TENABILITY CRITERIA IN UNIQUE SITUATIONS AND ATYPICAL BUILDINGS

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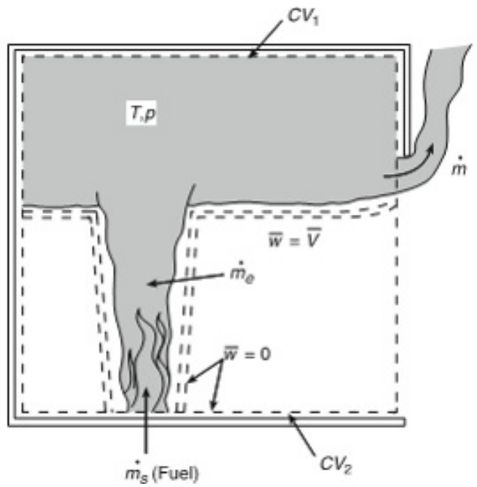
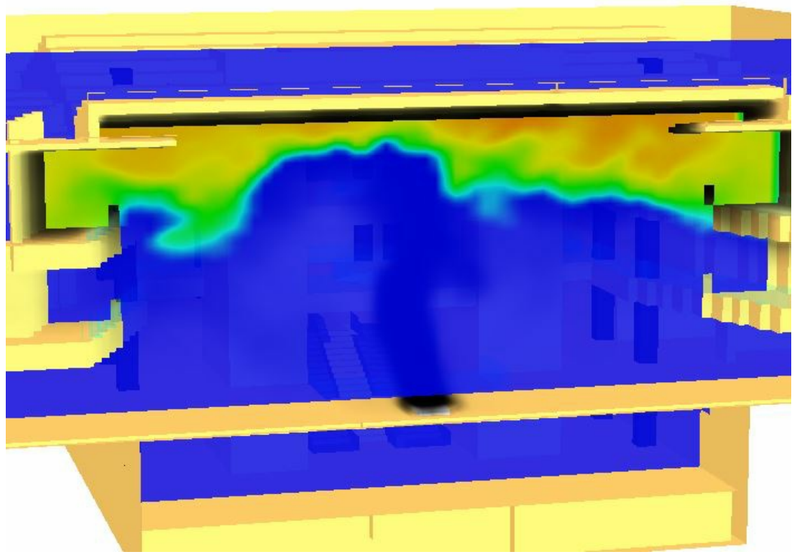
INTRODUCTION

- **Active Smoke Control Systems**
  - Smoke Containment
  - Smoke Management
- **Analysis of Smoke Management Systems**
  - Algebraic Equations versus CFD

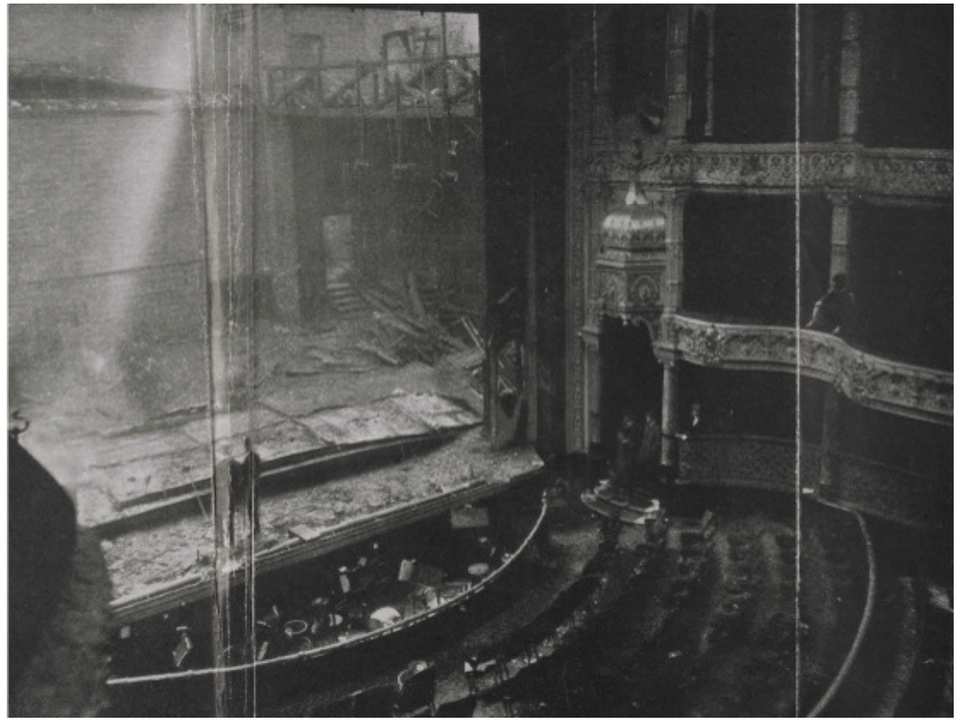




SMOKE CONTROL

Smoke control research after the 1881 Ring Theater Fire in Vienna

First successful use of smoke control in 1911 during the Empire Palace Theater Fire in Edinburg



