Fire and Life Safety Evaluation

197 Bonderson Engineering Project Center

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Contents

- Applicable Codes
- Building Location and Description
- Structural Fire Protection
- Egress Analysis
- Fire Suppression System
- Fire Detection and Alarm
- Performance Based Analysis

Applicable Codes

- California Building Code (CBC), 2013 Edition
- California Fire Code (CFC), 2013 Edition
- NFPA 13 Standard for the Installation of Sprinkler Systems, 2013 Edition
- NFPA 72 National Fire Alarm and Signaling Code, 2013 Edition
- SFPE Handbook of Fire Protection Engineering, Fourth Edition

Building Location

Building Description

- Building Area: 1st Floor- 12,240 ft²
2nd Floor- 6,335 ft²
Total- 18,575 ft²
- Two-Story Building
- Concrete Slab and Steel Frame Construction
- Construction Type: II-B
- Fully Sprinklered
- Equipped with Fire Detection and Alarm Notification Devices
- Type B Occupancy
- Atrium at Entry

Structural Requirements

CBC Table 601

Building Element	Fire-Resistance Rating Requirement (Hours)
Primary Structural frame	0
Bearing walls (exterior)	0
Bearing walls (interior)	0
Nonbearing walls and partitions (interior)	0
Floor construction and associated secondary members	0
Roof construction and associated secondary members	0

CBC Table 602

Fire Separation Distance - X (feet)	Fire-Resistance Rating Requirement for Exterior Walls (Hours)	
	Group F-1	Group A, B, S-2
$X < 5$	2	1
$5 \leq X < 10$	1	1
$10 \leq X < 30$	0	0
$X \geq 30$	0	0

Interior Finishes

CBC Table 803.9

Group	Interior exit stairways, interior exit ramps and exit passageways	Corridors and enclosure for exit access stairways and exit access ramps	Room and enclosed spaces
A-3	B	B	C
B	B	C	C
F	C	C	C
S	C	C	C

Class A: = Flame spread index 0-25; smoke-developed index 0-450.

Class B: = Flame spread index 26-75; smoke-developed index 0-450.

Class C: = Flame spread index 76-200; smoke-developed index 0-450.

- Interior finish of walls and ceilings of atrium must not be less than Class B

Occupancy Classification

CBC Table 1021.1

Occupant Load per Story	Minimum Number of Exits
1-500	2

CBC Section 1005

Component	Egress Capacity Factor (inch per person)
Stairways	0.3
Other egress components	0.2

CBC Table 1004.1.2

Classification	Occupant Load Factor (ft ² per occupant)
Assembly without fixed seats (Unconcentrated)	15
Classroom Area	20
Shop and other vocational rooms	50
Offices	100
Accessory storage areas, mechanical equipment room	300

1st Floor

Classification	Color
Classroom Area	Yellow
Shop and other vocational rooms	Red
Offices	Green
Assembly	Purple
Accessory storage areas, mechanical equipment room	Blue

Area	12,240 ft ²
Occupant Load	240
Egress Capacity	1,620
Required Number of Exits	2
Number of Exits	6

- Changing Project Integration from a Vocational Room to Assembly would add 98 occupants, but would still comply with code

Project Integration Room

Door Swing

2nd Floor

Classification	Color
Classroom Area	Yellow
Shop and other vocational rooms	Red
Offices	Green
Assembly	Purple
Accessory storage areas, mechanical equipment room	Blue

Area	6,335 ft ²
Occupant Load	171
Egress Capacity	320
Required Number of Exits	2
Number of Exits	2

Exit Locations

Exit Locations

Interior Stairway

- Exception to required enclosed exit access stairways between stories (CBC 1009.3 Exception 5).
- Portion of exit access travel distance must be less than 200 feet (CBC 404.9)

Egress Requirements

Table 1016.2

Occupancy	Exit Access Travel Distance (feet)
A, F-1	250
B	300
S-2	400

Table 1014.3

Occupancy	Common Path of Egress Travel (feet)
B	100
A, F, S	75

- Building complies with exit access travel distance and common path of egress travel.
- No dead ends in corridors more than 20 feet in length.

