SAND2015-1999PE

Culminating Project
The Laboratory Building

Cal Poly Fire Protection Engineering

Joshua Herrera

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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INTRODUCTION

Contents

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- Prescriptive Design
  - Occupancy
  - Suppression
  - Alarm System
  - Structural Fire Protection
- Performance-Based Design
  - Scope, Goal, Objectives, and Criteria
  - Egress
  - Tenability
  - Fire Scenarios
  - Models
- Recommendations

Applicable Codes

- NFPA 13 Automatic Sprinkler Systems Handbook (2013)
- NFPA 72 National Fire Alarm and Signaling Code (2013)
- NFPA 101 Life Safety Code (LSC) (2012)
- International Building Code (IBC) (2012)
- International Fire Code (IFC) (2012)
- NFPA Fire Protection Handbook (20th Edition)
- SFPE Handbook of Fire Protection Engineering (4th Edition)
- DOE Standard 1066-99: Fire Protection Design Criteria
- Various Sandia Specifications

Sandia National Laboratories (SNL)

- Sandia is a multi-program laboratory operated by Lockheed Martin Co. for the U.S. DOE
- Albuquerque, NM
- Kirtland AFB

The Laboratory Building

- Nanoscale science research center
- Cleanroom
- Chemical stockroom
- 20 acres of land adjacent to SNL
- Barrier free access to visiting collaborators
- 1 story

- Lab Space Dedicated to:
  - Chem/bio synthesis and characterization
  - Optical microscopy and spectroscopy
  - Physical synthesis
  - Thin film fabrication
  - Spatially resolved scanned probe characterization
  - Advanced computation

The Laboratory Building

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PRESCRIPTIVE BASED DESIGN

Occupancy Classification

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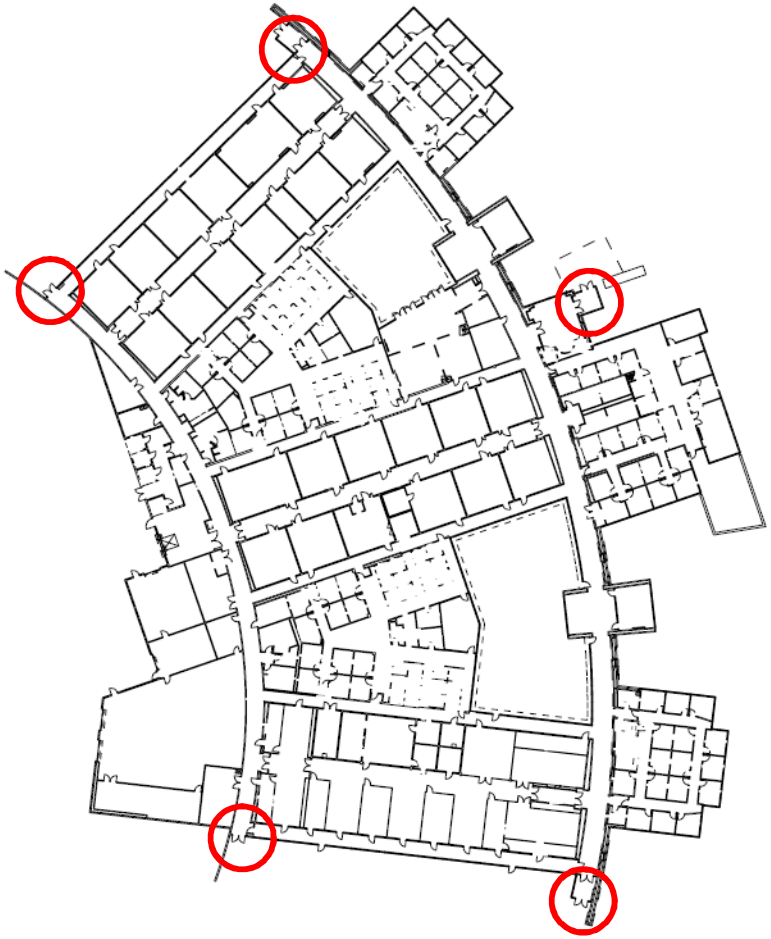
Occupancy Classification

Room	LSC (Ch. 6)	IBC (Ch. 3)
Office	Business	B
Laboratory	Industrial	B
Conference	Assembly	A-3
Mechanical	Industrial - General	F-1
Chemical Storage	Industrial - High Hazard	H-3
Cleanroom	Industrial - High Hazard	H-5

Occupant Loads

Occupant Loads (IBC 1004.1.2)		
Use	**Factor (ft^2 per person)**	**Load**
Assembly	15 net	627
Business	100	298
Group H-5	200	27
Storage	300	2
Mechanical	300	18
TOTAL		**972**

Exits

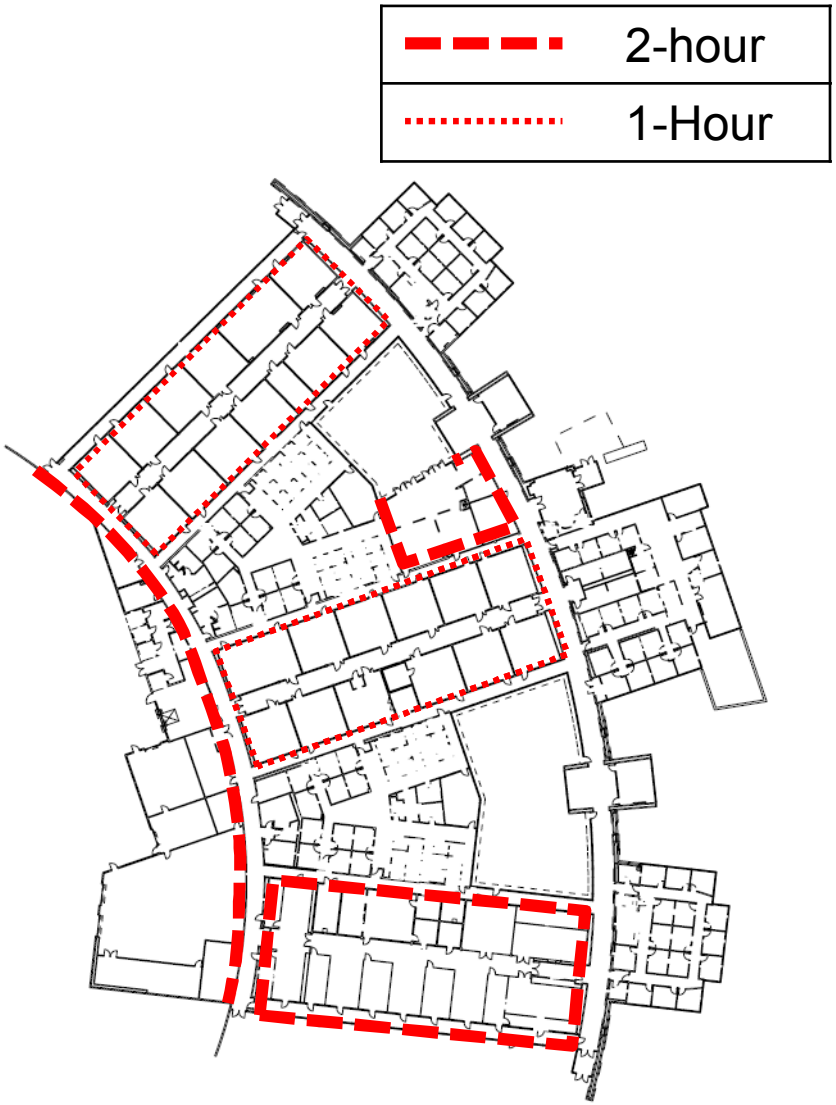


Required Exits (IBC 1021)	
Occupant Load	**Exits**
IBC Table 1021.2(2)	1
1-500	2
501-1000	3

- Rooms in F-1 have a single exit.
- 1/3 of the diagonal is 144 ft.
- Closest exits are located 167 ft. apart

Fire Barriers

- Fire barriers shall have a fire-resistance rating in accordance with ASTM E 119 (IBC 703.2)
- Fire barriers are permitted to separate the building into control areas to meet maximum allowable quantities for hazardous materials (IBC 414.2.1)
- Fire barriers separating occupancies within a building, with a 2-hour rating, can serve as a horizontal exit (IBC 707.3.10; 1025.2)



Travel Distance

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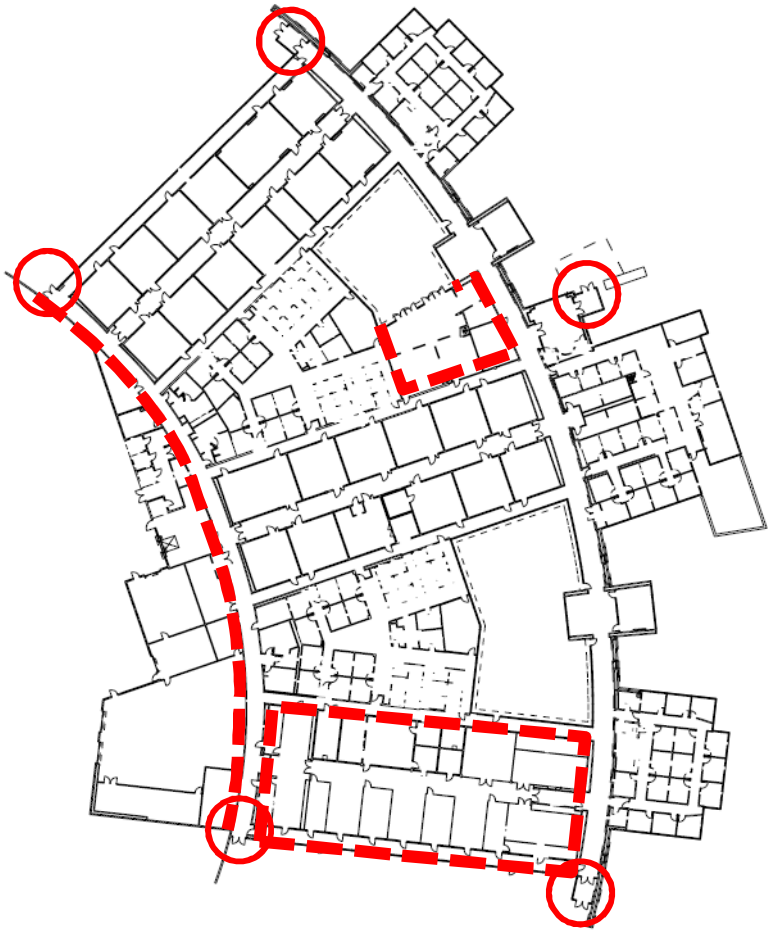
Travel Distance (feet)

Occupancy	LSC	IBC	Actual
Business/B	300	300	192
Assembly/A-3	250	250	142
Industrial (General)/F-1	250	250	103
Industrial (High)/H-3	**75**	**150**	47
Industrial (High)/H-5	**75**	**200**	70



Interior Finishes

IBC Interior Finish Classes (803.9)

Group	Wall and Ceiling Class		Floor Class
	Corridor	Room	
B	C	C	II
A-3	B	C	II
F-1	C	C	II
H-3	B	C	II
H-5	B	C	II

Wall/Ceiling Finish Index (IBC 803.1.1; ASTM E 84)

Class	Flame Spread	Smoke Developed
A	0-25	0-450
B	26-75	0-450
C	76-200	0-450

- DOE-STD-1066-99 Sect. 9.3.1
  - Flame Spread Index: 25
  - Smoke Developed Index: 50
- Decorative Material: 10% of wall area
- Meets code due to more stringent DOE requirements

Floor Finish (IBC 804.2; NFPA 253)

Class	Minimum Critical Radiant Flux
I	0.45 W/cm^2
II	0.22 W/cm^2

Structural Fire Protection - Area

- No surrounding buildings – max allowable area (IBC 506)
- Exception IBC 506.2.1 W/30=2

$Occupancy$	$A_{act}\,(ft^2)$	$A_t\,(ft^2)$	I_f*	I_s	$A_a\,(\mathrm{ft}^2)$	$Ratio$
B**	62,512	23,000	1.5	3	126,500	0.49
A-3***	2,104	9,500	1.5	3	52,250	0.04
F-1**	8,085	15,500	1.5	3	85,250	0.09
H-3****	711	14,000	1.5	0†	35,000	0.02
H-5	9,088	23,000	0.75	3	109,250	0.08
SUM						**0.72**

*506.2.1 – Where building meets IBC 507, width of public way is limited to maximum of 60
**507.3 – Considered an unlimited area building
***507.6 – Considered an unlimited area building
****507.8 Considered an unlimited area building
†506.3 Exception – No sprinkler increase permitted

Structural Fire Protection - Resistance

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Required Separation (IBC Old)

Use	A-3	B	F-1	H-3	H-5
A-3		1	2	3	4
B			2	1	1
F-1				1	1
H-3					1

Corridor Rating (IBC 1018.1)

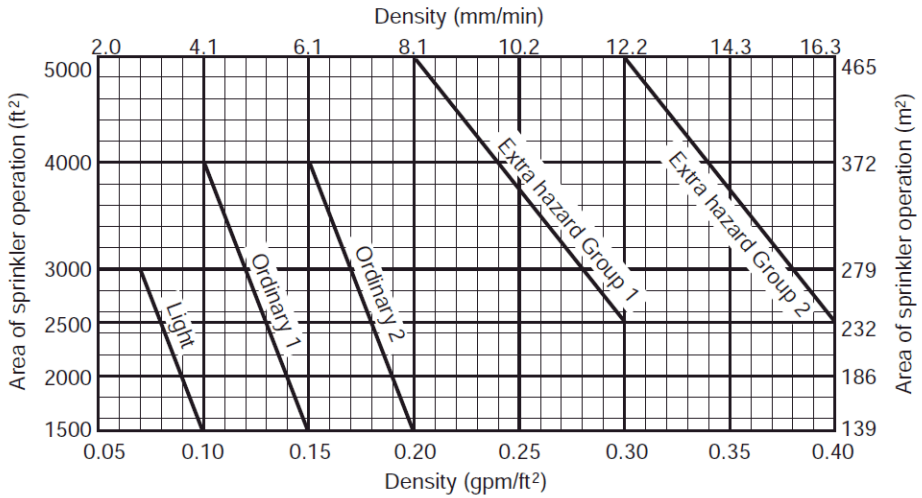
Use	Load	Rating*
H-5	>30	1

*With a sprinkler system

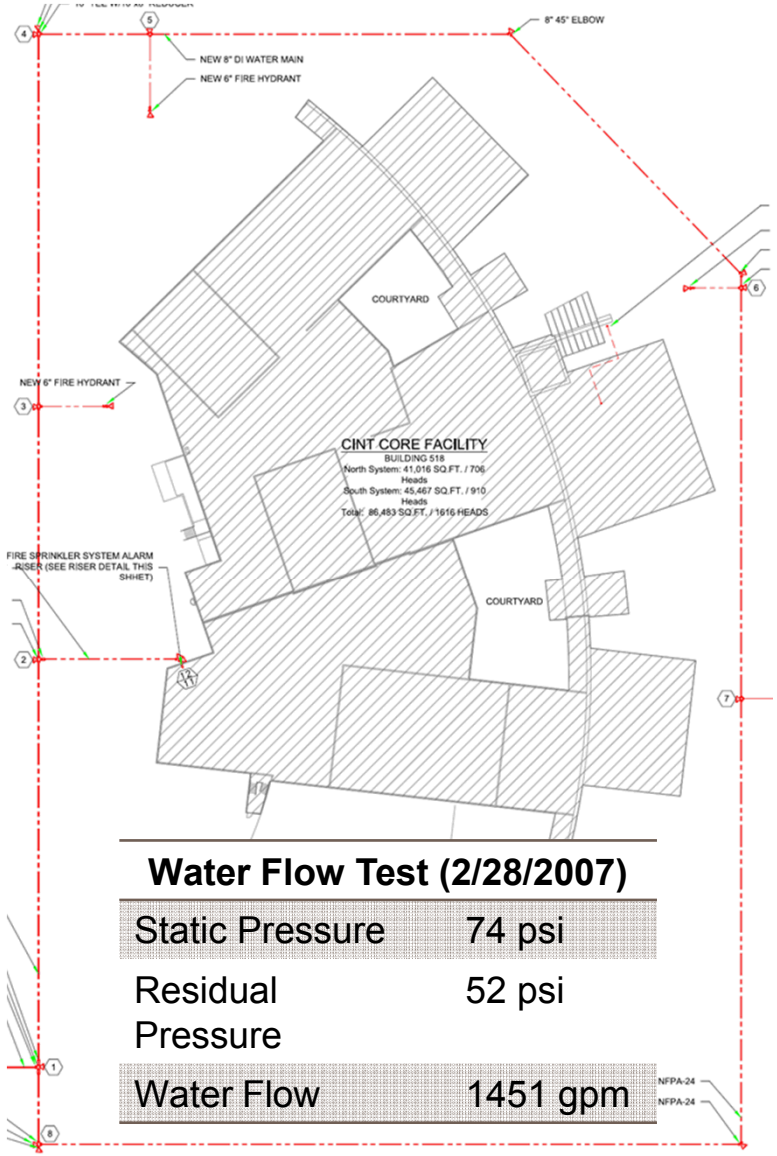
- Type IIB Construction
  - DOE Order 420.1
  - Steel decks
  - Steel bar joists
  - Steel wide flange beams
  - Steel columns
  - Exterior nonbearing walls (no fire resistance)