Tenability Guides

- Visibility
- Temperature
- Toxicity

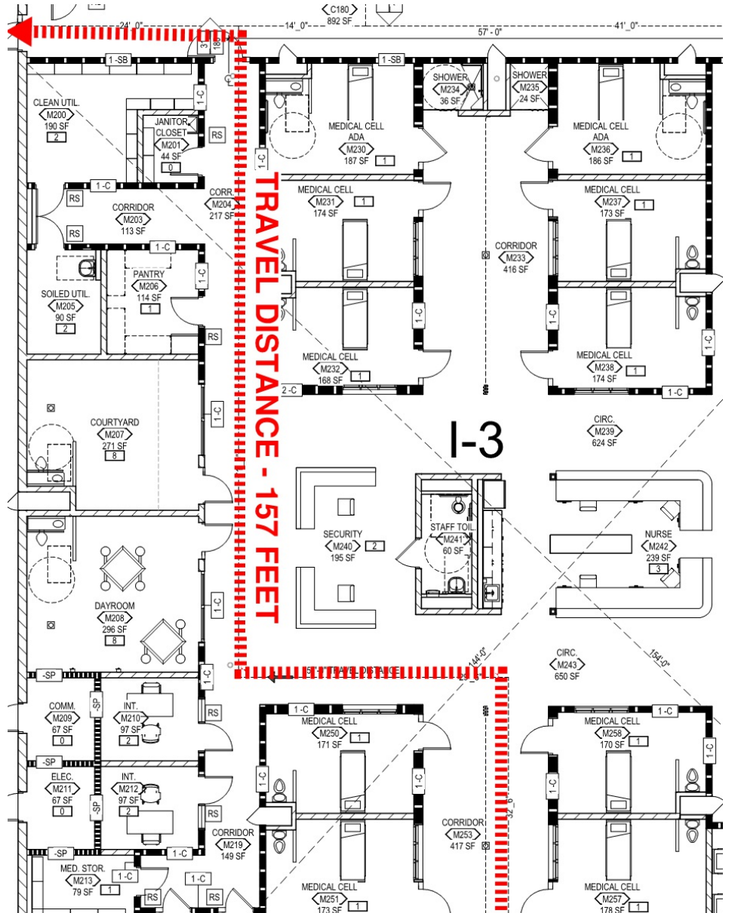
VISIBILITY

- While temperature and toxic gases are the final causes of death, many evacuees are trapped in an early stage of a fire by relatively thin smoke.
- The presence of smoke in an occupied enclosure obscures illumination from windows and other light sources, so that escaping occupants can find themselves in dimly lit conditions.
- The threshold of fire smoke density and visibility limits for safe evacuation has been examined by multiple institutions.

Degree of familiarity with inside the building	Smoke density (extinction coefficient)	Visibility
Unfamiliar	0.15 1/m	13m
Familiar	0.5 1/m	4m

VISIBILITY - SIZE OF ENCLOSURE

Enclosure Size	Visibility
Small enclosures and short travel distances	OD/m 0.2 (visibility 5 m)
Large enclosures and long travel distances	OD/m 0.08 (visibility 10 m)



VISIBILITY - CALCULATIONS

Reflecting Sign Proportionality Constant = 3

Illuminating Sign Proportionality Constant = 8

$$S = \frac{K}{e} \quad (1)$$

(2)

$$S = visibility\ (m)$$

$$K = proportionality\ constant$$

$$e = extinction\ coefficient\ (m^{-1})$$

VISIBILITY - NFPA 130

Smoke obscuration levels should be maintained below the point at which a sign internally illuminated is discernible at 30 meters and doors and walls are discernible at 10 meters.

TEMPERATURE

Exposure to heat can lead to incapacitation or death in fire victims in three ways :