Required Occupancy Separation

CBC Table 508.4			
Occupancy	A	S-2	B, F-1
A	0	0	1
S-2		0	1
B, F-1			0

CBC Table 1018.1	
Occupancy	Required Fire-Resistance Rating
A, B, S, F	0

- Does not comply with separated occupancies.
- No fire-resistance rated corridor required per Table 1018.1.
- 1 Hour Fire Barrier must separate atrium spaces from adjacent spaces (CBC 404.6)
- A fire barrier is not required between the atrium and the adjoining spaces provided that such spaces are accounted for in the design of the smoke control system (CBC 404.6 Exception 3).

1st Floor Separation

2nd Floor Separation

Allowable Height and Area

Group		Type of Construction								
		Type I		Type II		Type III		Type IV	Type V	
		A	B	A	B	A	B	HT	A	B
	Height (feet)	UL	160	65	55	65	55	65	50	40
	Stories (S) Area (A)									
Group A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
Group B	S	UL	11	5	3	5	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
Group F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
Group S-2	S	UL	11	5	3	4	3	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500

Building Height: 2 Stories

1st Floor Area: 12,240 ft²

Frontage Area Increase

$$I_f = [F/P - 0.25]W/30 \quad (\text{Equation 5-2})$$

where:

I_f = Area increase due to frontage.

F = Building perimeter that fronts on a public way or open space having 20 feet (6096 mm) open minimum width (feet).

P = Perimeter of entire building (feet).

W = Width of public way or open space (feet) in accordance with Section 506.2.1.

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

$$I_f = [1.0 - 0.25] \frac{30}{30}$$

$$I_f = 75\% \text{ Increase}$$

Area Increases

Original Allowable Area Per Story	9,500 ft ²
Frontage Increase	7,125 ft ²
Automatic Sprinkler Increase	19,000 ft ²
Allowable Area Per Story	35,625 ft ²

$$A_a = \{A_t + [A_t \times I_f] + [A_t \times I_s]\} \quad (\text{Equation 5-1})$$

where:

A_a = Allowable building area per story (square feet).

A_t = Tabular building area per story in accordance with Table 503 (square feet).

I_f = Area increase factor due to frontage as calculated in accordance with Section 506.2.

I_s = Area increase factor due to sprinkler protection as calculated in accordance with Section 506.3.

- 1st Floor Area: 12,240 ft²
- Allowable building height and story increase due to automatic sprinkler system installation is not needed.

Fire Suppression System

- Fully Sprinklered
- Wet-Pipe System
- Quick Response Sprinklers (K-Factor 5.6, 200°F Activation Temperature)
- 270 Total Sprinklers
- Light Hazard (Public Areas, Offices, Classrooms)
- Ordinary Hazard 1 (Storage, Equipment, Maintenance, Vocational Rooms, School Shop)
- No Fire Pump

Fire Suppression Design

Classification	Density (gpm/ft ²)	Original Area of Sprinkler Operation (ft ²)	*Reduced Area of Sprinkler Operation (ft ²)	Hose Stream Allowance (gpm)	Duration (minutes)
Light Hazard	0.1	1500	990	100	30
Ordinard Hazard I	0.15	1500	990	250	60

*Area of Sprinkler Operation permitted to be reduced without revising density per NFPA 13 11.2.3.2.3.1

Reduction Calculation

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

Ceiling Height = 14'1"