Suppression

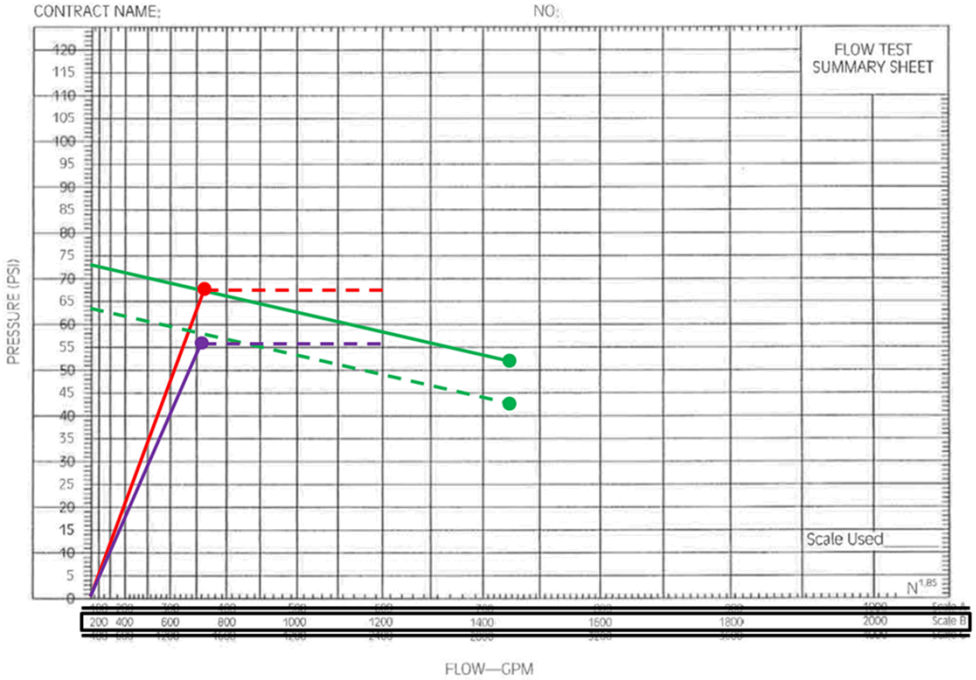
Space	Classification (NFPA 13)	Density (gpm/ft^2)		Area (ft^2)		Hose (gpm)		Duration (min)
		NFPA 13	Sandia 15310	NFPA 13	Sandia 15310	NFPA 13	Sandia 15310	NFPA13
Office	Light Hazard	0.10	**0.15**	1500	1500	100	**500**	30
Laboratory Class C	Ordinary Hazard 1	0.15	**0.17**	1500	**3000**	250	**500**	60-90
Cleanroom	Special Hazard	0.20	0.20	3000	3000	-	500	-
FLS	Extra Hazard 2	0.40	-	2500	-	500	-	90-120



Suppression – Water Supply



Water Flow Test (2/28/2007)	
Static Pressure	74 psi
Residual Pressure	52 psi
Water Flow	1451 gpm



	Sprinkler Demand (Hand Calculations)
	Hose Stream Allowance (500 gpm)
	Sprinkler Demand (Designer's Calculations)
	Hose Steam Allowance
	Water Supply
	85% Supply (Sandia Spec.15310 Sect. 4b)

Fire Alarm System - Characteristics

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- Proprietary Supervising Station
- FACP (QuickStart 4), FATC, Annunciator (QSA)
- Initiating Devices:
  - Smoke Detector – No detection throughout the building (IBC 907.2)
    - Fire Alarm Safety Functions (IBC 907.3)
    - Control door release, HVAC, and toxic gas shutdown
    - Protect FACP & FATC (IBC 907.4.1)
  - Manual Pull Stations – Exits; every 400 feet; every 150 feet along chemical transportation route (IBC 415.10.2).
  - High Sensitivity Smoke Detection (HSSD)
  - Toxic Gas Monitoring System
  - Water Flow and Tamper Switches
- Notification Devices: Horn/Strobe (Wheelock)
- Class A Circuits: Redundant path; operates past single open; path integrity results in trouble signal (NFPA 72, 12.3.1)

Fire Alarm System

Table 1: dBA and Current Ratings for Multitone Audible Portion

	RMS Current (amps)										dBA @ 10ft (UL Reverberant)					
	24 VDC				12 VDC				120 VAC		24 VDC		12 VDC		120 VAC	
	HI Output		STD Output		HI Output		STD Output		HI Output	STD Output						
	@ 24 VDC	UL max*	@ 24 VDC	UL max*	@ 24 VDC	UL max*	@ 24 VDC	UL max*	UL max*	UL max*	HI Output	STD Output	HI Output	STD Output	HI Output	STD Output
Horn	0.074	0.108	0.033	0.044	0.145	0.176	0.023	0.034	0.050	0.042	92	87	90	77	85	82
Bell	0.040	0.053	0.018	0.024	0.077	0.095	0.014	0.020	0.041	0.039	86	80	85	69	82	75
March Time Horn	0.067	0.104	0.033	0.038	0.109	0.142	0.023	0.034	0.050	0.040	89	84	89	74	85	79
Code-3 Horn	0.069	0.091	0.026	0.035	0.100	0.142	0.023	0.034	0.050	0.042	88	83	88	73	82	75
Code-3 Tone	0.061	0.075	0.026	0.035	0.088	0.105	0.015	0.021	0.042	0.040	85	80	84	70	79	75
Slow Whoop	0.069	0.098	0.028	0.037	0.100	0.142	0.025	0.035	0.050	0.042	90	89	89	75	85	82
Siren	0.080	0.104	0.027	0.036	0.122	0.152	0.021	0.030	0.045	0.041	89	84	89	75	85	82
HI/LO	0.044	0.057	0.020	0.026	0.089	0.114	0.018	0.026	0.042	0.039	86	81	86	71	82	79

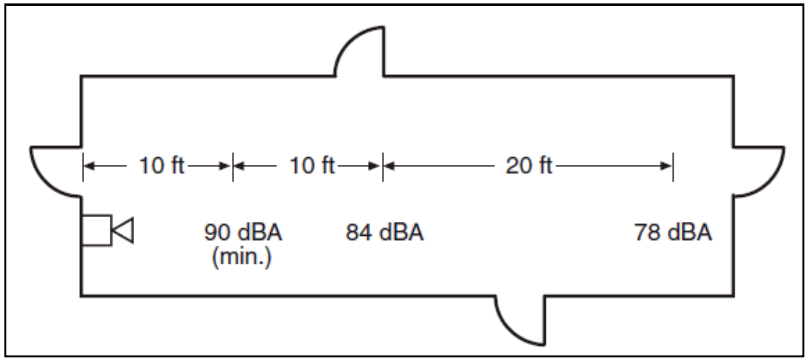

Table 2: Strobe Current Ratings

	RMS Current (amps)						
Model	MT-121575	MT-241575	MTWP-2475	MT-24MCW			
Candela	1575cd	1575cd	180cd	15cd	30cd	75cd	110cd
@ 24VDC	0.152	0.060	0.094	0.041	0.063	0.109	0.140
UL max*	0.255	0.090	0.138	0.060	0.092	0.165	0.220

6 dB Rule (NFPA HB 14-3)

Sound Pressure (dBA)	Distance from Source (ft.)
92	10
86	20
80	40
74	80
68	160

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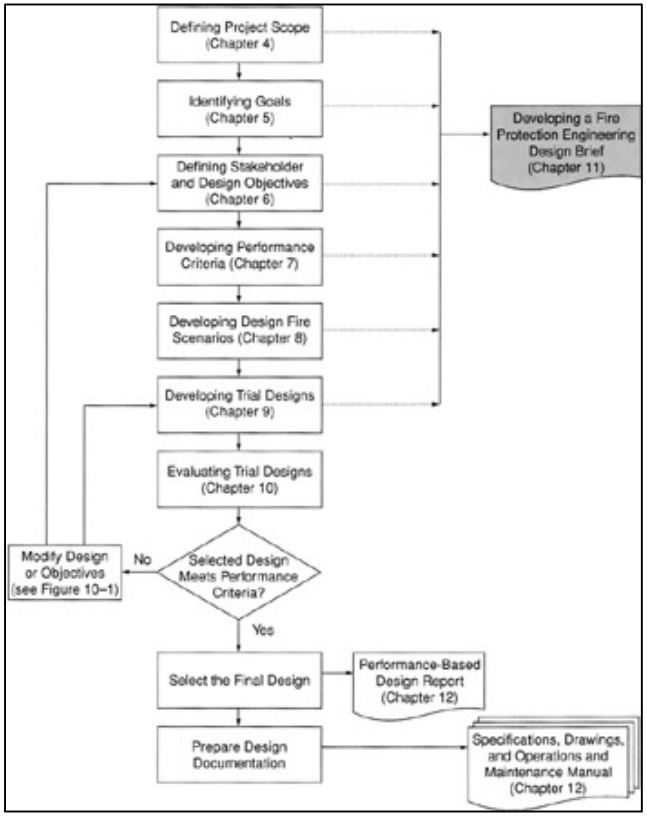
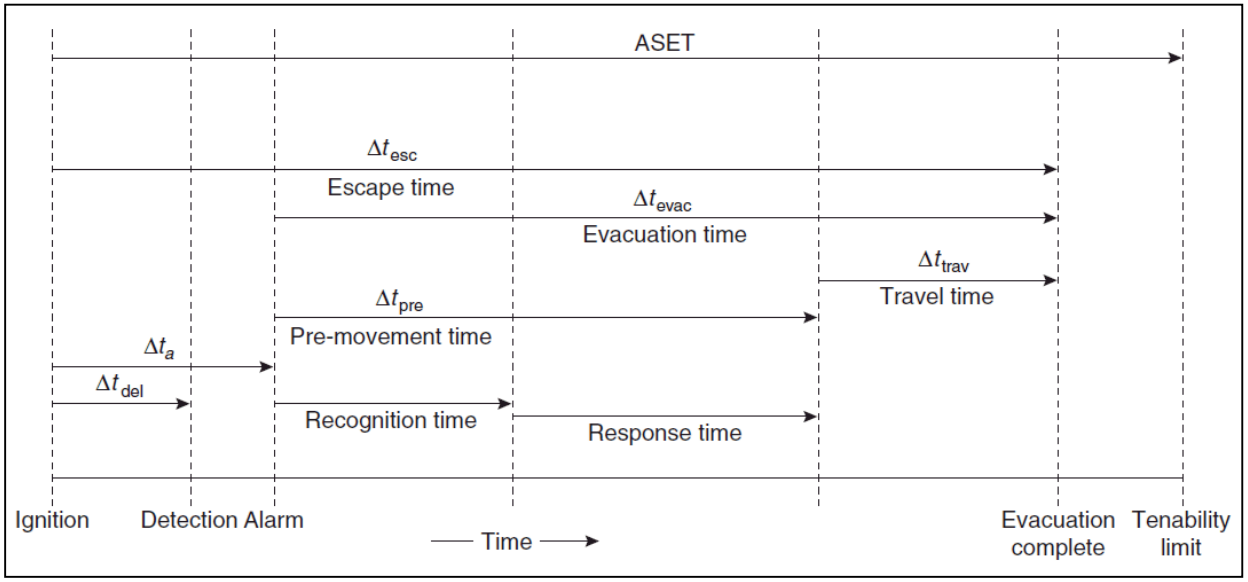
PERFORMANCE-BASED DESIGN

Project Scope



- The performance-based analysis will consist of ensuring the fire protection systems for laboratory building will perform under the three most likely fire scenarios.
- The systems must protect all occupants to safe egress and prevent the fire from spreading beyond the room of origin.
- The primary stakeholders are the building owner, the AHJ (DOE), the “Building and Fire Safety” department, the tenants, the building operations and maintenance, and the emergency responders.

Egress Analysis



- Assumptions
  - Instant queuing will occur at the 5 main exits (maximum specific flow F_{sm})
  - The exits will be used at optimum balance
  - No private exits are considered

Tenability Criteria

- Visibility: Many occupants may be visiting researchers and may not be familiar with the building layout.
  - **Visibility: 13 meters (SFPE HB 3rd Ed. Table 2-4.2)**
  - **Smoke Density: 0.15 m^{-}**
- Toxicity: Carbon monoxide is considered the most important asphyxiant formed in fires, therefore, we will only consider the CO levels for toxicity. Exposure of 2000 ppm CO would give the occupants 14 minutes to escape, however, with no knowledge of the size and RVM of the occupants, a more conservative criteria will be required.
  - **CO: 1000 ppm (SFPE HB 3rd Ed. Figure 2-6.5)**
- Temperature: After analyzing hyperthermia, skin burns, and respiratory burn limits, the most conservative temperature comes from convective heat transfer at 100% saturation
  - **Temperature: 60 C (SFPE HB 3rd Ed. Table 2-6.19)**
- Smoke Layer
  - **6 feet (IBC 909.8.1)**

Performance Criteria

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Fire Protection Goal	Stakeholder Objective	Design Objective	Performance Criteria
Minimize fire-related injuries	Allow safe egress for all occupants outside the room of origin	Maintain tenable conditions	Visibility > 13 m
			Smoke Layer Height > 1.83 m
			CO < 1000 ppm
			Room Temperature < 60 C
Minimize fire-related damage to the buildings and its contents	Prevent thermal damage	Prevent Flashover	Upper Layer Temperature < 500 C
Minimize undue loss of operations	Minimize smoke spread	Prevent fire and smoke from spreading outside the room of origin	Upper Layer Temperature < 500 C

Design Fire Scenarios

NFPA 101; 5.5.3	Common Scenarios*	Characteristics
1. Occupancy-specific fire	Intentionally set fire	Visitors
2. Ultrafast-developing fire in primary means of egress	Electrical malfunction	Chemical Storage
3. Normally unoccupied room	Smoking	Cleanroom
4. Concealed space next to large occupied room	Equipment	Located off-site (response time)
5. Slowly developing fire, shielded from fire protection	Carelessness	
6. Most Severe Fire	Heating	
7. Outside Exposure	Cooking	
8. Ordinary combustibles; fire protection ineffective		

**NFPA 805; Fire in the US (FEMA);*

Fire Scenarios

1. Lobby – Electrical Fire (NFPA 101, 5.5.3 (8))
   - Ordinary Combustibles; Fire Protection Ineffective.
2. Office – Heater Fire (NFPA 101, 5.5.3 (5))
   - Slowly developing fire shielded from fire protection.
   - The heater will be located under a desk and will be shielded by sprinklers. Portable heaters have been a common problem at SNL. Occupants can potentially leave to lunch and leave their heaters running.
3. High Hazard – Chemical Spill (NFPA 101, 5.5.3 (1))
   - Occupancy Specific Fire
   - 5 gallons of acetone