- Hyperthermia
- Body Surface Burns
- Respiratory Tract Burns

$$t_{exp} = (1.125X10^{7})T^{-3.4} \quad (3)$$

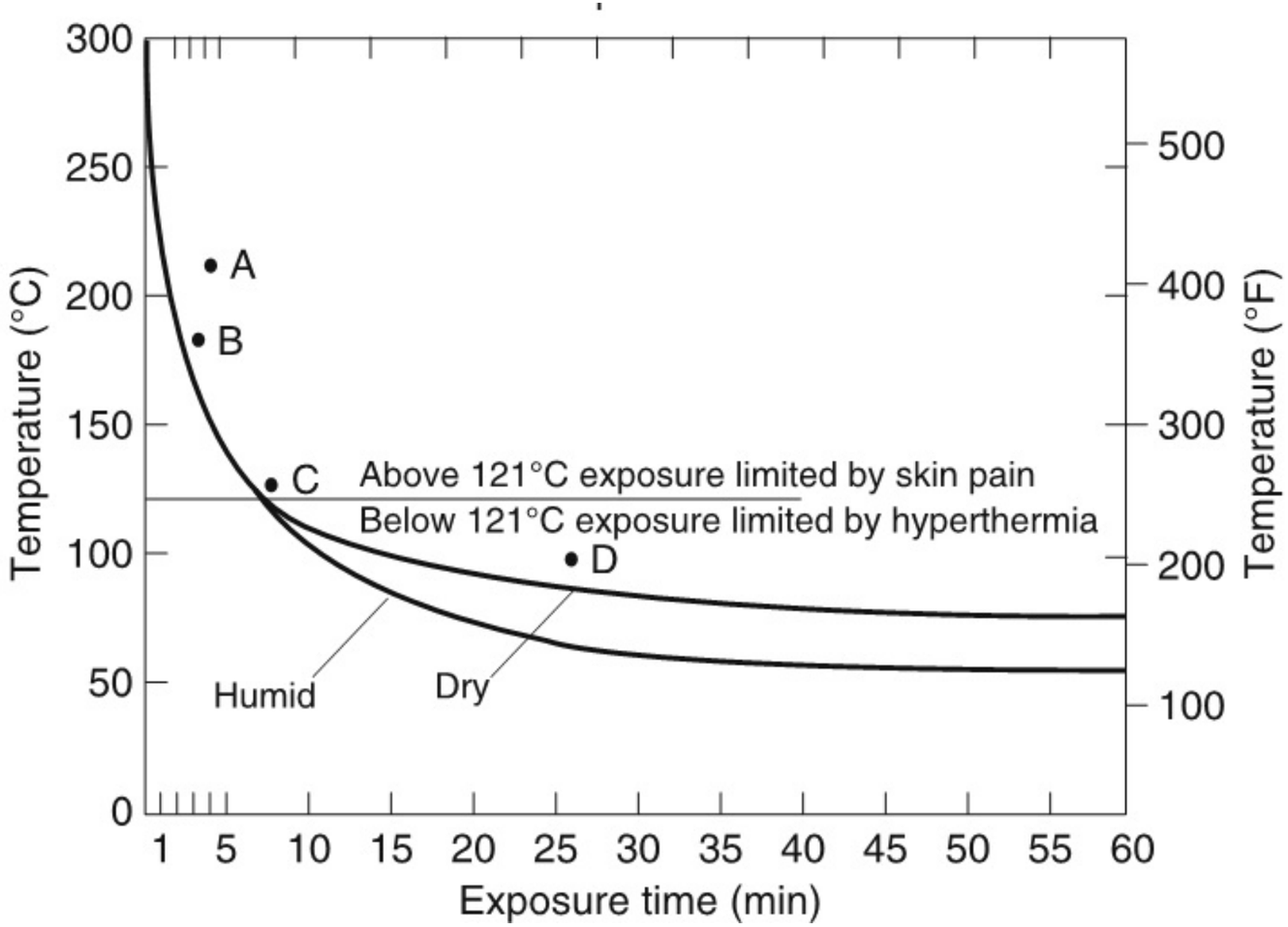
Where:

$t_{exp} = time\ of\ exposure\ (min)\ to\ reach\ a\ FED\ of\ 0.3$ (4)

$T = temperature\ (C)$

Temperature - Hyperthermia

Hyperthermia involves prolonged exposure to heated environments at temperatures to low to cause burns