$$Y = \frac{-3(14'1")}{2} + 55$$

$$Y = 33.875$$

$$\text{New Area} = 1500 \text{ ft}^2 \times (100\% - 33.875\%)$$

$$\text{New Area} = 992 \text{ ft}^2$$

Remote Area

Hand Calculations

Step No.	Nozzle Ident and Location		Flow in gpm		Pipe size	Pipe Fittings and Devices	Equivalent Pipe Length		Friction loss (psi/ft)		Pressure Summary		Normal Pressure		Notes	
1	1	BL-1	q				L	10	C=	120	Pt	7.0	Pt		k=	5.6
							F				Pe		Pv		Q=	123.75 x 0.10
			Q	12.4	1.049		T	10	pf	0.054	Pf	0.5	Pn		Pt=	(12.4/5.6)^2
2	2		q	15.4			L	9.167	C=	120	Pt	7.5	Pt		k=	5.6
							F				Pe		Pv			
			Q	27.8	1.049		T	9.167	pf	0.239	Pf	2.2	Pn			
3	3		q	17.5			L	13.583	C=	120	Pt	9.7	Pt		k=	5.6
						2-90 Elbow	F	8			Pe		Pv			
			Q	45.2	1.61		T	21.583	pf	0.073	Pf	1.6	Pn			
4	4	DN RN	q	18.8			L	27.833	C=	120	Pt	11.3	Pt		k=	5.6
						2-Tees	F	16			Pe	0.4	Pv			
			Q	64.1	1.61		T	43.833	pf	0.139	Pf	6.1	Pn			
5		CM To BL-2	q	0.0			L	12.375	C=	120	Pt	17.8	Pt		k=	5.6
							F				Pe		Pv			
			Q	64.1	2.635		T	12.375	pf	0.013	Pf	0.2	Pn			
6		BL-2 CM	q	64.0		3-Tees	L	125.142	C=	120	Pt	18.0	Pt		k=	15.1
						3-90 Elbow	F	54			Pe	5.2	Pv		Pe=	12 x 0.433
			Q	128.1	2.635		T	179.142	pf	0.046	Pf	8.2	Pn			
7		CM to TOR	q	0.0			L	58	C=	120	Pt	31.3	Pt		k=	15.1
						3-90 Elbow	F	21			Pe		Pv			
			Q	128.1	3.26		T	79	pf	0.016	Pf	1.3	Pn			
8		TOR to BOR	q				L	12	C=	120	Pt	32.6	Pt			
							F				Pe	5.2	Pv		Pe=	12 x 0.433
			Q	128.1	4.26		T		pf	0.004	Pf	0.0	Pn			
			q	0.0			L		C=		Pt	37.8	Pt			

Flow Test Summary Sheet

CONTRACT NAME: Bonderson Engineering Projects Center NO:

Water Supply

Static Pressure	80 psi
Residual Pressure	60 psi
Flow	1210 gpm

*Performed 09/03/02

System Demand

Discharge Rate	Pressure
128.1 gpm	37.8 psi

Fire Detection and Alarm

- Automatic and Manual Fire Alarm System
- Elevator Recall/Shunt
- Duct Detector Monitoring
- ADA Compliant Notification
- Fire Alarm Control Panel (FACP) located on first floor
- FACP is Notifier model NFS-640 (pictured)
- No Mass Notification System

Detection Devices

FAPT-851(A) in B210LP(A) Base

FAPT-851 with B210.png

FSH-751

6346cov.jpg

NOTIFIER FSD-751P

FST-851(A) in B210LP(A) Base

B210-2251.jpg

1st Floor

COLOR	DESCRIPTION
Red	ACCLIMATE SMOKE DETECTOR
Yellow	HARSH SMOKE DETECTOR
Green	DUCT SMOKE DETECTOR
Blue	HEAT DETECTOR

2nd Floor

COLOR	DESCRIPTION
Red	ACCLIMATE SMOKE DETECTOR
Yellow	HARSH SMOKE DETECTOR
Green	DUCT SMOKE DETECTOR
Blue	HEAT DETECTOR

Performance Based Design

- Two Fire Scenarios:
 1. Corridor Fire
 2. Project Integration Room
- Used Fire Dynamics Simulator to evaluate tenability requirements (ASET)
- Used Pathfinder to determine RSET

ASET vs RSET

Figure 3-12.1. Egress time model.

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

t_d = Time from fire ignition to detection

t_n = Time from detection to notification of occupants of a fire emergency

t_{p-e} = Time from notification until evacuation commences

t_e = Time from the start of evacuation until it is completed

s_f = Safety factor

RSET

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

t_d = 9.6 seconds

t_n = 10 seconds

t_{p-e} = Time from notification until
evacuation commences

t_e = Time from the start of evacuation
until it is completed

s_f = Safety factor

Frame: 8

Time: 9.6

>65 (kW/m3)

