Fire Protection Analysis

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Project Outline

Applicable Codes

- California Building Code (CBC), 2013 Edition
- California Fire Code (CFC), 2013 Edition
- NFPA 13 Automatic Sprinkler System Handbook, 2013 Edition
- NFPA 14 Standard for the Installation of Standpipe and Hose Systems, 2013 Edition
- NFPA 72 National Fire Alarm and Signaling Code, 2013 Edition
- NFPA 92 Standard for Smoke Control Systems, 2015 Edition

Building Description

- 6 stories
- Height = 108 feet
 - Non high-rise
- Total Area = 188,372 square feet
- Construction Type = Type 1B
- Separated Occupancy
- 5 Story Atrium, L2-L6
- Natural Ventilation Smoke Control System

Non High-Rise

- CBC Section 403.1
 - “When a building is located on sloping terrain and there is building access on more than one level, the enforcing agency may select the level that provides the most logical and adequate fire department access.”
- Level 1 to Upper Roof = 108 feet
- Level 2 FD Access to Level 6 = 64 feet

Occupancy Classification

Room Description	Occupancy	CBC Reference
Lecture Hall, Conference Room	A-3	303.4
Classroom, Lab, Office, Conference Room <50 occupants, Restroom, Atrium, Corridors	B	304
Mechanical , Electrical, Telecomm, Server, Fire Pump Room	S-1	311.2
Storage, Janitorial	S-2	311.3
Chemical Storage, Hazardous Waste	H-3	307.5

Egress Analysis

CBC Egress Requirements

Floor by Floor Egress Analysis

Non Compliance

Travel Distance/Dead Ends

CBC Egress Requirements

Occupant Load, CBC Table 1004.1.2	
Use	Occupant Load Factor (ft ² per person)
Accessory Storage/ Mechanical Equipment Room	300
Assembly without Fixed Seating, unconcentrated	15
Business	100
Educational, Classroom	20
Educational, Lab	50

Means of Egress Capacity		
Egress Component	Capacity (inches/person)	Reference
Stairways	0.2	CBC 1005.3.1, Exception 1
Other Egress Components	0.15	CBC 1005.3.2, Exception 1

Required Number of Exits, CBC Table 1021.1	
Occupant Load Per Story	Minimum Number of Exits from Story
1-500	2
501-1000	3

1st Floor

Area	23,146 ft ²
Occupant Load	659
Egress Capacity	2,160
Required Exits	3
Provided Exits	3

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs

2nd Floor

Area	43,458 ft ²
Occupant Load	650
Egress Capacity	3,480
Required Exits	3
Provided Exits	7

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs
- Group H-3

3rd Floor

Area	43,209 ft ²
Occupant Load	770
Egress Capacity	960
Required Exits	3
Provided Exits	4

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs

4th Floor

Area	33,307 ft ²
Occupant Load	525
Egress Capacity	720
Required Exits	3
Provided Exits	3

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs

5th Floor

Area	25,294 ft ²
Occupant Load	339
Egress Capacity	480
Required Exits	2
Provided Exits	2

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs

6th Floor

Area	19,958 ft ²
Occupant Load	289
Egress Capacity	480
Required Exits	2
Provided Exits	2

- Group B
- Group S-1, S-2
- Group A-3
- Corridors
- Shafts
- Exit Stairs

3rd Floor Student Workspace

Travel Distance/Dead Ends – L2 East Wing

Occupancy	Exit Travel Distance (CBC Table 1016.2)	Common Path of Travel (CBC Table 1014.3)	Dead Ends (CBC 1018.4, Exception 2)
A	250	75	50
S-1	250	100	
S-2	400	100	
B	300	100	
H-3	150	2

Structural Fire Protection

Allowable Height and Area

Required Occupancy Separation

Atrium Separation

Allowable Height and Area

Allowable Area						Provided Area	
Construction Type 1B	Group B	Group A-3	Group S-1	Group S-2	Group H-3	Floor	Area (square feet)
Base Area (Table 503)	UL	UL	48,000	79,000	60,000	1	23,146
Sprinkler Increase (506.3)	UL	UL	96,000	158,000	0*	2	43,458
Frontage Increase (506.2)	UL	UL	36,000	59,250	45,000	3	43,209
Allowable Area Per Story	UL	UL	180,000	296,250	105,000	4	33,307
						5	25,294
						6	19,958
						Total	188,372