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Performance-Based Design

FIRE SCENARIO 1 – LOBBY PRINTER

Fire Scenario 1 – Lobby

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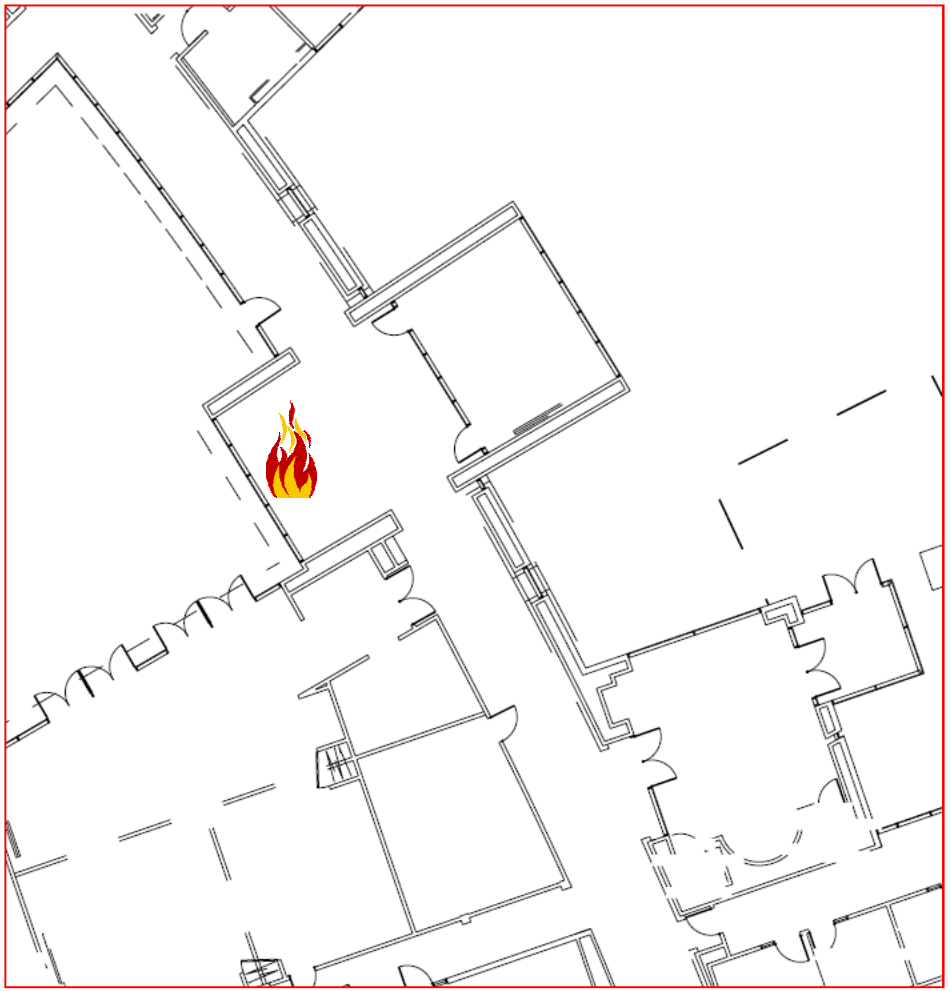
Fire Scenario 1 – Lobby

- Ignition Source: Printer
- Secondary Ignition: Keyboard, Monitor, Desktop tower, Cushioned office chair
- Open room therefore the smoke will spread along the main corridors.
- Fire Protection features are considered ineffective

Fire Scenario 1 – Lobby



FS1 Lobby – HRR

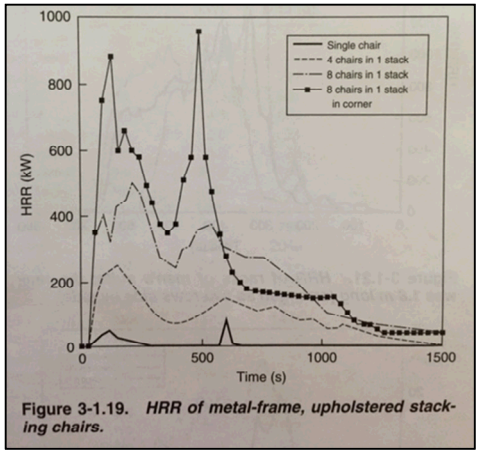


Figure 3-1.19. *HRR of metal-frame, upholstered stacking chairs.*

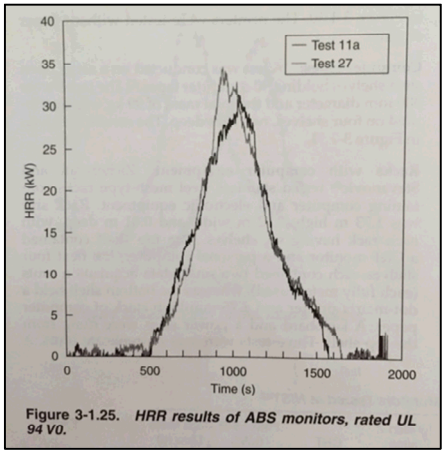


Figure 3-1.25. *HRR results of ABS monitors, rated UL 94 V0.*

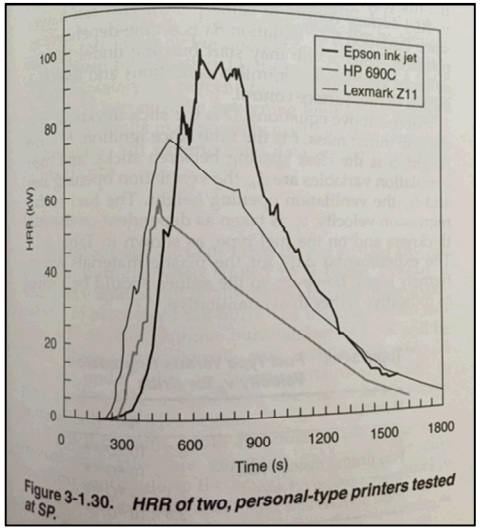


Figure 3-1.30. *HRR of two, personal-type printers tested at SP.*

Figure 3-1.23. *HRR of computer CPU tested by SP.*[81]

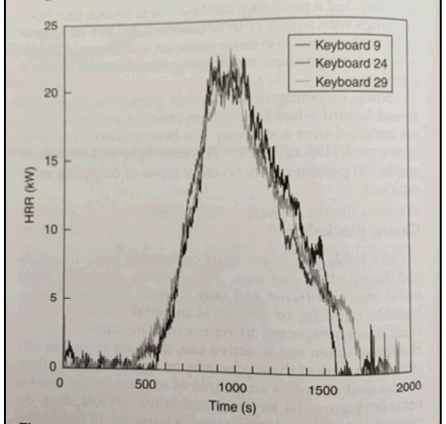


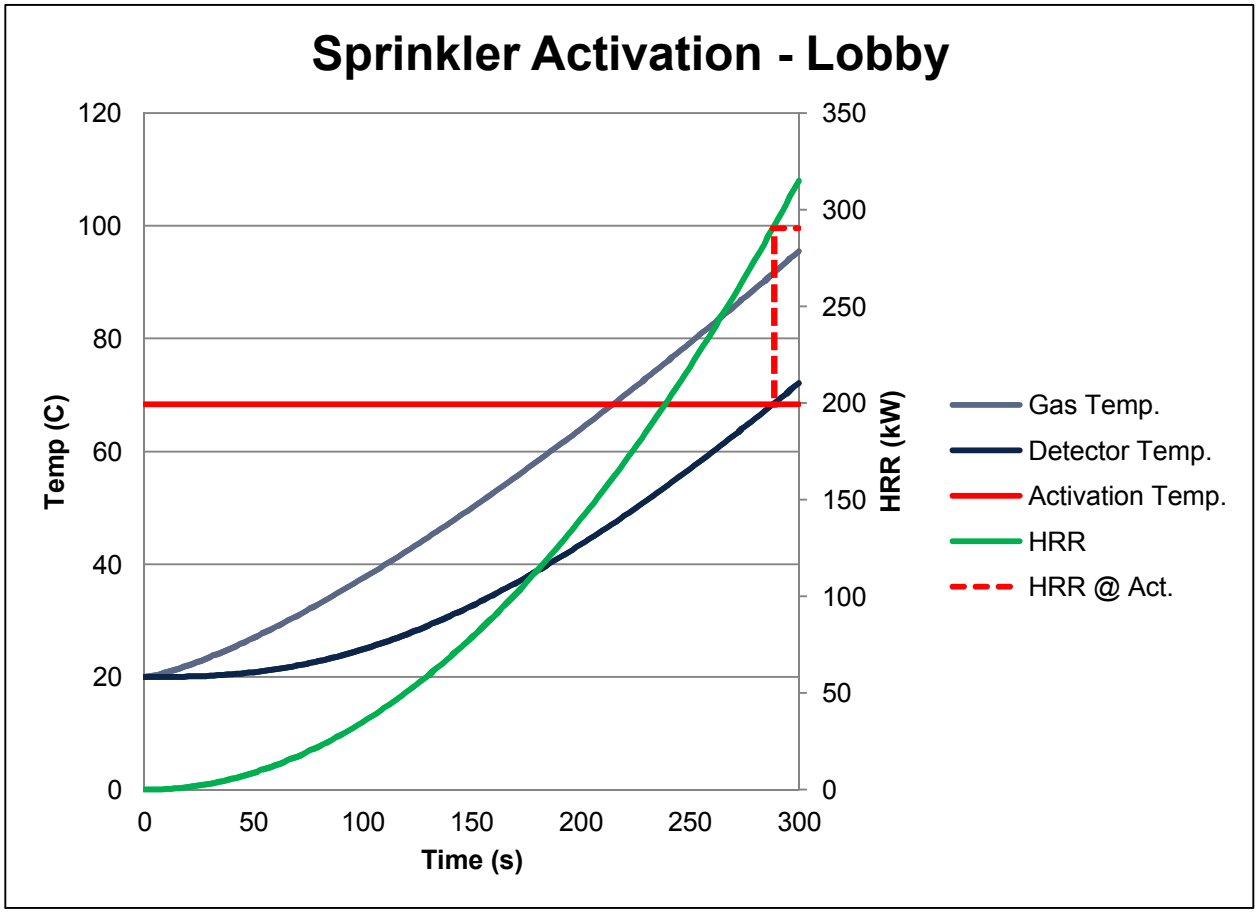
Figure 3-1.24. *HRR of polystyrene computer keyboards tested at NIST.*[82]

Item	Peak HRR (kW)
Keyboard	23
Monitor	35
Desktop Tower	35
Printer	100
Chair	100
TOTAL	**293**

*HRR taken from SFPE HB Chapter 3-1. Approximate growth time for all of the computer products is 300 seconds.

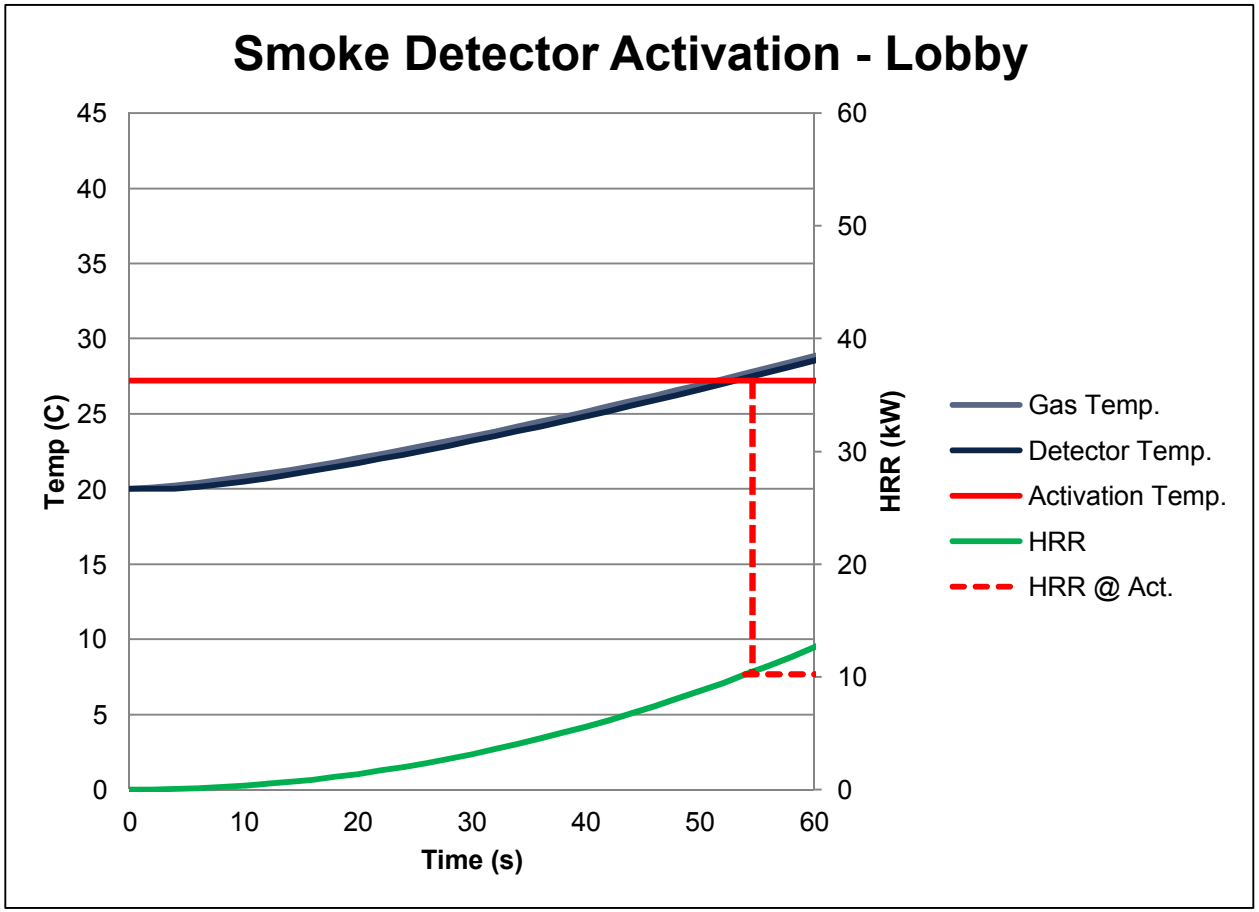
- Assume no incubation period.
- REAC will be PU (chair) due to its higher CO and Soot output over ABS (plastic cases)

FS1 Lobby – Egress Analysis (t_d)



288 s (290 kW)

FS1 Lobby – Egress Analysis (t_d)



54 s (10.2 kW)

FS1 Lobby – Egress Analysis (t_{p-e})

- Proulx studied 3 office buildings (SFPE HB 3-358)
  - Canadian government buildings
  - Evacuation drill conducted annually
  - 1000 occupants
  - No warning of fire drill
  - Finished phone calls
  - Saved computer data
  - Secured files
  - Gathered belongings
  - MEAN PRE-EVACUATION TIME: **50 s**

FS1 Lobby – Egress Analysis (t_e)

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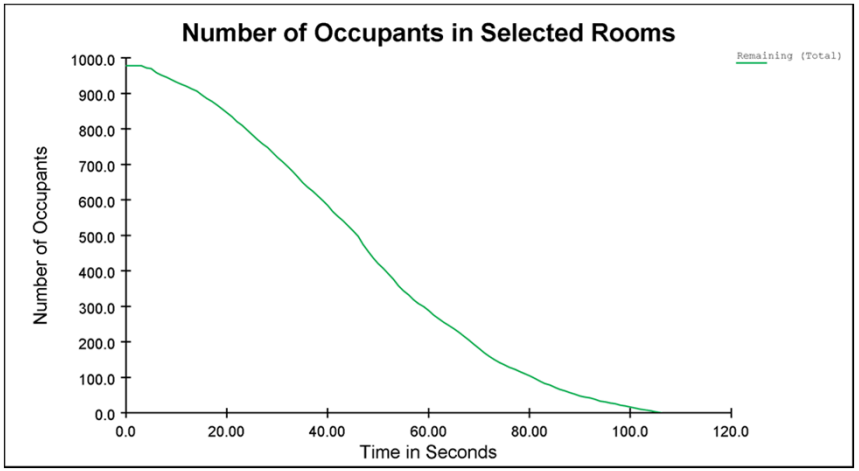
Hand Calculations

- $W_e = 4.33\ ft$
- $F_{sm} = 24 \frac{person}{min \cdot ft}$
- $F_c = 103.9 \frac{persons}{min \cdot door}$
- $P = 972\ people$
- $Doors = 5$
- $t_e = \mathbf{112\ s} = 1.87\ min$