Temperature - NFPA 130

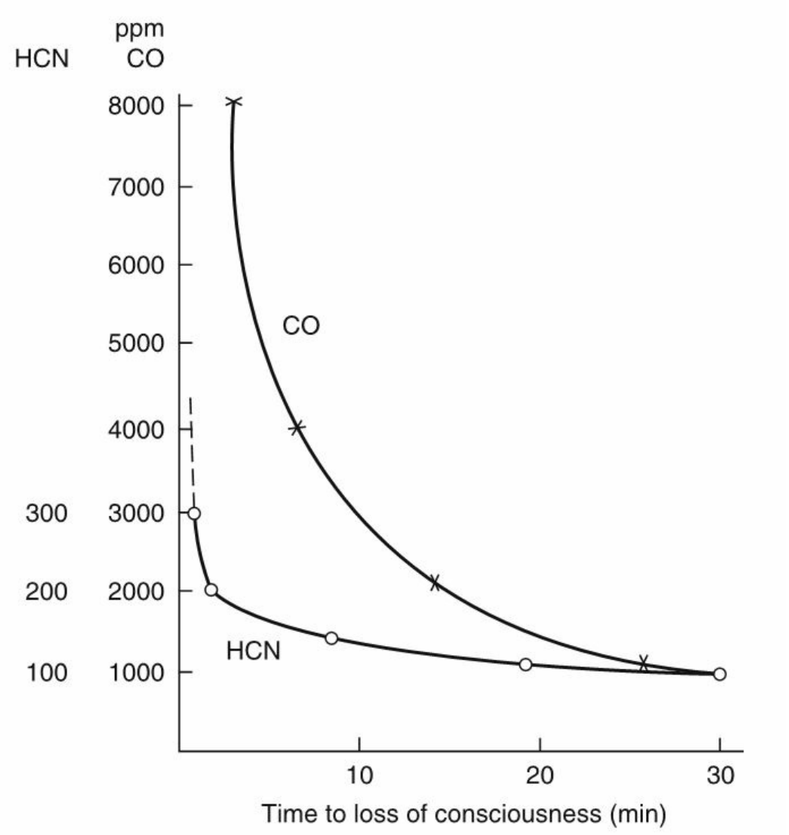
Maximum Temperature Exposure Times Table B.2.1.1

Exposure Temperature		Without Incapacitation (min.)
°C	°F	
80	176	3.8
75	167	4.7
70	158	6.0
65	149	7.7
60	140	10.1
55	131	13.6
50	122	18.8
45	113	26.9
40	104	40.2

TOXICITY

- Death from smoke inhalation
- Products of combustion
  - Impacted by type of fuel and conditions where combustion occurs
- Wide range of effects on occupants
  - Asphyxiants, sensory/ respiratory irritants, toxic

TOXICITY - CO AND HCN



- CO exposure accounts for the majority of fire fatalities
- Fractional Effective Dose (FED) is used to address exposure to effluents as a function of time

FRACTIONAL EFFECTIVE DOSE (FED)

$$X_{\mathrm{FED}} = \sum_{i=1}^{n} \sum_{t_1}^{t_2} \frac{C_i}{(C \cdot t)_i} \Delta t$$

$$X_{\mathrm{FED}} = \sum_{t_1}^{t_2} \frac{\varphi_{\mathrm{CO}}}{35\ 000} \Delta t + \sum_{t_1}^{t_2} \frac{\varphi_{\mathrm{HCN}}^{2,36}}{1{,}2 \times 10^{6}} \Delta t$$

$$\nu_{\mathrm{CO_2}} = \exp\left[\frac{\varphi_{\mathrm{CO_2}}}{5}\right]$$

TOXICITY - NFPA 130

Time (min)	Tenability Limit		
	AEGL 2	0.3	0.5
4	–	1706	2844
6	–	1138	1896
10	420	683	1138
15	–	455	758
30	150	228	379
60	83	114	190
240	33	28	47

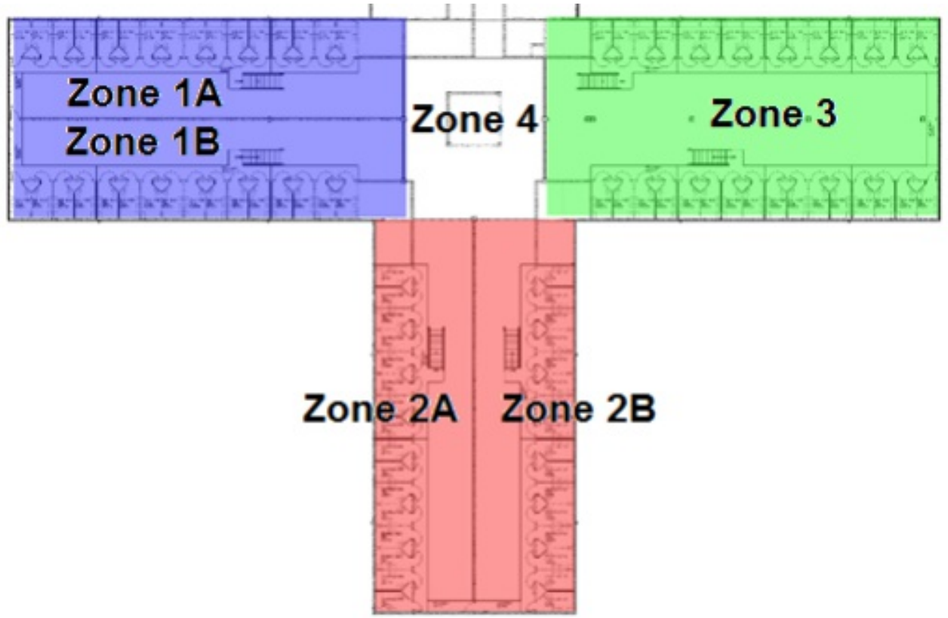
- AEGL 2: General population including susceptible individuals
- 0.3: More sensitive populations
- 0.5: Healthy Adult Population