Allowable Height						Provided
Construction Type 1B	Group B	Group A-3	Group S-1	Group S-2	Group H-3	
Allowable Height (Table 503)	160					108
Allowable Stories (Table 503)	11	11	11	11	6	6

Required Occupancy Separation

CBC Table 508.4				
Occupancy	A	S-2	B, S-1	H-3
A	N	N	1	2
S-2	N	N	1	2
B, S-1	1	1	N	1
H-3	2	2	1	1

CBC Table 1018.1	
Occupancy	Required Corridor Fire Resistance Rating (sprinklered)
H-3	1
A, B, S	0

- **404.6 Enclosure of Atriums.** Atrium Spaces shall be separated from adjacent spaces by a 1 hour fire barrier

- CAL POLY**
Fire Protection Engineering

Detection/Notification System

Overview

Beam Detection

Spot Smoke Detection

Sequence of Operations

Detection/Notification System – Overview

- Fire Alarm with in-building fire emergency voice alarm communication system (EVACS)
- Manual fire alarm system
- Complete automatic smoke detection not required (CBC Section 907.2.10.2 Exception 1)
- Beam detection in atrium
- Spot smoke detection at atrium horizontal exits and elevators

Atrium Beam Detection

Spot Smoke Detectors

Sequence of Operations

EVENT		ACTION															
		SUPERVISORY CONDITION AT FACU	TRUBLE CONDITION AT FACU	ALARM CONDITION AT FACU	ACTIVATE FIRE ALARM AUDIOVISUAL DEVICES AND VOICE ALARM COMMUNICATION	DISPLAY TEXT ON LCD ANNUNCIATOR	ACTIVATE SHUNT TRIP RELAY	SHUTDOWN AIR HANDLER UNIT	DEACTIVATE MAGNETIC DOOR HOLDERS	ACTIVATE SUPERVISORY SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	ACTIVATE TROUBLE SIGNAL TO RECEIVING STATION (CAMPUS POLICE)	BYPASS ALL ALARM OUTPUTS (NOTIFICATION, SHUNTS, RELAY OUTPUTS) FOR TESTING	OPEN ATRIUM DOORS WITH MOTORIZED DOOR OPERATORS	ACTIVATE ATRIUM PASSIVE SMOKE EVACUATION SYSTEM			
FIRE ALARM CONTROL UNIT																	
	PANEL SUPERVISORY CONDITION (TEST BYPASS) ON ACM-24 AT	X				X				X		X					
	PANEL TROUBLE CONDITION (AC POWER FAIL, LOW BATTERY, OPEN CIRCUIT, GROUND FAULT, ETC.)		X							X							
	PANEL ALARM CONDITION			X	X	X			X		X						
	MANUAL PULL STATION ACTIVATION			X	X	X			X		X						
	SPOT SMOKE DETECTOR ACTIVATION			X	X	X			X		X						
	DUCT SMOKE DETECTOR ACTIVATION			X	X	X		X	X		X						
	AIR HANDLING UNIT DUCT SMOKE DETECTOR ACTIVATION			X	X	X	X				X						
	SPRINKLER TAMPER SWITCH	X				X				X	X						
	SPRINKLER WATER FLOW ACTIVATION			X	X	X			X		X						
	FIRE PUMP RUNNING			X	X	X			X		X						
	FIRE PUMP LOSS OF PH ASE	X				X				X							
	FIRE PUMP PHASE REVERSAL	X				X				X	X						
	HEAT DETECTOR ACTIVATION (ELEVATOR EQUIPMENT)			X	X	X	X			X		X					
	ELEVATOR LOBBY/ EMR SMOKE / ELEVATOR HOISTWAYS			X	X	X		X		X		X					
	SHUNT TRIP POWER SUPERVISION	X				X				X							
	GENERAL ALARM (ANYWHERE WITHIN THE BUILDING)			X	X	X	X			X		X					
	ATRIUM SMOKE CONTORL SYSTEM ALARM			X	X	X			X		X		X	X			
	BEAM SMOKE DETECTION WITHIN ATRIUM			X	X	X			X		X		X	X			
	PULL STATION WITHIN ATRIUM			X	X	X			X		X		X	X			
	SPRINKLER WATER FLOW WITHIN ATRIUM			X	X	X			X		X		X	X			