Pathfinder

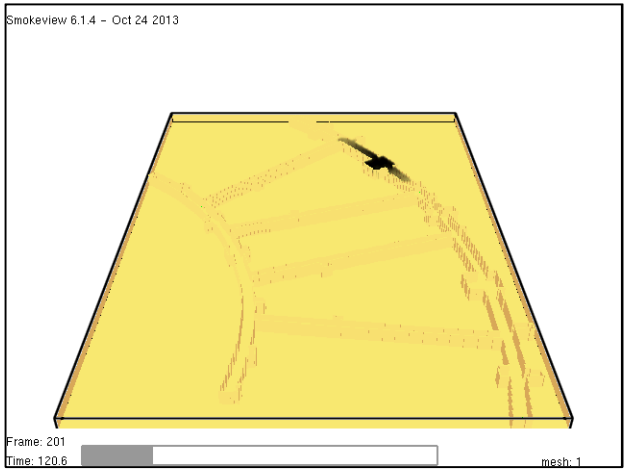


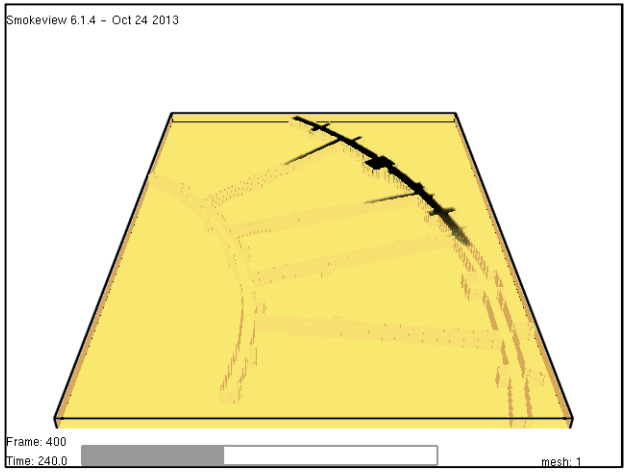
$t_e = \mathbf{106.3\ s}$

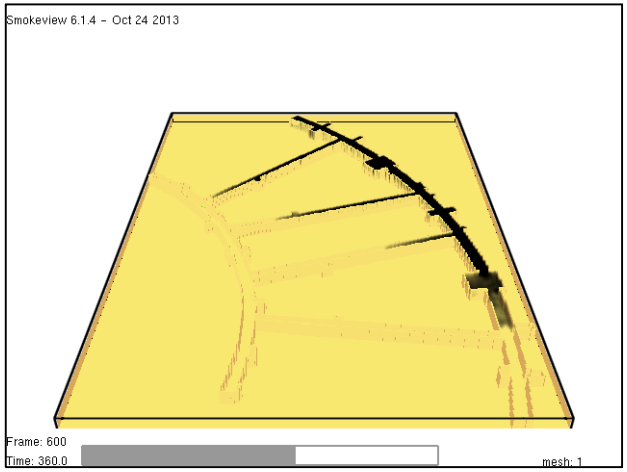
FS1 Lobby – Egress Analysis (RSET)

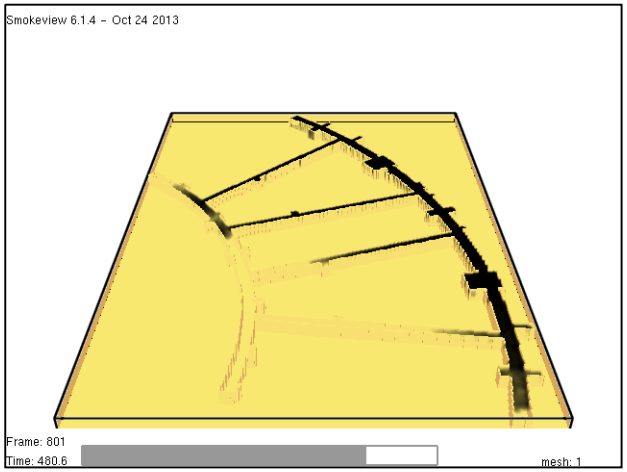
- $RSET = t_d + t_{p-e} + t_e$
  - $RSET\ (Sprinkler) = 288 + 50 + 112 = \mathbf{450}\ (\mathbf{7.5\ min})$
  - $RSET\ (Smoke\ Detector) = 54 + 50 + 112 = \mathbf{216\ s}\ (\mathbf{3.6\ min})$
  - $RSET\ (Instant\ Detection) = 0 + 50 + 112 = \mathbf{162\ s}\ (\mathbf{2.7\ min})$

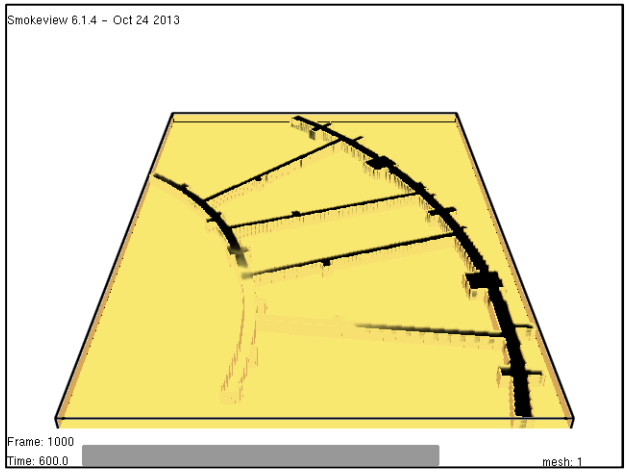
FS1 Lobby – Model





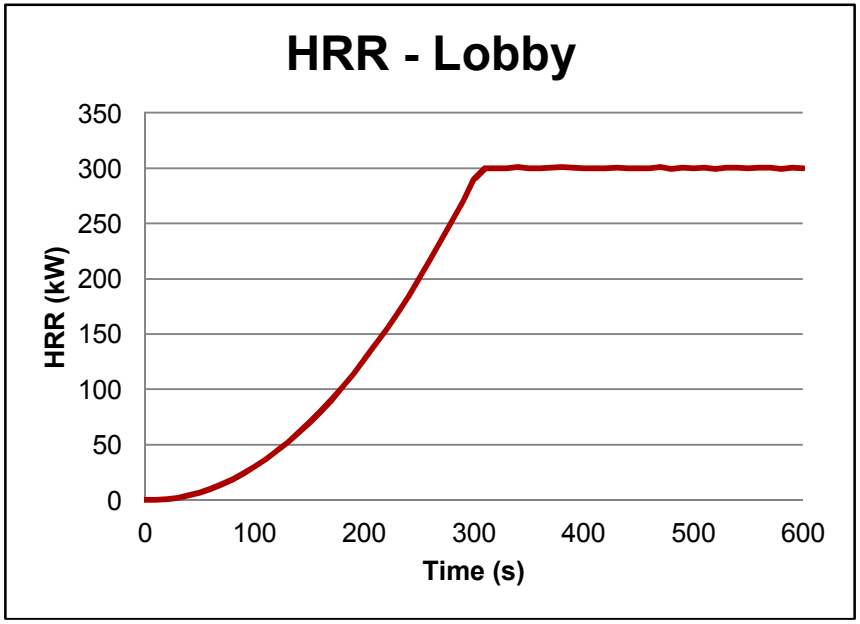




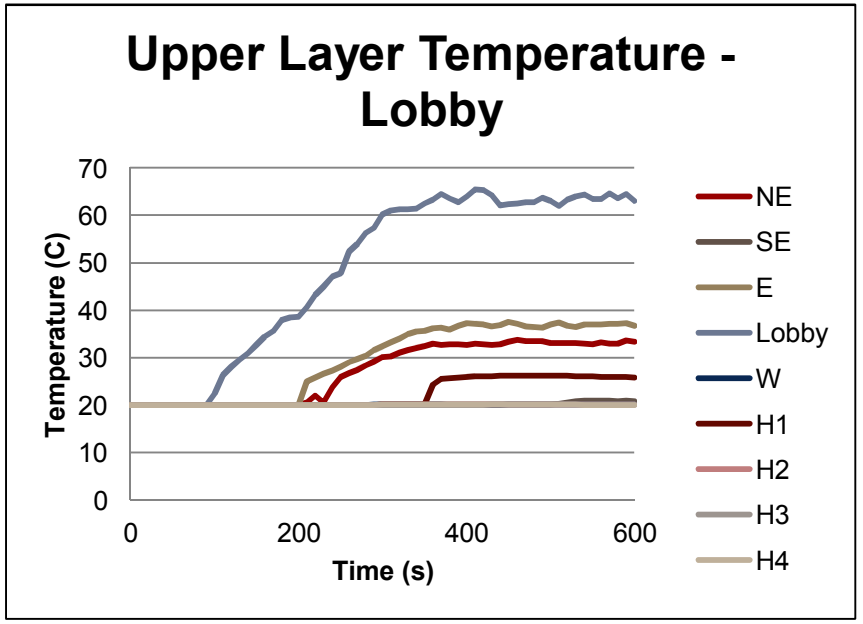


FS1 – Results (Flashover)

- **300 kW @ 300 s**

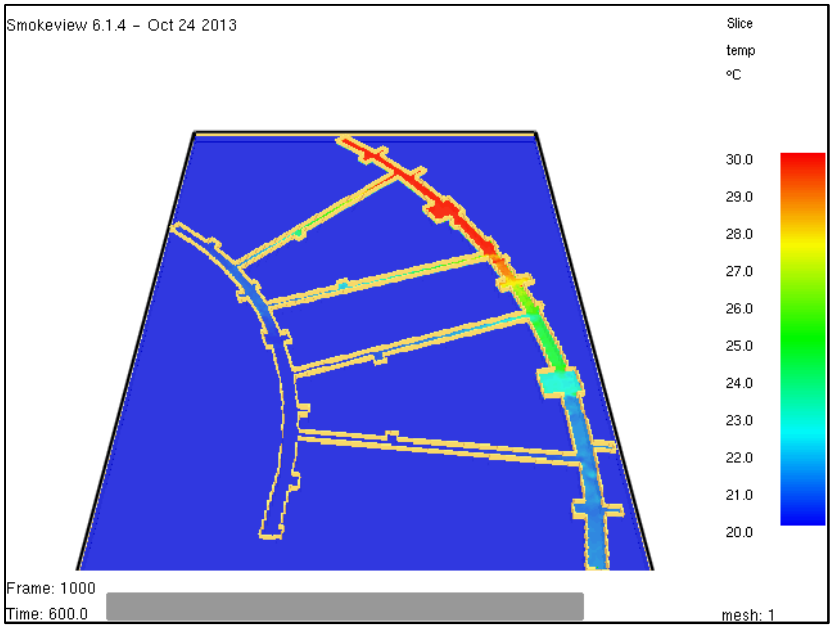


- **Passed (500 C)**

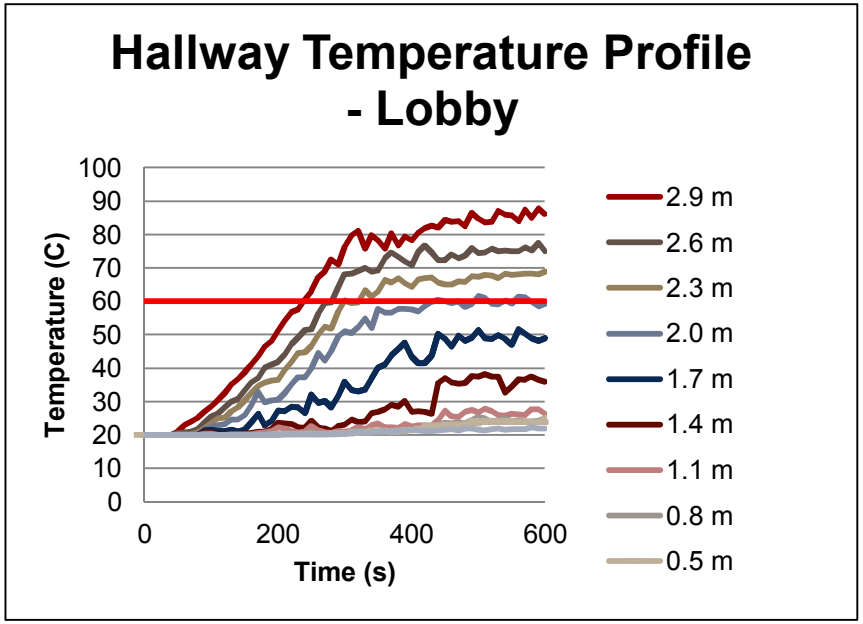


FS1 Lobby – Results (Temp.)

- **Temp. - Passed (60 C)**

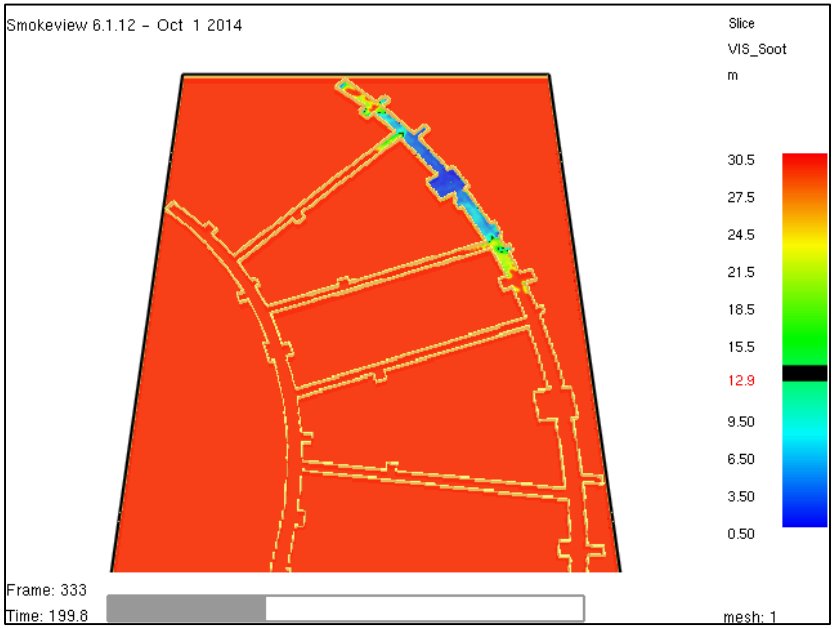


- **Tenable at 1.8 meters**

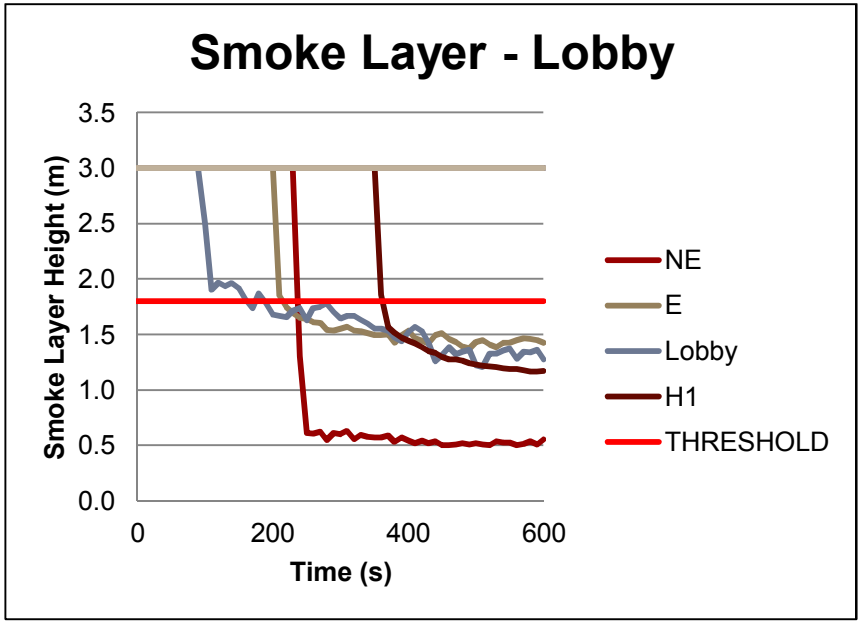


FS1 Lobby – Results (Smoke)

