported the smoke in 75 percent of the cases. When two passive, noncommittal persons joined each student, only 10 percent of the students reported the smoke.

Consider

- Hotel Room, 3AM
- Bell ringing in hallway
- No visible smoke, odors, etc.
- People milling around casually

Explain your general impression
and probable state of mind

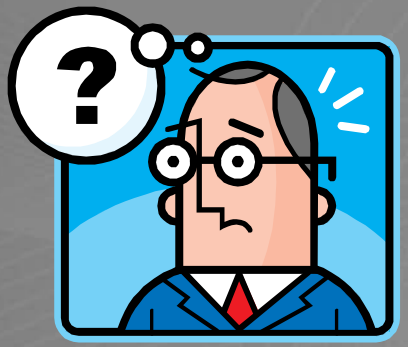
NOW Consider

- Hotel Room, 3AM
- Bell ringing in hallway
- Smoke visible outside your window
- People yelling, crashing, banging
- Doorknob feels warm
- Sound of fire trucks approaching

Panic Reaction?

- Research indicates that people exhibit panic reaction in a very small (≈<1%) number of instances
- During the decision-making period, people tend to remain calm, ‘analytical’ & cooperative
- Only when directly confronted with direct fire products does panic set in

Questions/Answers



9th annual cny engineering expo 2012

SFPE

Human Factors - Egress Analysis for High Hazard Occupancies

Presented by: Michael J. Klemenz, PE, SFPE