Fire Suppression System

Overview

Hazard Classification

Design Criteria

Fire Pump

Hydraulic Calculations

Fire Suppression System – Overview

- Fully Sprinklered, Wet pipe sprinkler system
- Light Hazard and Ordinary Hazard Group 1
- Quick Response Sprinklers
- Fire Pump
- Class I Standpipe System

Suppression – Hazard Classification

Area Description	Hazard Classification	NFPA 13 Reference
Classrooms, auditoriums, corridors, offices, conference rooms	Light Hazard	5.2
Laboratories, storage, mechanical, electrical	Ordinary Hazard Group 1	5.3.1

Suppression – Design Criteria

Hazard	Max Area (ft ²)	Density (GPM/ft ²)	Operation Area (ft ²)	Combined HSA (GPM)	Duration (min)
Light	225	0.1	1500 (911.25)	100	30
OH Group 1	130	0.15	1500 (911.25)	250	60-90

Suppression – QR Area Reduction

Note: $y = \frac{-3x}{2} + 55$

NFPA 13 11.2.3.2.3.1

Ceiling Height = 10.5 feet

Area Reduction = 39.25%

Design Area = $(100\% - 39.25\%)(1500 \text{ ft}^2) = 911.25 \text{ ft}^2$

Suppression – Fire Pump

	Pressure (psi)	Flow (GPM)
Churn	125	0
Design	113	750
150%	86	1125

Suppression – Remote Area Level 6

CALCULATION DESIGN INFORMATION	
AREA:	"6-3" 5'-3"
OCCUPANCY:	LAB
HAZARD:	ORDINARY HAZARD GR. 1
DENSITY:	0.15 GPM / SQ.FT.
AREA OF OPERATION:	920 SQ.FT.
AREA PER HEAD:	130 SQ.FT. (MAX.)
HOSE STREAM ALLOWANCE:	
INSIDE:	100
OUTSIDE:	150
SYSTEM DEMAND	
PSI REQ. AT BASE OF RISER:	108.4
GPM REQ. AT BASE OF RISER:	273.4
PSI REQ. AT SOURCE:	26.71
GPM REQ. AT SOURCE:	523.4
PSI AVAILABLE AT SOURCE:	52.11
TOTAL PSI SAFETY FACTOR:	25.4

Suppression – Hydraulic Calculations

City Water Supply:
 C1 - Static Pressure : 54
 C2 - Residual Pressure: 49
 C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet
 for Pf - Elev - Hose Flow

A1 - Adjusted Static: 51.696
 A2 - Adj Resid : 47.866 @ 790.2
 A3 - Adj Resid : 37.967 @ 1382.9

Pump Data:

P1 - Pump Churn Pressure : 125.2
 P2 - Pump Rated Pressure : 110.9
 P2 - Pump Rated Flow : 790.2
 P3 - Pump Pressure @ Max Flow : 67.9
 P3 - Pump Max Flow : 1382.9
 City Residual Flow @ 0 = 3307.91
 City Residual Flow @ 20 = 2576.03
 City Water @ 150% of Pump = 43.24

Demand:

D1 - Elevation : 33.565
 D2 - System Flow : 273.395
 D2 - System Pressure : 149.546
 Hose (Adj City) : 150
 Hose (Demand) : 100
 D3 - System Demand : 373.395
 Safety Margin : 25.499

	Hand Calculation	Computer Based
PSI required at BOR	98.4	108.4
GPM required at BOR	273.6	273.4
PSI required at Source	21.2	26.7
GPM required at Source	523.6	523.4
PSI available at Source	52.1	52.1
PSI Safety Factor	30.9	25.4

Performance Based Analysis

ASET/RSET

RSET – Pathfinder Model

Tenability Criteria

ASET – Pyrosim Model

Design Fire #1 – Balcony Spill Plume

Design Fire #2 – Axisymmetric Plume

Recommendations

Performance Based Analysis - Models

RSET – Pathfinder

ASET – Pyrosim/FDS

ASET vs. RSET

$$RSET = t_{\text{detection}} + t_{\text{pre-movement}} + t_{\text{movement}}$$

$t_{\text{detection}}$ = Time from ignition to detection and notification

$t_{\text{pre-movement}}$ = Time from notification to start of egress

t_{movement} = Time to completely evacuate

RSET – Pathfinder Model – Exits

Egress Component	Width (inches)
Level 2	
North/South Exterior Exit	144" each
East/West Horizontal Exits	96" each
Level 3-4	
East/West Horizontal Exits	96" each
Stair	36" Door 48" Stair
Level 5-6	
East Horizontal Exit	96"
Stair	36" Door 48" Stair