PRISONS

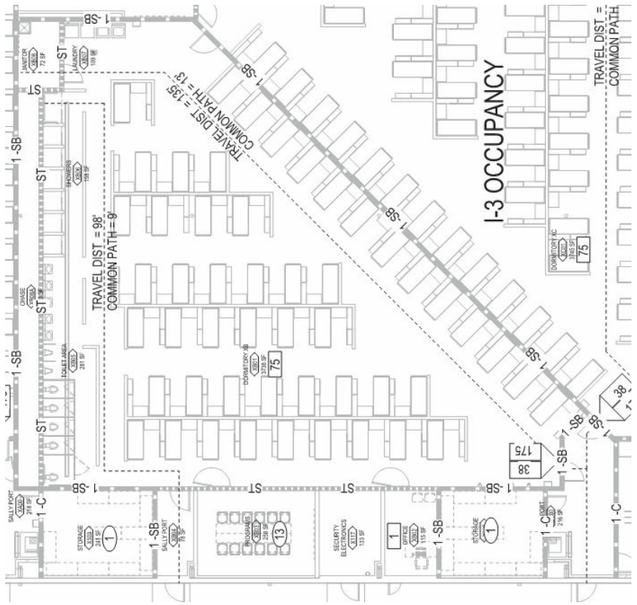
2009 IBC requires specific prison spaces to be provided with a tenable environment for exiting during a fire.

- Different characteristics compared to atrium and other buildings were smoke control is typically provided.
- Smaller with shorter travel distances to exits.
- Controlled items and limited combustibles.
- Occupants who are familiar with the space but free egress is not the first goal or possible for most.