- **Visibility Fail 200 s (13 m)**

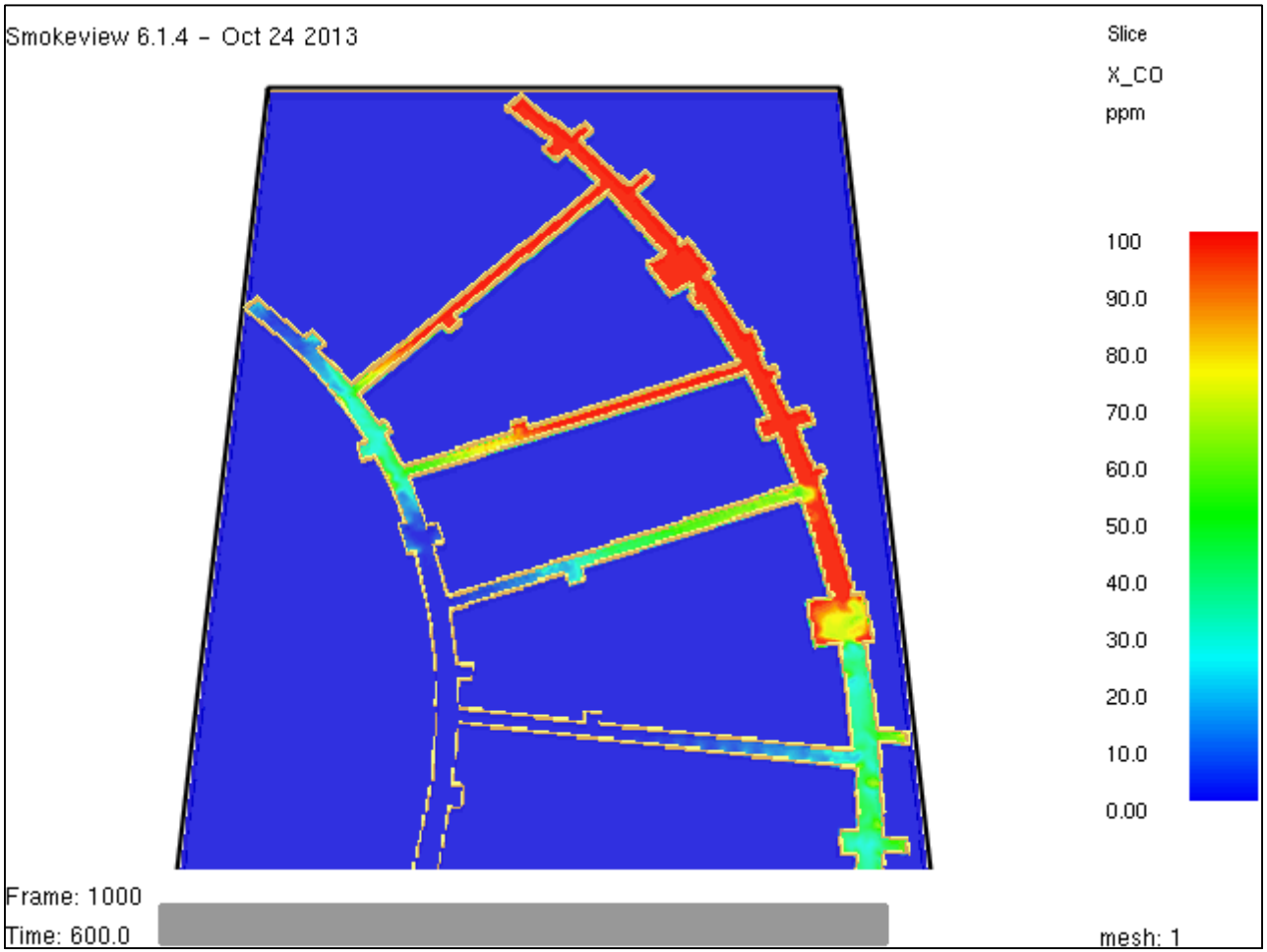


- **Lobby - 160 s (6 feet)**
- **East – 220 s (6 feet)**
- **NE – 235 s (6 feet)**



FS1 Lobby – Results (CO)

- **CO Passed (1000 ppm)**



FS1 Lobby – Summary

Criteria	Instant Detection	Smoke Detector	Sprinkler Activation	Reason
RSET (s)	**162**	**216**	**450**	
Flashover	Pass	Pass	Pass	Upper layer temperature of $500\ °C$ never exceeded
Temperature	Pass	Pass	**165**	A room temperature of 60 C was exceeded below a height of 1.8 m
Visibility	Pass	**200**	**200**	Visibility drops below 13 m from the E door to the NE door, blocking 2 exits.
Smoke Layer	Pass	Pass	**220**	The smoke layer descends below 6 feet at the E door in 220 s, eliminating the most common exit
CO	Pass	Pass	Pass	The CO concentration never exceed 1000 ppm

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Performance-Based Design

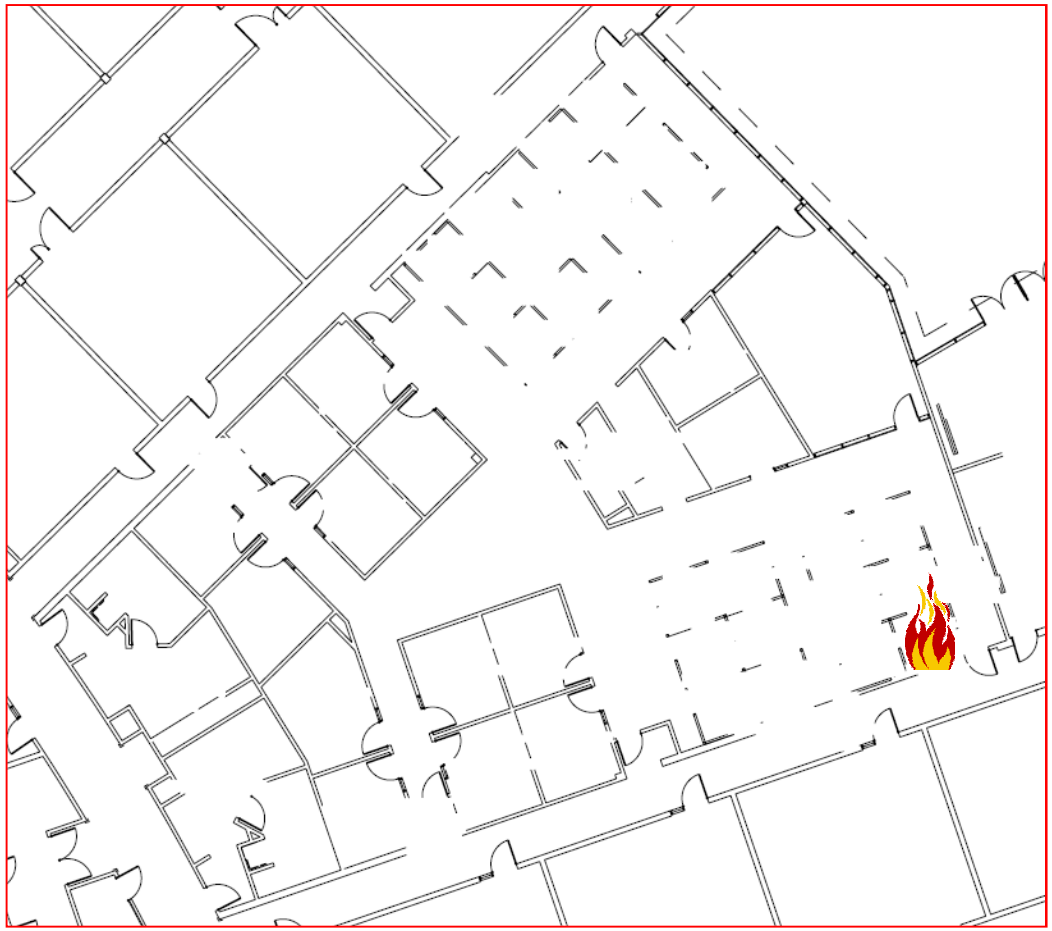
FIRE SCENARIO 2 – OFFICE HEATER

Fire Scenarios 2 – Office Heater Fire

Fire Scenarios 2 – Office Heater

- Ignition Source: Portable Heater
- Secondary Ignition: 1 office workstation
- Open layout, therefore the smoke will spread to the entire room of cubicles.
- The heater is located under the desk and shielded from the automatic detection, therefore, the sprinklers won't activate until the fire has spread to the workstation.

Fire Scenario 2 – Office Heater



FS2 Office - HRR

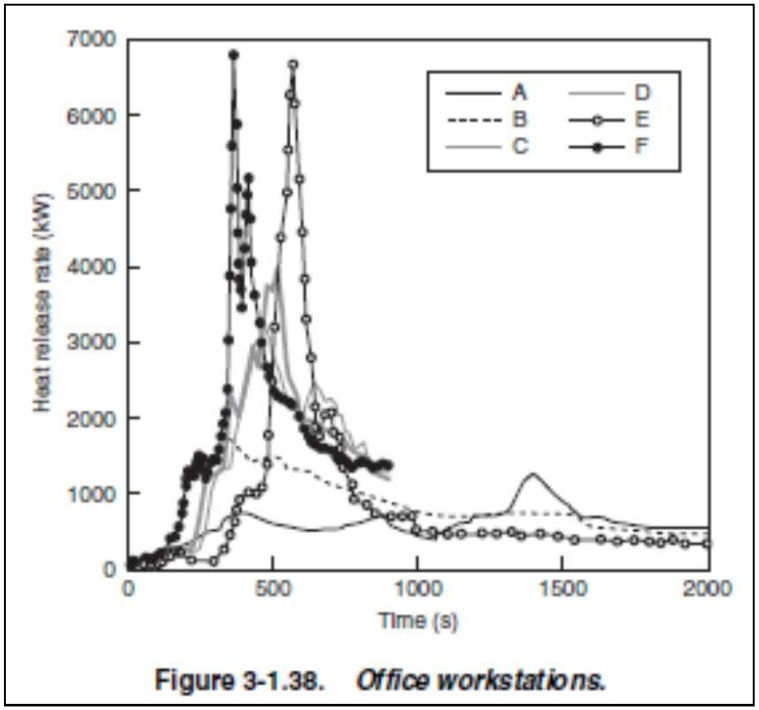


Figure 3-1.38. *Office workstations.*

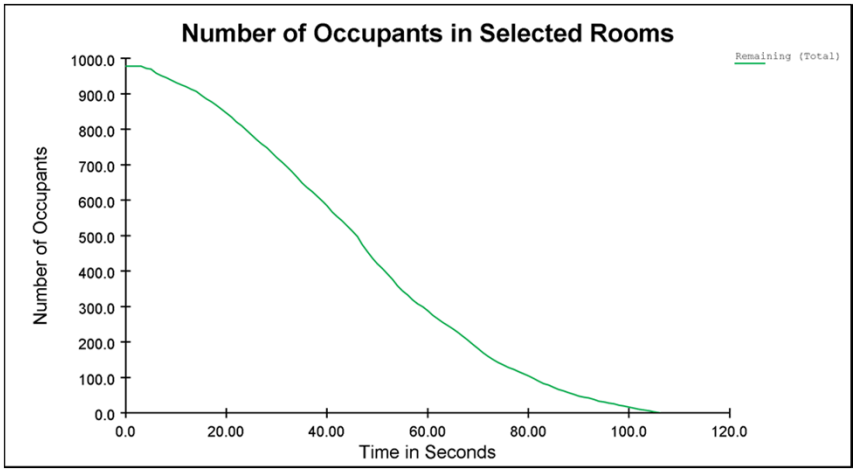
- HRR of 7 MW in 500 s
- FDS model assumes time begins when the workstation catches fire.

FS2 Office – Egress Analysis (t_d; t_{p-e})

- Detection Time
  - Sprinkler activation in the FDS model occurred in **140 s**.
- Pre-Evacuation Time
  - Modeled after Station Nightclub Fire Timetable

Action	Time (s)
Reaction time	10
Notify others	10
TOTAL	**20**

FS1 Lobby – Egress Analysis (t_e)

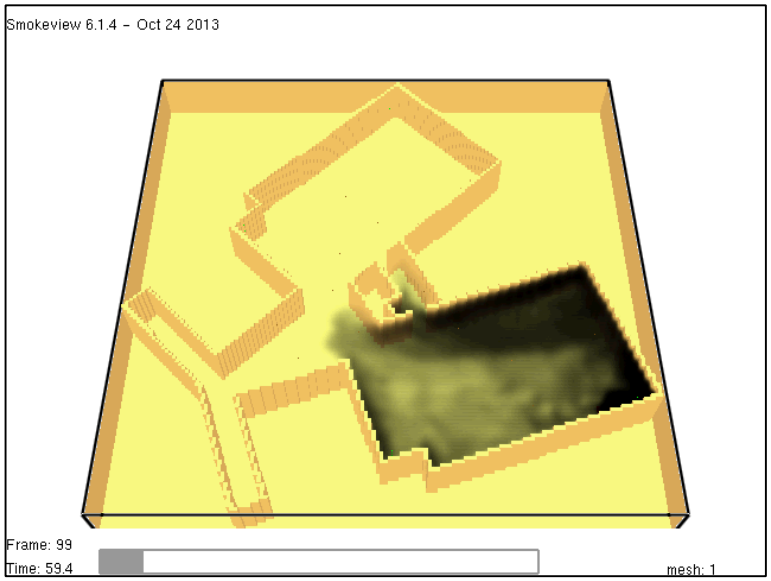


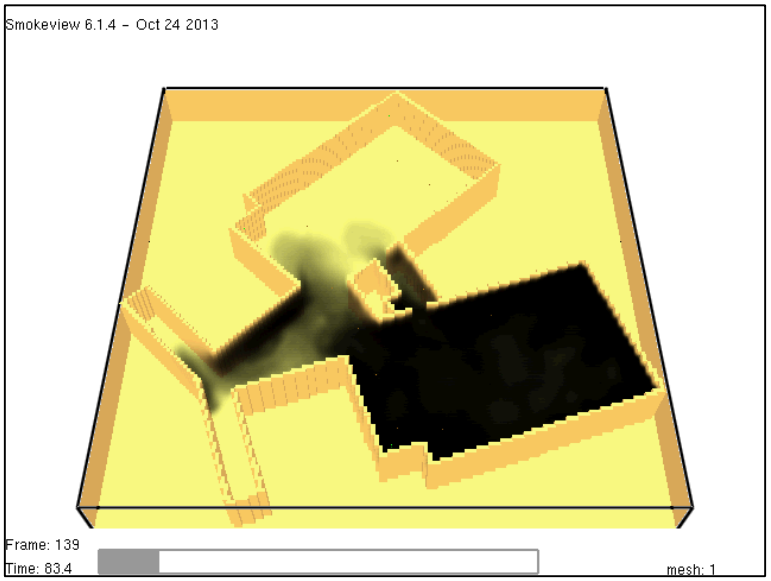
$$t_e = \mathbf{28\ s}$$

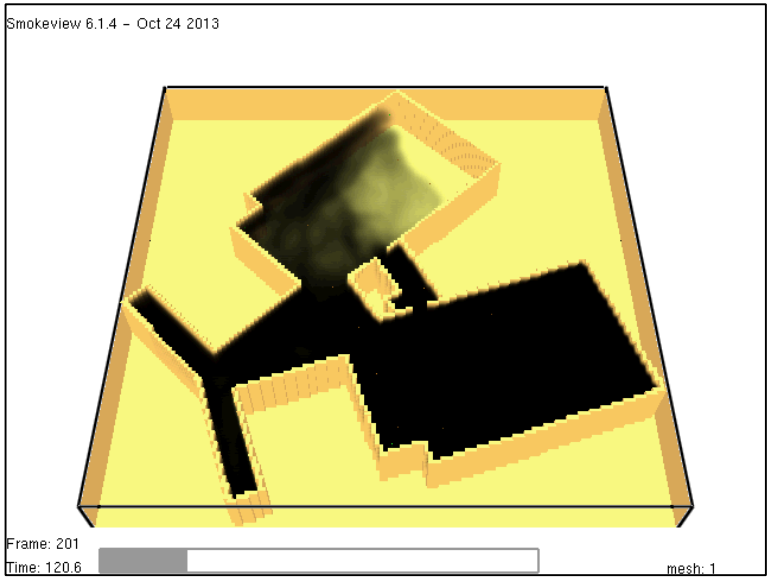
FS1 Lobby – Egress Analysis (RSET)

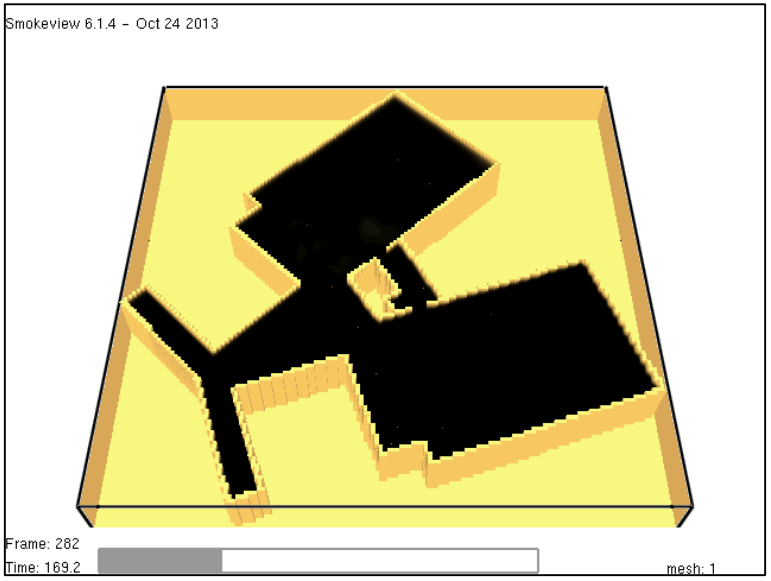
- $RSET = t_d + t_{p-e} + t_e$
  - $RSET\ (Sprinkler) = 140 + 20 + 28 = \mathbf{188\ s\ (3.1\ min)}$
  - $RSET\ (Instant\ Detection) = 0 + 20 + 28 = \mathbf{48\ s\ (0.8\ min)}$