RSET – Pathfinder Model – Occupant Load

Floor	Occupants
6	91
5	91
4	88
3	170
2	155
TOTAL	595

RSET – Pathfinder Model –Travel Time Results

Floor	Exit Time
6	44 seconds
5	37 seconds
4	37 seconds
3	95 seconds
2	53 seconds

Pathfinder egress simulation at 54 seconds

Tenability Criteria

Tenability Criteria	Limit	Reference
Visibility	10 meters	SFPE Handbook Table 2-6.11 (Large enclosures and travel distances)
Carbon Monoxide	1,667 ppm	NFPA Handbook Section 6 – Chapter 2
Temperature	60 °C	SFPE Handbook Section 2 - Chapter 6

- Measured at 6 feet above walking surface on each level

FDS Model Overview

- Level 2 Makeup Air Vents (2) = 133.5 ft²
- Exhaust Vents (4) = 50 ft²
- Devices
 - Spot Smoke Detectors
 - Beam Detectors
 - Sprinklers
- Slice Files
 - Visibility
 - CO Concentration
 - Temperature
- 6 computational meshes
 - 0.2m x 0.2m x 0.2m cells
 - 3,385,600 cells

Design Fire #1 – Balcony Spill Plume

- NFPA 92 3.3.9.2 A smoke plume that originates from a compartment fire, flows out the doorway, flows under a balcony, and flows upward after passing the balcony edge.

DF #1 – Balcony Spill Plume – HRR

FIGURE B.7.2(b) Rates of Energy Release in a *t*-Squared Fire. (Source: Nelson [60])

Reaction Inputs (SFPE Handbook Table 3-4.16)		
Property	Value	Units
Heat of Combustion	25,000	kJ/kg
Soot Yield	0.05	kg/kg
CO Yield	0.04	kg/kg

Figure 16. Effect of specimen mass on rate of heat release

DF #1 – HRR – Sprinkler Activation

- Activation Time = 127 seconds
- HRR = 750 kW

DF #1 – Balcony Spill Plume –HRR

DF #1 – Balcony Spill Plume – Temperature

DF #1 – Balcony Spill Plume – CO

DF #1 – Balcony Spill Plume – Visibility

DF #1 – Balcony Spill Plume – ASET Summary

Floor	Temperature	Carbon Monoxide	Visibility
Level 2	Tenability maintained for 300 seconds	Tenability maintained for 300 seconds	270 s
Level 3			200 s
Level 4			250 s
Level 5			> 300 s
Level 6			> 300 s

DF#1 – Balcony Spill Plume – ASET vs. RSET

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	31*	36**	53	120	180	270	YES
3			95	162	243	200	NO
4			37	104	156	250	YES
5			37	104	156	> 300	YES
6			44	111	167	> 300	YES

*L2 Elevator spot smoke detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

Design Fire #2 – Axisymmetric Plume

- NFPA 92 3.3.9.1 A plume that rises above a fire, does not come into contact with walls or other obstacles, and is not disrupted or deflected by airflow

DF #2 – Axisymmetric Plume – HRR

Design Fire #2 – Temperature

Design Fire #2 – Carbon Monoxide

Design Fire #2 – Visibility

DF #2 – Axisymmetric Plume – ASET Summary

	Temperature	Carbon Monoxide	Visibility
Level 2	Tenability maintained for 300 seconds	Tenability maintained for 300 seconds	> 300 s
Level 3			> 300 s
Level 4			190 s
Level 5			190 s
Level 6			174 s

DF#2 – Axisymmetric Plume – ASET vs. RSET

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	44*	36**	53	133	200	> 300	YES
3			95	175	263	> 300	YES
4			37	117	176	190	YES
5			37	117	176	190	YES
6			44	124	186	174	NO