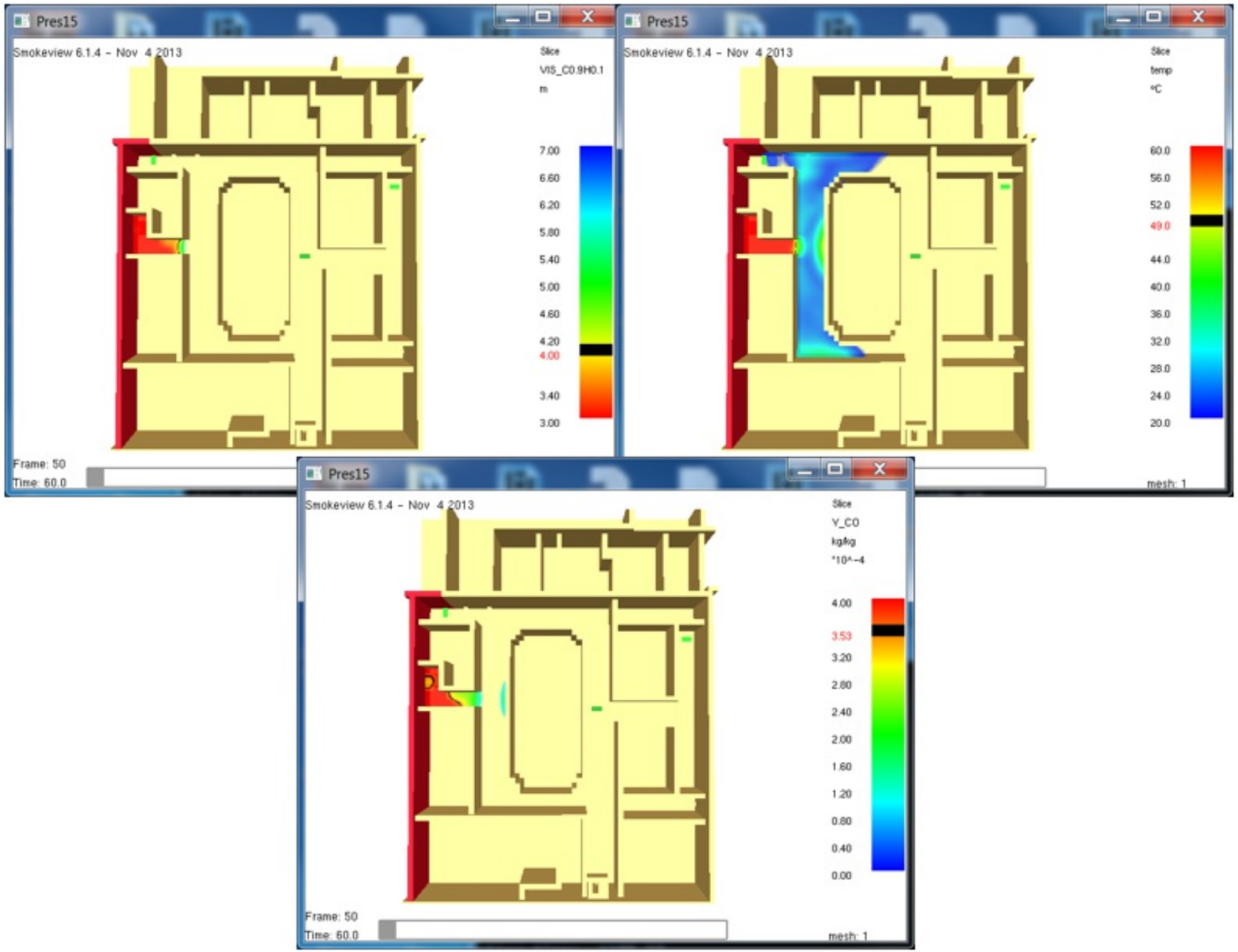
PRISON LAYOUTS - LARGE CELL BLOCK



DORMATORY AND SINGLE CELLS



PRISON TENABILITY



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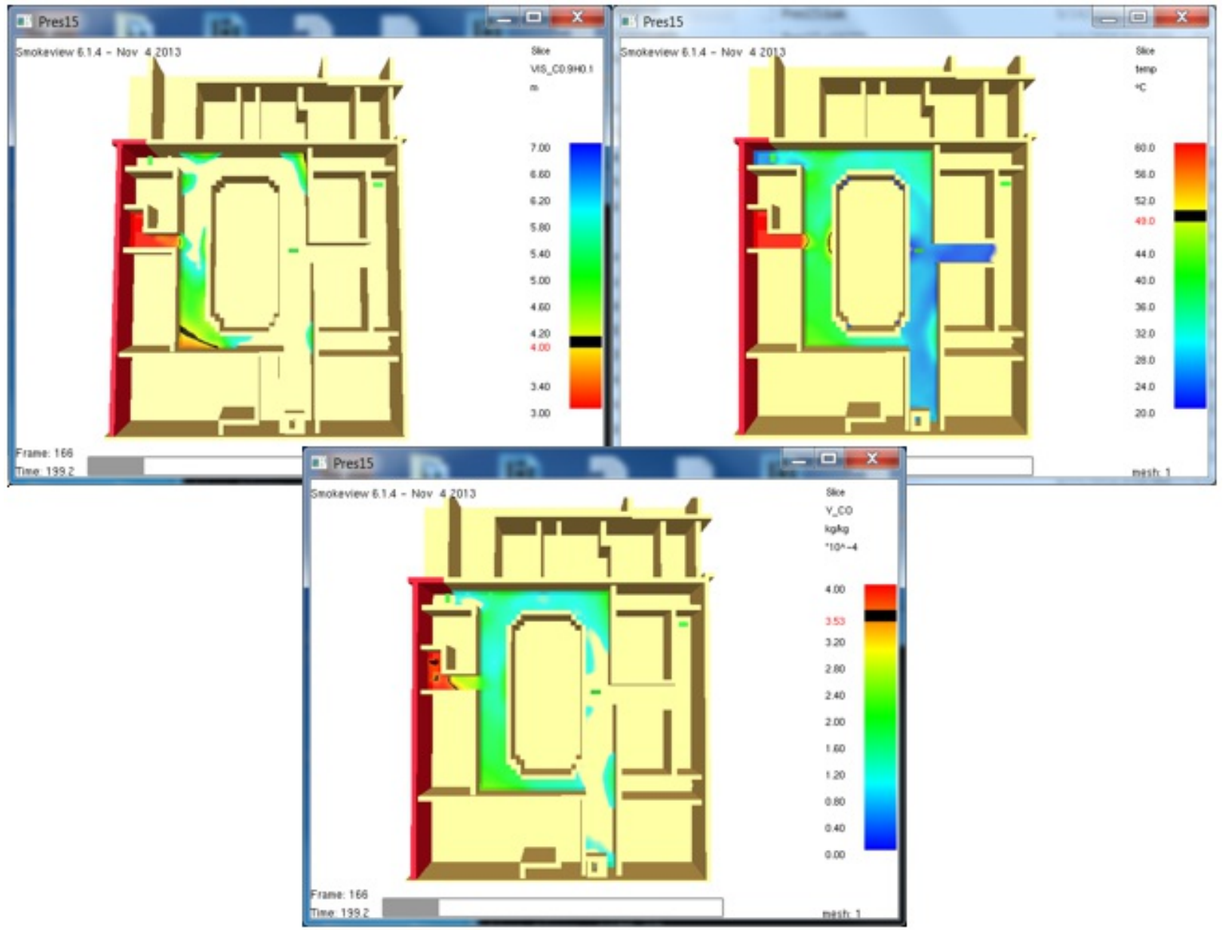