FS2 Office – Model



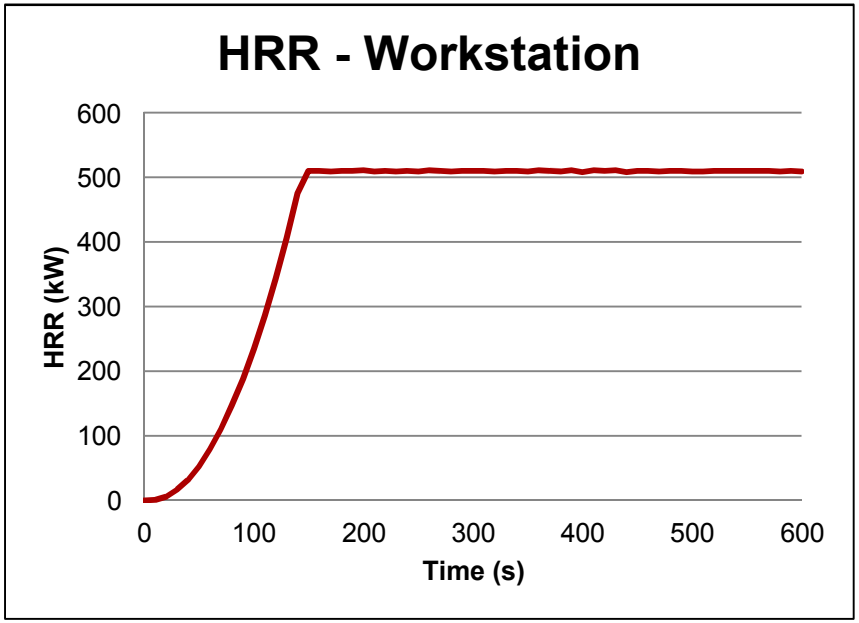




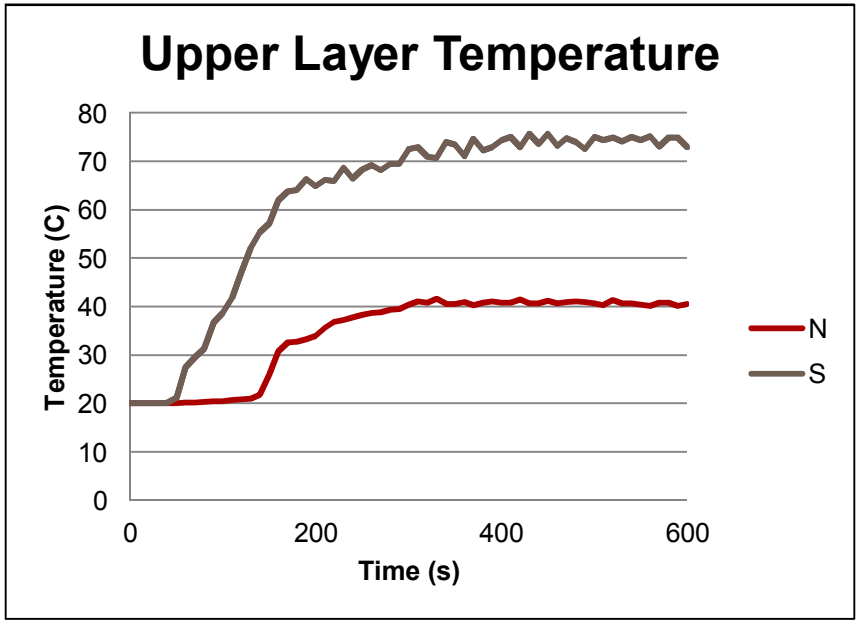


FS2 Office – Results (Flashover)

- **510 kW @ 140 s**

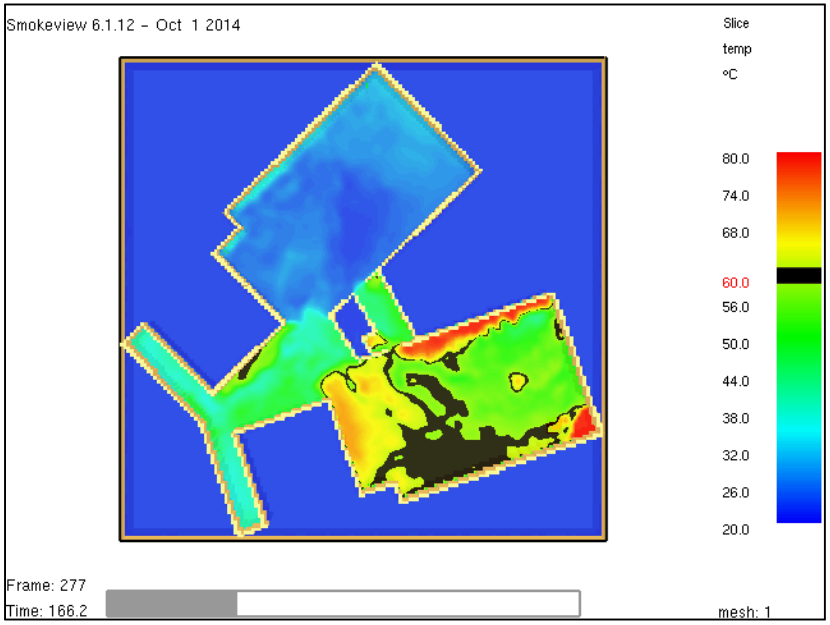


- **Pass (500 C)**

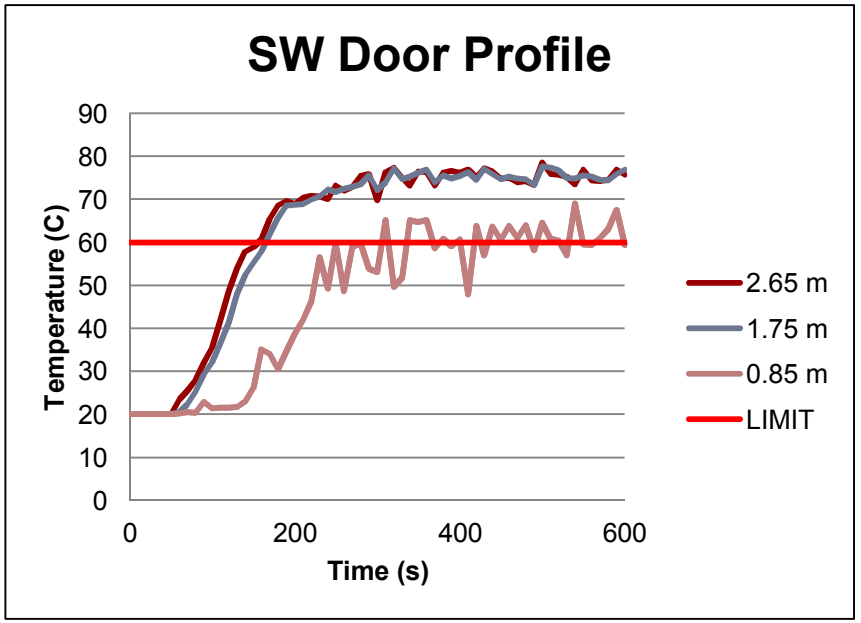


FS2 Office – Results (Temp.)

- **165 s (60 C @ S. Room)**

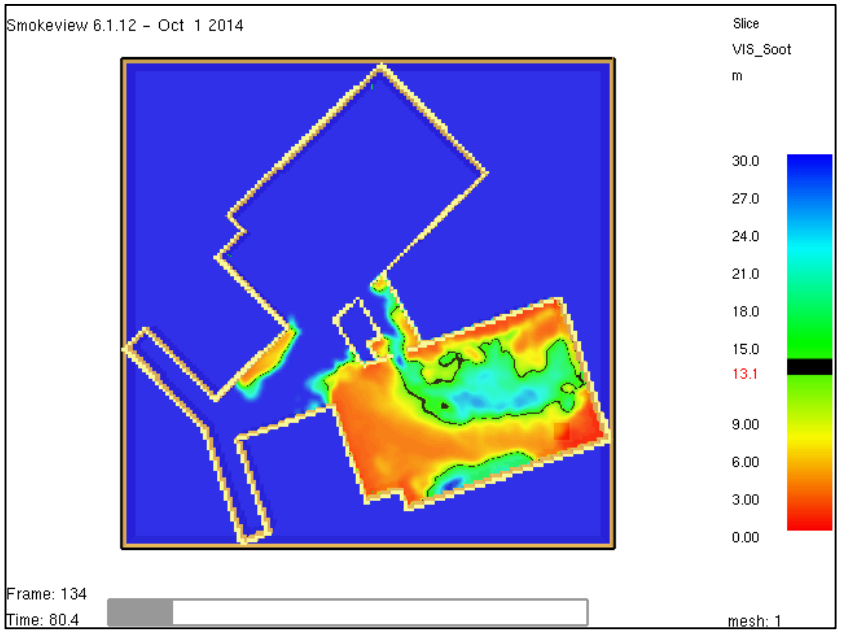


- **165 s (60 C @ 1.75 m)**

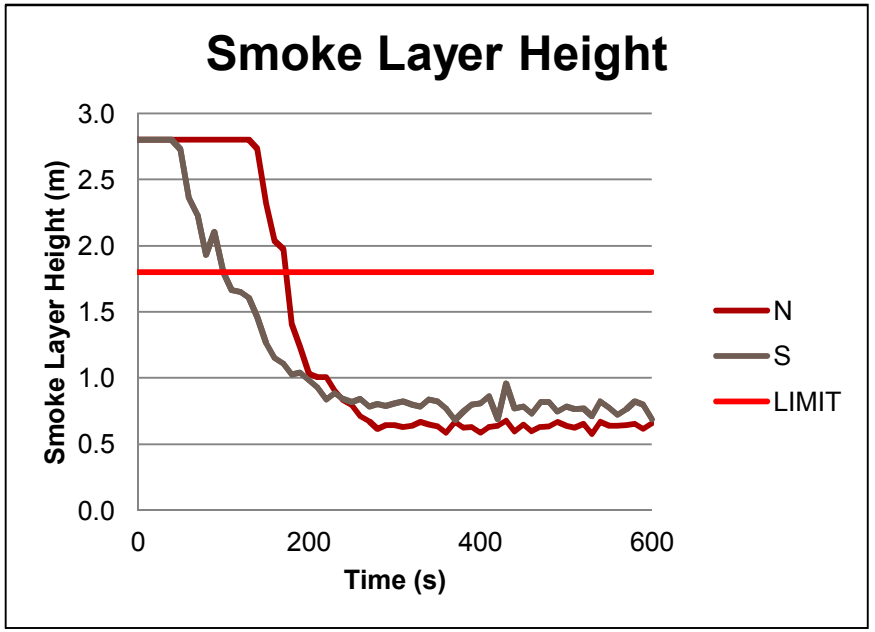


FS2 Office – Results (Smoke)

- **80 s (Visibility – 13 m)**

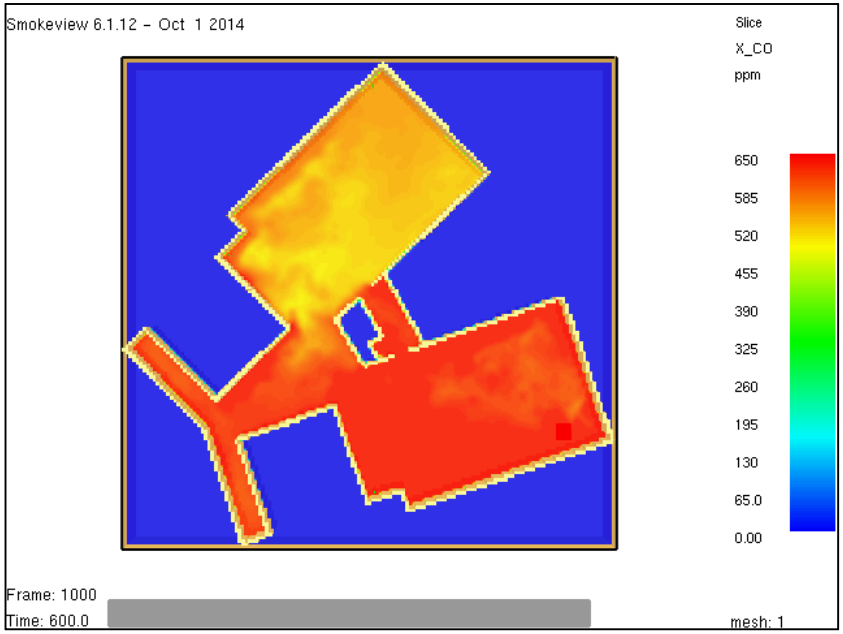


- **100 s (Height – 1.8 m)**

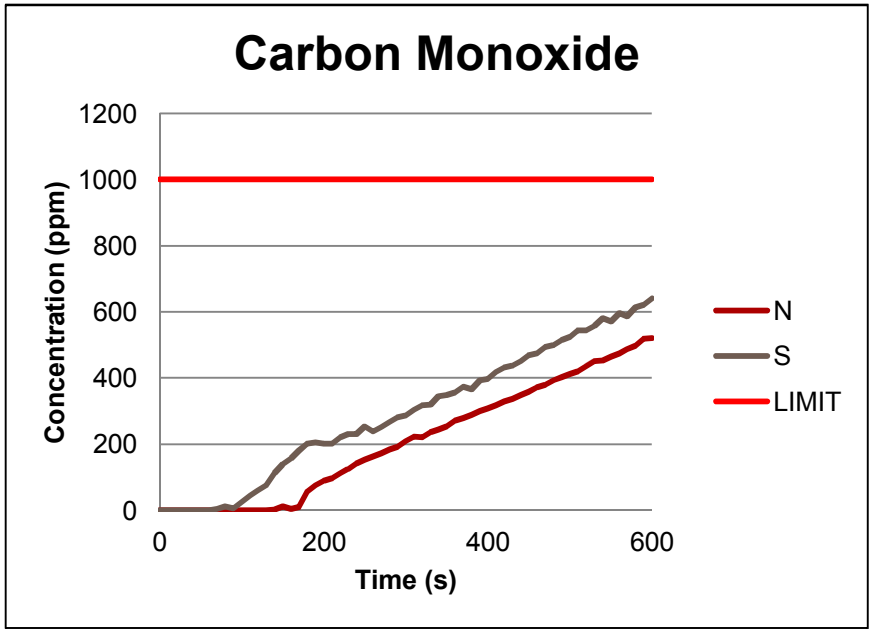


FS2 Office – Results (CO)

- **Pass (CO – 1000 ppm)**



- **Pass (CO – 1000 ppm)**



FS2 Office – Summary

Criteria	Instant Detection	Sprinkler Activation	Reason
RSET (s)	**48**	**188**	
Flashover	Pass	Pass	Upper layer temperature of $500\ °C$ never exceeded
Temperature	Pass	**165**	A room temperature of 60 C was exceeded below a height of 1.8 m
Visibility	Pass	**80**	Visibility drops below 13 m in the south office
Smoke Layer	Pass	**100**	The smoke layer descends below 6 feet in the south office.
CO	Pass	Pass	The CO concentration never exceed 1000 ppm

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Performance-Based Design

FIRE SCENARIO 3 – CHEMICAL SPILL

Fire Scenarios 3 – Chemical Spill

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- Spill Fire
- 5 gallons of Acetone
- High Hazard Occupancy
- High Sensitivity Smoke Detection (HSSD)
  - *The amount and location of chemicals in the model do not indicate the exact quantities and locations of chemicals in the laboratory building; however, the fire scenario is a good indication of possible hazards that may occur in any high hazard occupancy resulting from a spill fire.