*L3 Beam detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

Performance Based Analysis Summary

- Design Fire #1
 - L3 Fail
 - Long RSET due to queuing at L3 student workspace
 - 2 exits required, 1 provided
- Design Fire #2
 - L6 Fail
 - Not enough ventilation in current smoke control system

Recommendations – L3 Student Workspace

Problem:

- 2 exits required, 1 provided
- $ASET < RSET$ (Design Fire #1)

Solution #1:

- Change use of space

Solution #2:

- 72" exit reduces $1.5 \times RSET$ to 177s ($< ASET = 200s$)
 - Not possible to add second exit and meet 1/3 diagonal spacing

Recommendations – New Design

New Design – Increased Ventilation

- Increase vent area from 100 square feet to 250 square feet
- Increase makeup air vent area from 133.5 square feet to 341 square feet

New Design– DF #2 – ASET vs. RSET

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	44*	36**	53	133	200	> 300	YES
3			95	175	263	> 300	YES
4			37	117	176	264	YES
5			37	117	176	265	YES
6			44	124	186	225	YES

*L3 Beam detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

Conclusion

- Structural Fire Protection, Fire Alarm, Fire Suppression System all code compliant
- Egress
 - Dead end corridor
 - L3 Student Workspace Exits
- Smoke Control System
 - Recommend increased ventilation to provide $A_{SET} > R_{SET}$

Fire Department Access

Construction Member Rating

CBC Table 601	
Building Element	Type 1B
Primary Structural Frame	2
Exterior Bearing Walls	2
Interior Bearing Walls	2
Exterior Nonbearing Walls	0 (Table 602)
Interior NonBearing Walls	0
Floor Construction	2
Roof Construction	1

CBC Table 602	
Fire Separation Distance (feet)	Type 1B
$X < 5$	1
$5 < X < 10$	1
$10 < X < 30$	1
$X > 30$	0

Control Areas (CBC Table 414.2.2)

Floor Level		% of Max Allowable Quantity per Control Area (CBC Table 307.1(1) and 307.1(2))	Number of Control Areas Per Floor	Fire-Resistance Ratings for Fire Barriers in Hours
Above Grade Plane	6	12.5	2	2

- ■ ■ ■ ■ ATRIUM SEPARATION/CONTROL AREA
 SEPARATION 1 HR. FIRE RATED WALL
 ASSEMBLY, CBC
 404.5 EXCEPTION 3
- ■ ■ ■ ■ ■ ■ ■ ■ ■ 1 HR. FIRE RATED SEPARATION
- ■ ■ ■ ■ ■ ■ ■ ■ ■ EXIT ENCLOSURE & SHAFT ENCLOSURES
 2 HR. FIRE RATED WALL ASSEMBLY,
 CBC
 707.4 AND 1020.1
- ■ ■ ■ ■ ■ ■ ■ ■ ■ CONTROL AREA SEPARATION
 2 HR. FIRE RATED WALL ASSEMBLY,
 CBC
 414.2.4

Suppression – Standpipe

Suppression – Standpipe

City Water Supply:

C1 - Static Pressure : 54
C2 - Residual Pressure: 49
C2 - Residual Flow : 914

City Water Adjusted to Pump Inlet for Pf - Elev - Hose Flow

A1 - Adjusted Static: 51.872
A2 - Adj Resid : 49.314 @ 790.2
A3 - Adj Resid : 40.224 @ 1382.9

Pump Data:

P1 - Pump Churn Pressure : 125.2
P2 - Pump Rated Pressure : 110.9
P2 - Pump Rated Flow : 790.2
P3 - Pump Pressure @ Max Flow : 67.9
P3 - Pump Max Flow : 1382.9
City Residual Flow @ 0 = 3307.91
City Residual Flow @ 20 = 2576.03
City Water @ 150% of Pump = 43.24

Demand:

D1 - Elevation : 24.254
D2 - System Flow :
D2 - System Pressure : 144.081
Hose (Adj City) :
Hose (Demand) : 1000
D3 - System Demand : 1000
Safety Margin : 0.911

CALCULATION DESIGN INFORMATION

STANDPIPE NO.: S/P # 1
OCCUPANCY: LIGHT / ORD. HAZ. DR. 1
FLOW @ TOP MOST OUTLET: 500 GPM
PRESS. @ TOP MOST OUTLET: 100 PSI
FLOW FOR ADDITIONAL S/P: 500 GPM
TOTAL STANDPIPE FLOW: 1000 GPM