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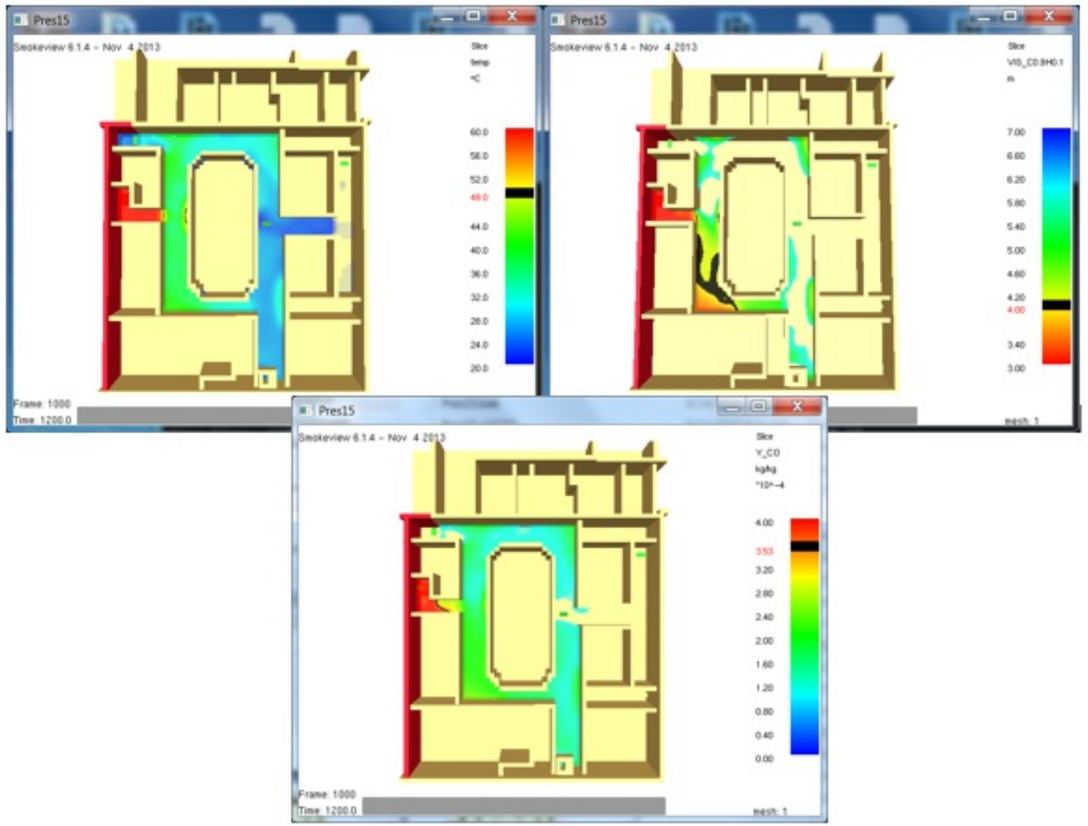