FS3 Spill – HRR

Calculation	Property
$\forall = 5\ gal = 0.0189\ m^3$	Spill Volume
$\delta = 0.0007\ m$	Spill Depth
$A_s = \frac{\forall}{\delta} = \frac{0.0189\ m^3}{0.0007\ m} = 27\ m^2$	Initial Spill Area
$A = 1.55 A_s = 1.55(27\ m^2)$	Maximum Area
$D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(41.85\ m^2)}{\pi}} = 7.3\ m$	Diameter of Maximum Area
$\dot{m}'' = \frac{\dot{m}''_\infty}{5} = \frac{0.041\ kg \cdot m^{-2} s^{-1}}{5} = 0.0082 \frac{kg}{m^2 s}$	Mass Burner Rate
$\dot{q} = \Delta h_c \dot{m}'' A = \left(25.8 \frac{MJ}{kg}\right)\left(0.0082 \frac{kg}{m^2 s}\right)(41.85\ m^2) = \mathbf{8853.8\ kW}$	Steady State Burning Rate
$t_b = \frac{m_f}{\dot{m}'' A} = \frac{\forall \rho}{\dot{m}'' A} = \frac{(0.0189\ m^3)(791 \frac{kg}{m^3})}{(0.0082 \frac{kg}{m^2 s})(41.85\ m^2)} = \mathbf{43.6\ s}$	Burn Time
$T_{FP} = \mathbf{-14\ °C}$	Acetone Flash Point

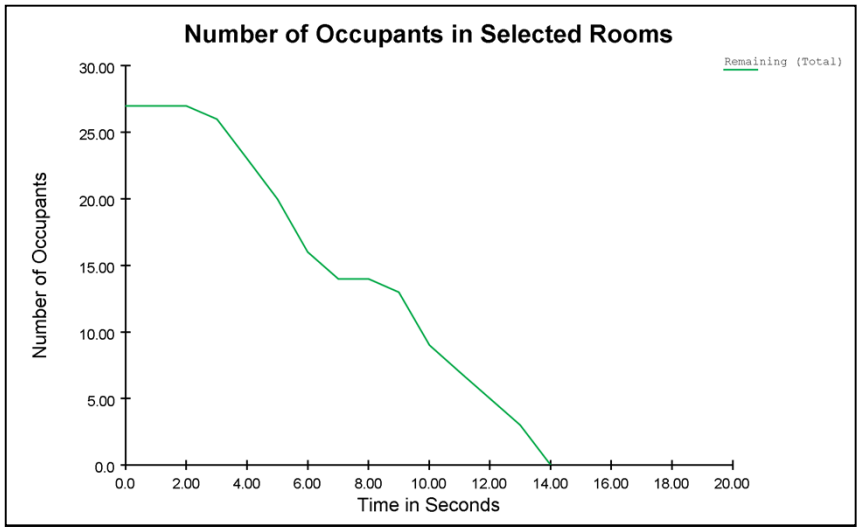
FS3 Spill – Egress Analysis

- Detection Time
  - Instantaneous max HRR
  - HSSD
  - **3 s**

- Pre-Evacuation Time

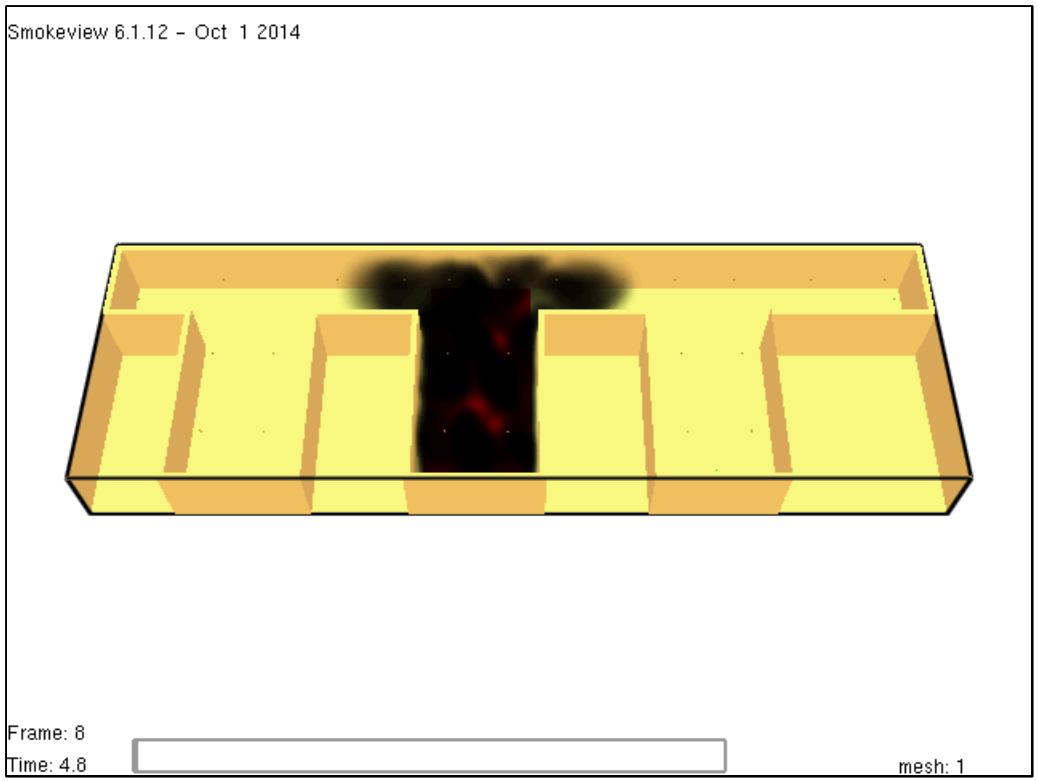
P-E Action	Time (s)
Reaction Time	3
Notify Others	10
TOTAL	**13**

- Evacuation Time: **14 s**



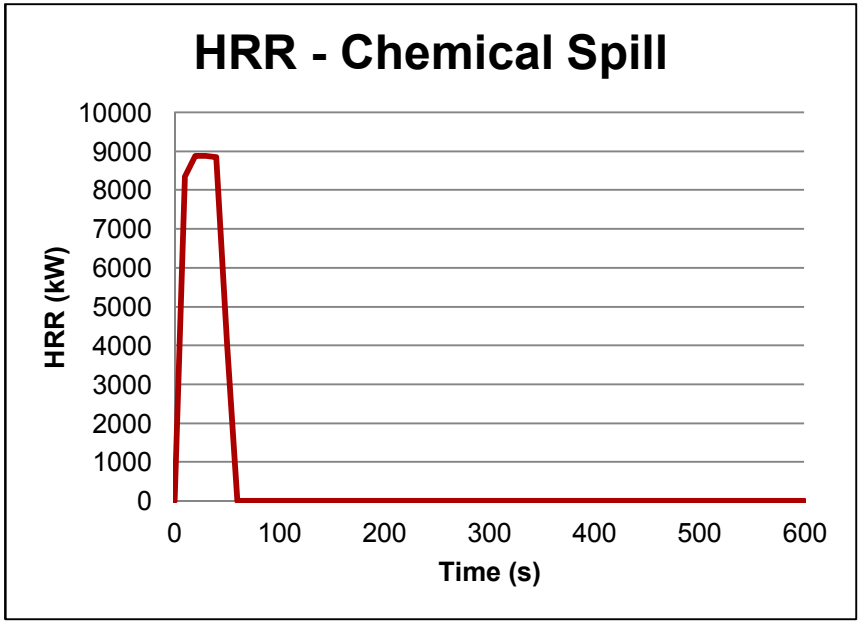
- **RSET = 30 s**

FS3 Spill – Model

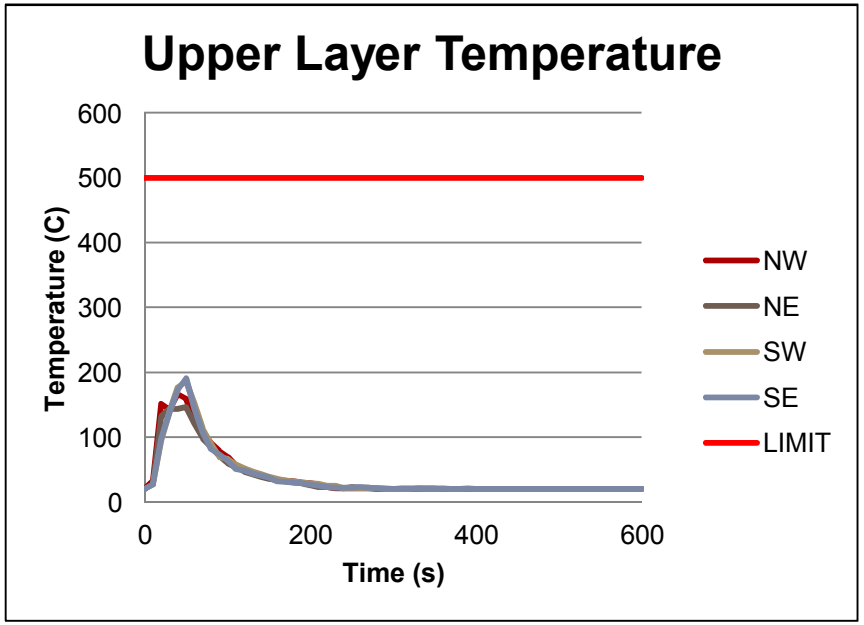


FS3 Spill – Results (Flashover)

- **8.8 MW for 44 s**

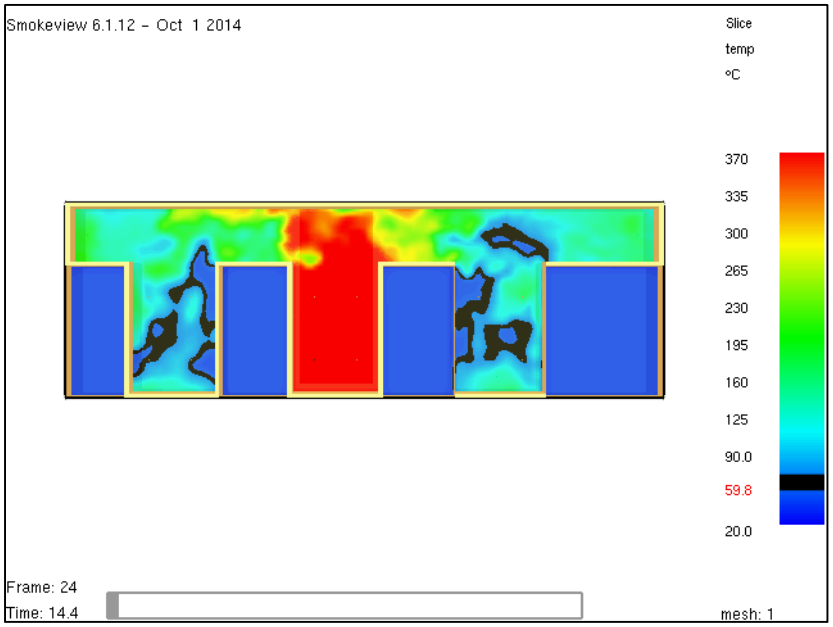


- **Pass (500 C)**

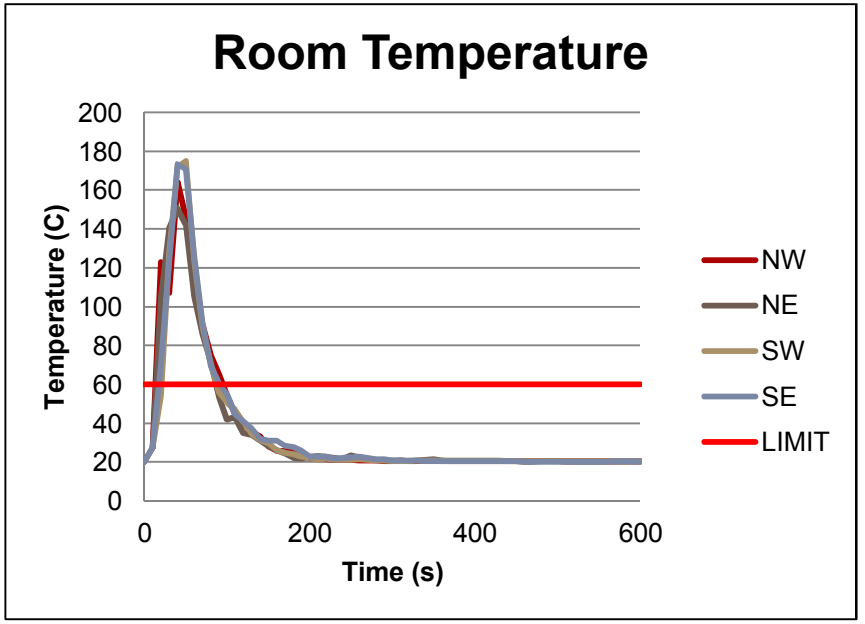


FS3 Spill – Results (Temp.)

- **14 s (60 C @ S. Room)**

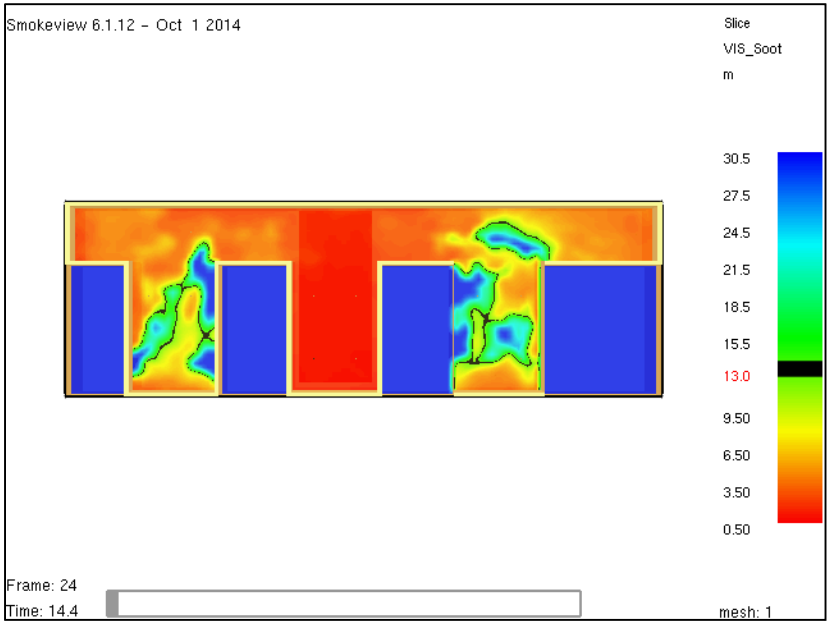


- **14 seconds (60 C)**

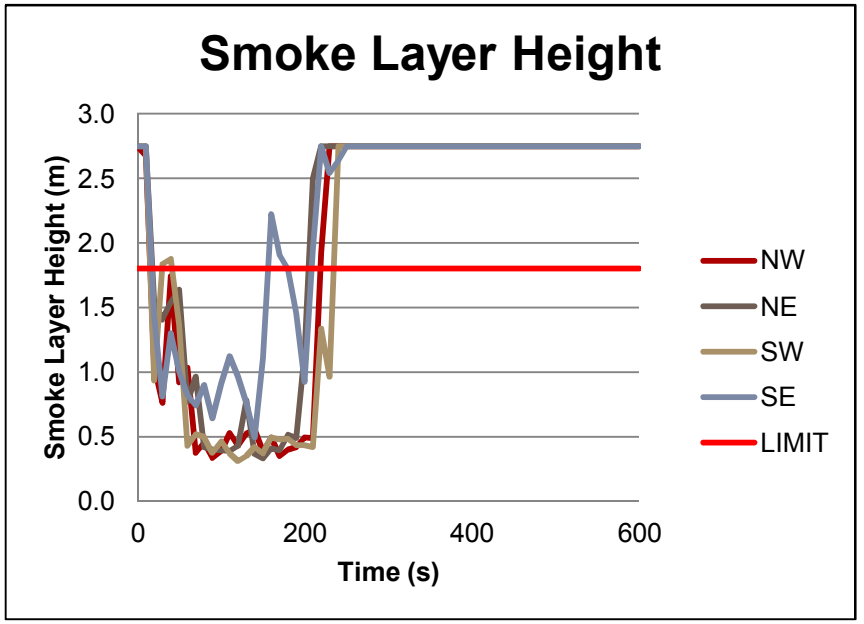


FS3 Spill – Results (Smoke)