HOSE STREAM ALLOWANCE:

INSIDE: N/A OUTSIDE: N/A

SYSTEM DEMAND

PSI REQ. AT PUMP DISCHARGE: 144.08
GPM REQ. AT PUMP DISCHARGE: 1000
PSI REQ. AT SOURCE: 47.18
GPM REQ. AT SOURCE: 1000
PSI AVAILABLE AT SOURCE: 48.09
TOTAL PSI SAFETY FACTOR: 0.91

		NFPA 14 Reference
Pressure at most remote outlet	100 psi	7.8.1
Flow at most remote outlet	500 gpm	7.10.1.1.1
Flow for each additional standpipe	250 gpm	7.10.1.1.3
Maximum Flow	1000 gpm	7.10.1.1.5
Duration	30 minutes	9.2

Design Fire #1 - Mesh Resolution

$$D^* = \left(\frac{\dot{Q}}{\rho_{\infty} c_p T_{\infty} \sqrt{g}} \right)^{2/5}$$

$$\dot{Q} = 750 \text{ kW}$$

$$\partial x = 0.2 \text{ m}$$

$$\frac{D^*}{\partial x} = 4.27$$

NUREG 1824 – Recommends between 4 and 16

Design Fire #2 - Mesh Resolution

$$D^* = \left(\frac{\dot{Q}}{\rho_{\infty} c_p T_{\infty} \sqrt{g}} \right)^{2/5}$$

$$\dot{Q} = 3000 \text{ kW}$$

$$\partial x = 0.2 \text{ m}$$

$$\frac{D^*}{\partial x} = 7.44$$

NUREG 1824 – Recommends between 4 and 16

Mesh Sensitivity Analysis

Mesh Configuration	Description	Number of Cells
1	All cells 0.4m	423,200
2	Bottom three meshes 0.2m, top three meshes 0.4m	1,200,200
3	All cells 0.2m	3,385,600

- Existing smoke control system
- Design Fire #2 Axisymmetric Plume

Stack Effect

$T_{\text{ext}} < T_{\text{int}}$

$T_{\text{ext}} > T_{\text{int}}$

New Design – Stack Effect

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	54*	36**	53	143	215	> 300	YES
3			95	185	278	> 300	YES
4			37	127	191	> 300	YES
5			37	127	191	256	YES
6			44	134	201	209	YES

*L3 Beam detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

- Increased ventilation design, Design Fire #2 Axisymmetric Plume
- Ambient Temperature = 12°F

New Design – Reverse Stack Effect

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	39*	36**	53	128	192	> 300	YES
3			95	170	255	> 300	YES
4			37	112	168	> 300	YES
5			37	112	168	282	YES
6			44	119	179	168	NO

*L3 Beam detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

- Increased ventilation design, Design Fire #2 Axisymmetric Plume
- Ambient Temperature = 112°F

Soot Yield Sensitivity Analysis

- Increased ventilation design
- Design Fire #2 Axisymmetric Plume

Soot Yield	% of Simulation Value
0.025	50
0.05	100
0.075	150
0.1	200

Floor	50%	100%	150%	200%
2	> 300 s	> 300 s	> 300 s	> 300 s
3	> 300 s	> 300 s	> 300 s	> 300 s
4	> 300 s	264 s	202 s	168 s
5	> 300 s	265 s	204 s	175 s
6	> 300 s	225 s	168 s	163 s

Floor	Detection Time	Pre-movement Time	Travel Time	Total RSET	RSET x 1.5	ASET	ASET>RSET?
2	28*	36**	53	117	176	> 300	YES
3			95	159	139	> 300	YES
4			37	101	152	168	YES
5			37	101	152	175	YES
6			44	108	162	163	YES

*L3 Beam detector

**NFPA Fire Protection Handbook Table 4.2.1 (Mid-rise office building)

CO Yield Sensitivity Analysis

CO Yield	% of Simulation Value
0.04	100
0.08	200
0.12	300

- Time = 300 seconds
- Increased ventilation design, Design Fire #2 Axisymmetric plume
- CO Yield = 0.12

Makeup Air Velocity – DF #2 – Existing Design

Time = 300 seconds

Makeup Air Velocity – DF #2 – New Design

Time = 300 seconds