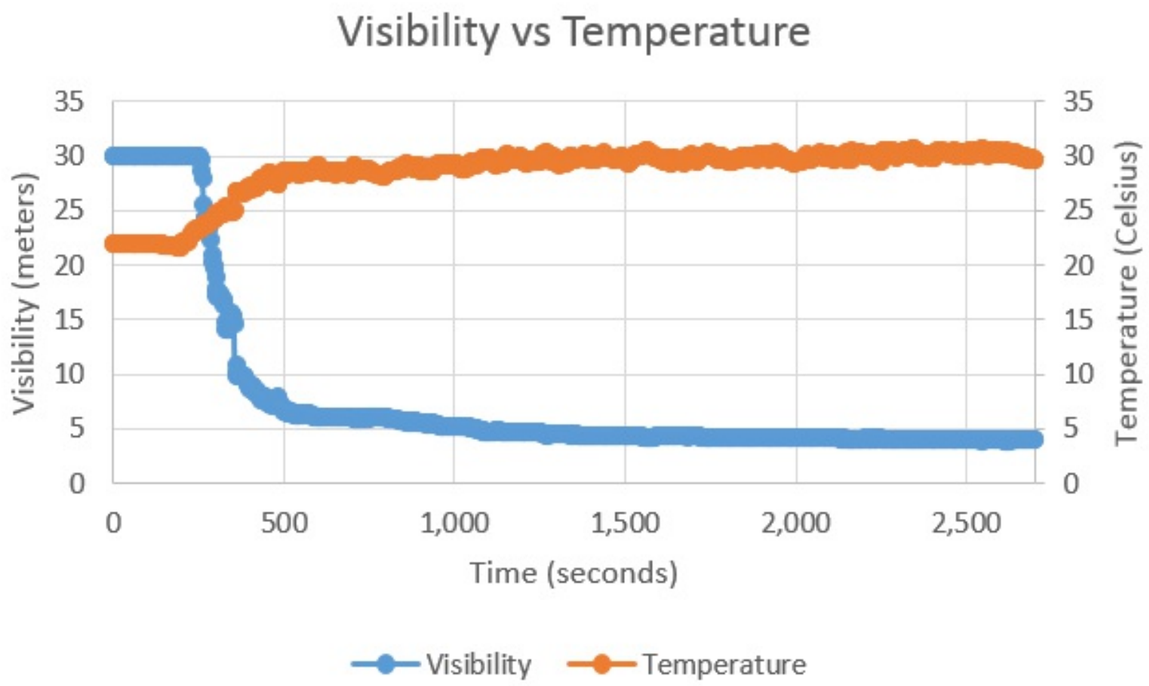
AMUSEMENT PARKS

- Required for enclosed rides by some local jurisdictions in locations with amusement attractions and other stake holders.
- Occupants can become trapped or unable to egress freely.
- Park staff and dedicated emergency personal are familiar with the building and evacuation procedures.

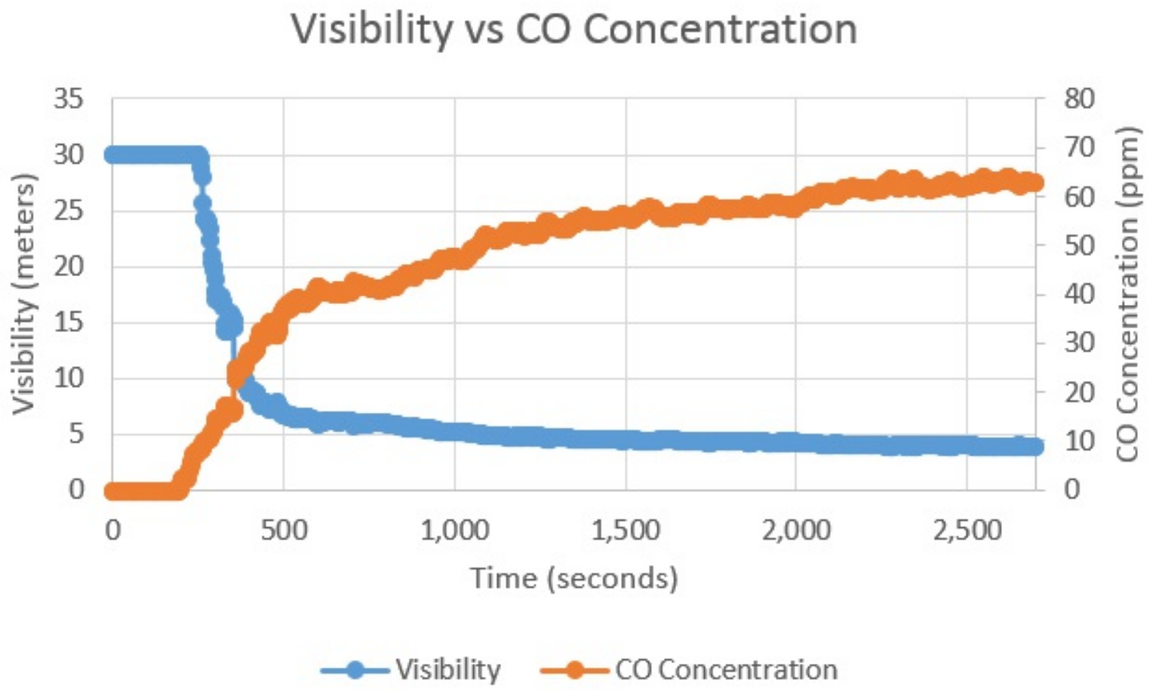
AMUSEMENT PARKS - CHALLENGES

- Worst case scenario is occupant being restrained in a ride during a fire.
- Toxicity and Temperature must be evaluated for extended periods of time, sometimes at elevated levels (higher than 6 feet above highest walking surface).
- Visibility criteria could be different for restrained occupants because wayfinding is not a concern.
- Visibility is required for park staff and first responders in order to assist occupants who are restrained. These occupants are familiar with their surroundings.
- Researched tenability criteria should be used.

AMUSEMENT PARKS - VISIBILITY VS TEMPERATURE



AMUSEMENT PARKS - VISIBILITY VS CO CONCENTRATION



Questions?