- **14 s (Visibility – 13 m)**

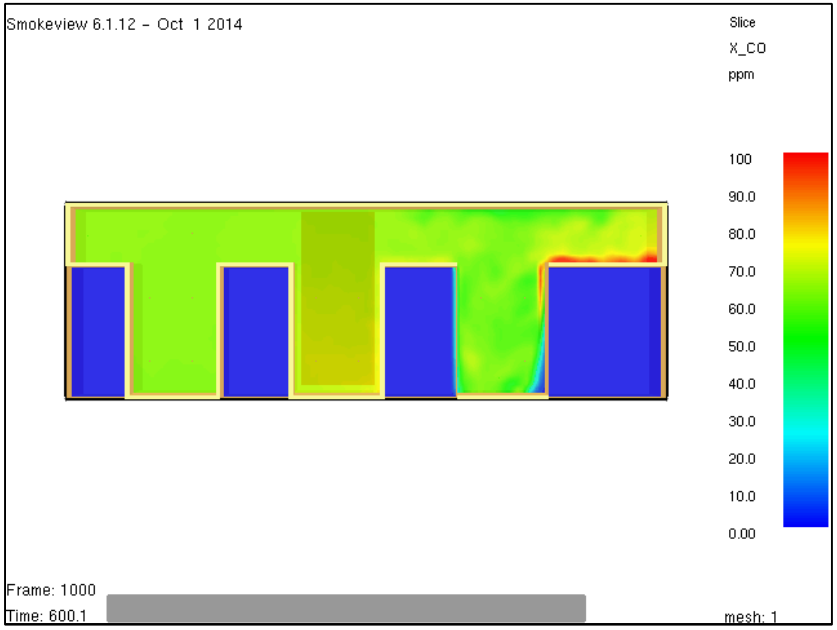


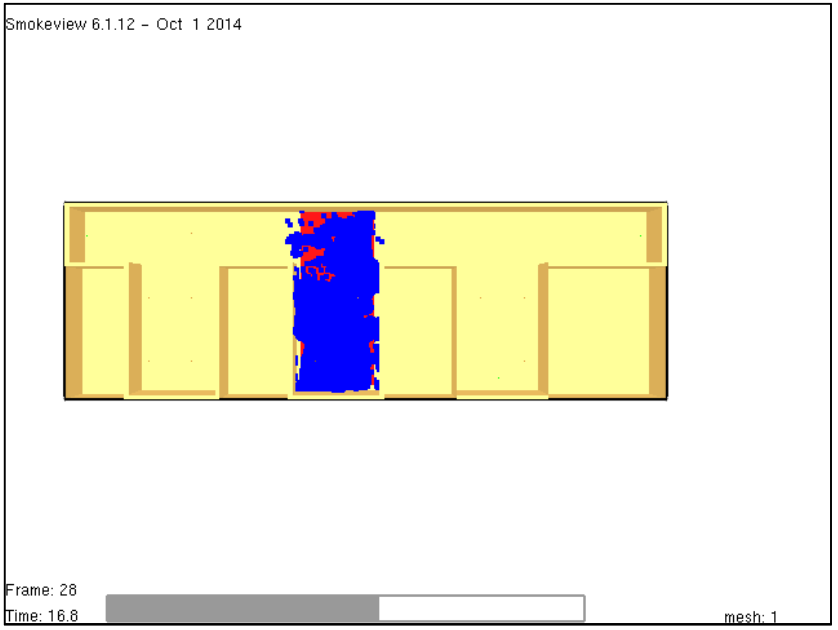
- **14 s (Height – 1.8 m)**



FS3 Spill – Results (CO)

- **Pass (CO – 1000 ppm)**





FS3 Cleanroom – Summary

Criteria	Pass/Fail	Reason
RSET	**30**	
Flashover	Pass	Upper layer temperature of 500 C never exceeded
Temperature	14	A room temperature of 60 C was exceeded below a height of 1.8 m
Visibility	14	Visibility drops below 13 m
Smoke	14	The smoke layer descends below 6 feet
CO	Pass	The CO concentration never exceed 1000 ppm

Risk Analysis

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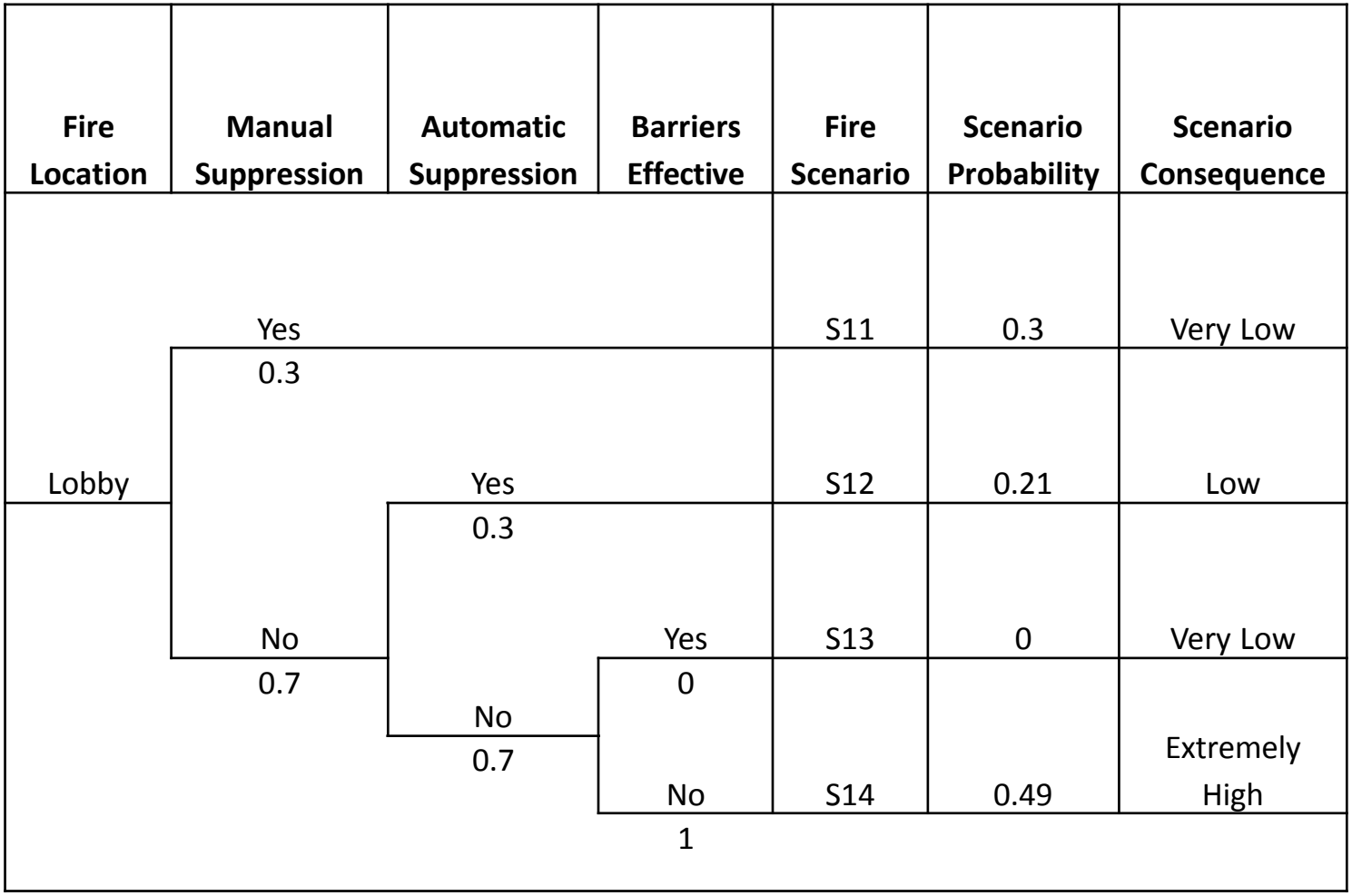
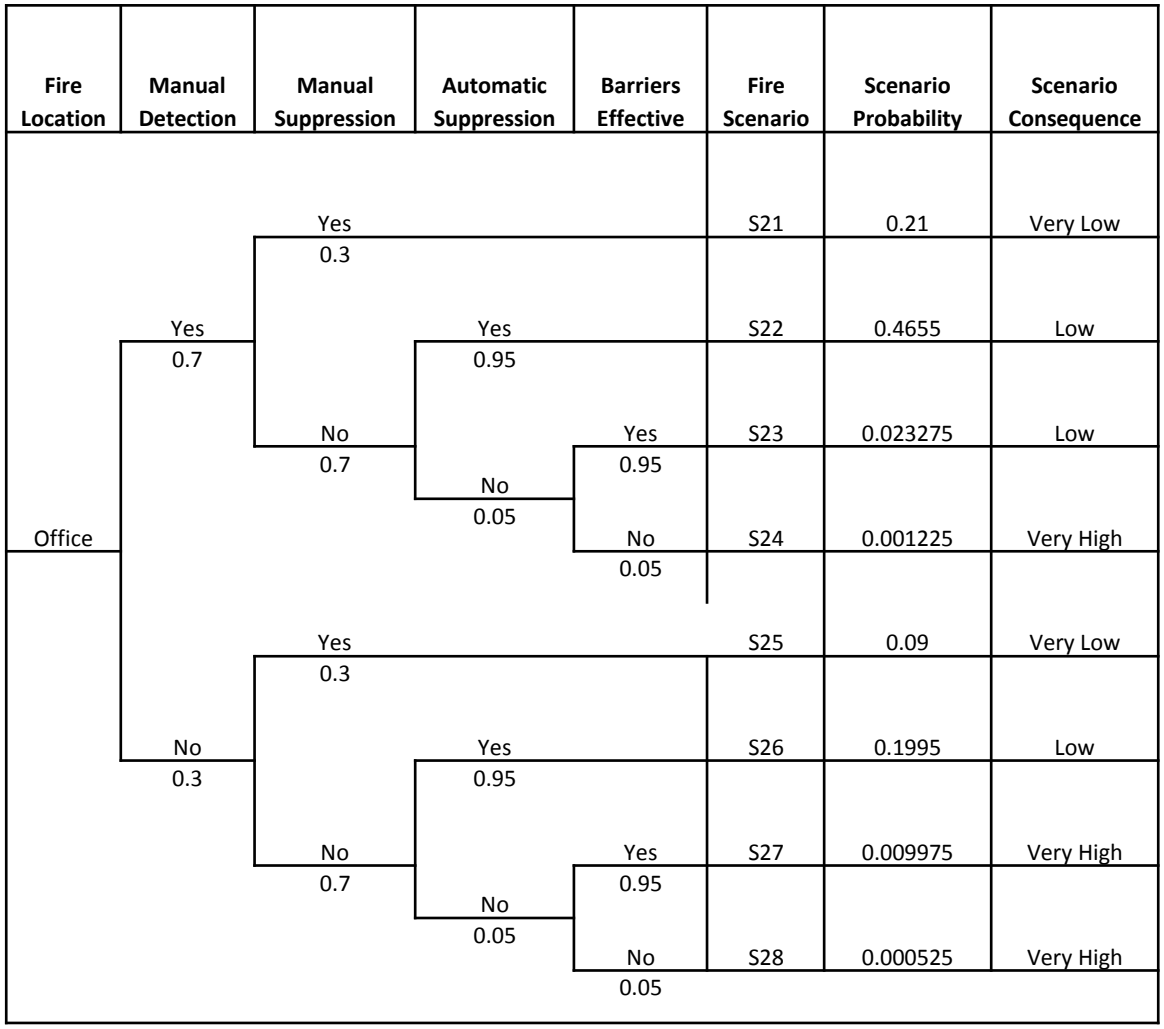
- Qualitative Analysis
- Event Trees
- Risk Ranking Matrix
- Used to determine the priority level of recommendations

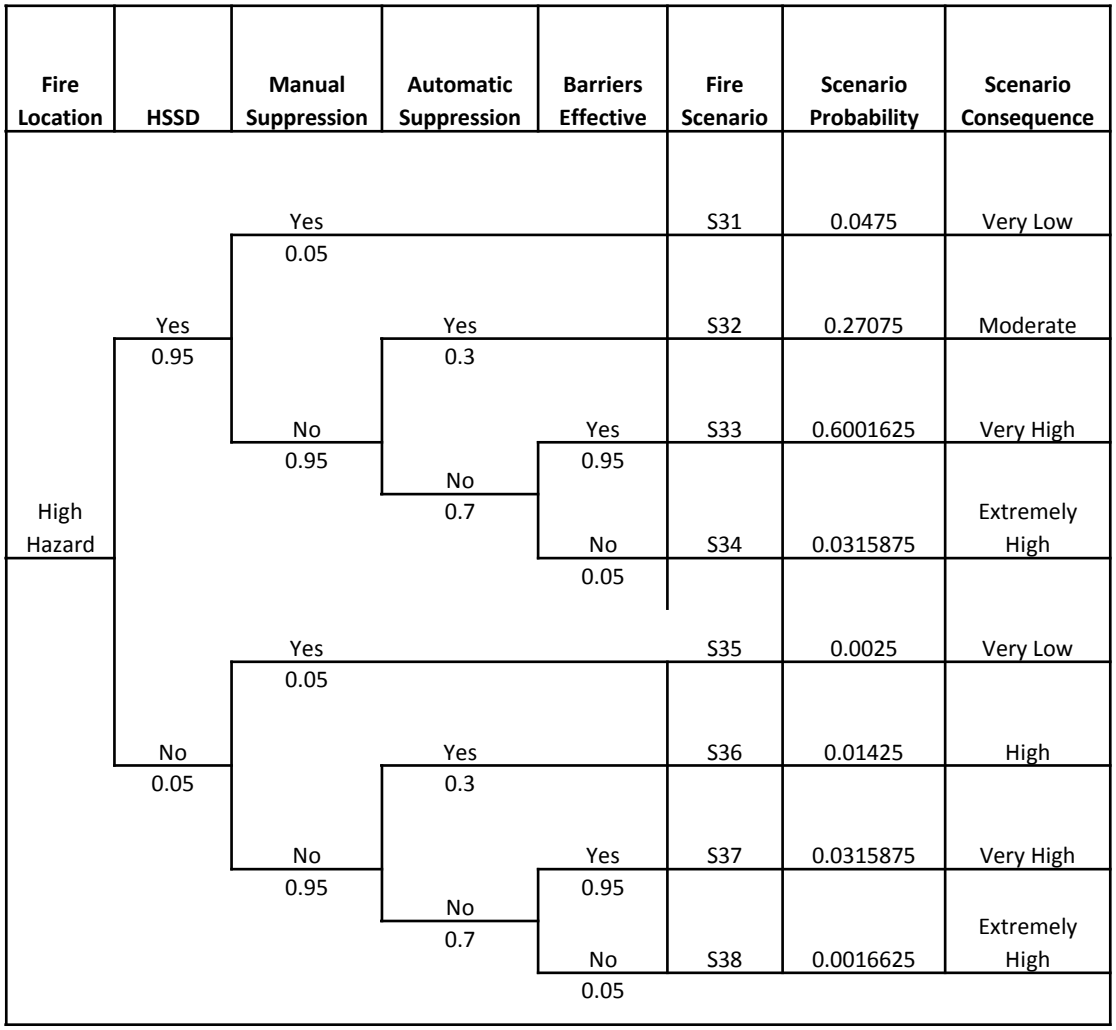
Risk Analysis – FS1 Event Tree



Risk Analysis – FS2 Event Tree



Risk Analysis – FS3 Event Tree



Risk Analysis – Risk Ranking Matrix

Sandia National Laboratories

	Probability of Scenario Occurrence					
Consequence	Extremely Low (0.000-0.019)	Very Low (0.020-0.039)	Low (0.040-0.099)	Moderate (0.100-0.299)	High (0.300-0.499)	Very High (0.500-1.000)
Extremely High	S38	S34			S14	
Very High	S24, S28, S27	S37				S33
High	S36					
Moderate				S32		
Low		S23		S12, S26	S22	
Very Low	S13, S35		S25, S31	S21	S11	

Key

High Risk	Moderate Risk	Low Risk	Negligible Risk

Recommendations

Sandia National Laboratories

	Recommendation	Reason
1	Separate the two lobby areas from the corridor.	Separating the lobby from the corridor by means of a wall will prevent the smoke from spreading to the corridors and will also provide earlier sprinkler activation.
2	Reduce the probability of a chemical spill in the high hazard area.	By working with the building owner to ensure liquid chemicals are being stored, dispensed and transported appropriately, we can reduce the chance of a spill. Spill containment may be necessary in the high hazard area.
3	Install manual pull stations at the exits of the two office blocks located in the center of the building.	The manual pull stations will allow the fire alarm to be activated long before an automatic sprinkler activates.
4	Ensure proper ITM of all fire protection and life safety features.	Proper ITM will ensure the sprinkler water supply is always on. It will also ensure space heaters are being used appropriately and combustibles are not accumulating in the building.
5	Verify the discrepancy between the designer's sprinkler calculations and the hand calculations.	By performing a more thorough sprinkler analysis with a computer program such as AutoSPRINK, we can determine if a water pump is necessary to provide enough water to meet the demand.

Acknowledgements

- My wife and son – Christiana and Noah
- Manager – Perry D' Antonio
- Sandia Building and Fire Safety Staff
- Dr. Mowrer, Dr. Pascual, and all of the Cal Poly FPE Professors
- The SNL Master's Fellowship Program advisors
- SFPE Cal Poly Chapter

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