mesh: 1

RSET

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

t_d = 9.6 seconds

t_n = 10 seconds

t_{p-e} = 0 seconds

t_e = Time from the start of evacuation
until it is completed

s_f = Safety factor

Table 3-12.3 *Design Behavioral Scenarios and Occupancy Types⁴*

Category	Occupant Alertness	Occupant Familiarity	Occupant Density	Enclosure/Complexity	Examples of Occupancy Types
A	Awake	Familiar	Low	One or many	Office or industrial
B1	Awake	Unfamiliar	High	One or few	Shop, restaurant, circulation space
B2	Awake	Unfamiliar	High	One with focal point	Cinema, theatre
Ci	Asleep	Familiar	Low	Few	Dwelling
	Long term, individual occupancy				Without 24 hr on-site management
	Managed occupancy				Serviced flats, halls of residence, etc.
Ciii	Asleep	Unfamiliar	Low	Many	Hotel, hostel
D	Medical care	Unfamiliar	Low	Many	Residential (institutional)
E	Transportation	Unfamiliar	High	Many	Railway station/airport

RSET-Pathfinder

First Floor

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

t_d = 9.6 seconds

t_n = 10 seconds

t_{p-e} = 0 seconds

t_e = 76.4 seconds

s_f = Safety factor

RSET-Pathfinder

Second Floor

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

t_d = 9.6 seconds

t_n = 10 seconds

t_{p-e} = 0 seconds

t_e = 94.3 seconds

s_f = Safety factor

Detection Time

$$RSET = t_d + t_n + t_{p-e}(s_f) + t_e(s_f)$$

RSET = Total Evacuation Time

$t_d = 9.6$ seconds

$t_n = 10$ seconds

$t_{p-e} = 0$ seconds

$t_e = 76.4$ and 94.3 seconds

$s_f = 1.5$

Total RSET First Floor = 135 Seconds

Total RSET Second Floor = 161 Seconds

RSET is rounded to 3 minutes for tenability equations

ASET-Visibility

- Measured at 6 feet above walking surface on each level
- Case could be made to reduce to 4 meters for occupants familiar with their escape route for small enclosures
- 30% of people turn back rather than enter a room at 4 meters

Tenability Criteria	Metric Units	Imperial Units
Visibility	10 meters	33 feet
Temperature	133°C	272°F
Toxicity (CO)	8,000 ppm	8,000 ppm

ASET-Temperature

$$t = (5 \times 10^7)(T^{-3.4})$$

Where: **t** = time to incapacitation (min)

T = temperature (°C)

Rearranging:

$$T = \sqrt[3.4]{5 \times 10^7 / 3}$$

$$T = 133^{\circ}\text{C}$$

Tenability Criteria	Metric Units	Imperial Units
Visibility	10 meters	33 feet
Temperature	133°C	272°F
Toxicity (CO)	8,000 ppm	8,000 ppm

ASET-Toxicity (CO)

$$\%COHb = (3.317 \times 10^{-5}) \times (\text{ppm CO})^{1.036} \times (\text{RMV}) \times (t)$$

Where: %COHb = Percentage of COHb in the blood

ppm CO = CO concentration in the air

RMV = 25 L/min for a person doing light work (such as walking)

t = exposure time (min) = 3 minutes

Rearranging:

$$\text{ppm CO} = [\%COHb / \{(3.317 \times 10^{-5}) \times (\text{RMV}) \times (t)\}]^{0.965}$$

$$\text{ppm CO} = [30 / \{(3.317 \times 10^{-5}) \times (25) \times (3)\}]^{0.965}$$

CO Concentration Criterion for a 3 Minute Exposure
= 8,680 ppm

Activity Level of Subject	V (L/min)	D (percent COHb)
Resting or sleeping	8.5	40
Light work- walking to escape	25	30
Heavy work- slow running, walking up stairs	50	20

ASET-Toxicity (CO)

Tenability Criteria	Metric Units	Imperial Units
Visibility	10 meters	33 feet
Temperature	133°C	272°F
Toxicity (CO)	8,000 ppm	8,000 ppm

Design Fire 1- Corridor Fire

Figure 3-1.96. *HRR of trash bags.*

Visibility- First Floor

30 Seconds

135 Seconds

Visibility- Second Floor

161 Seconds

Temperature- First Floor

180 Seconds

Temperature- Second Floor

180 Seconds

Toxicity- First Floor

180 Seconds

Toxicity- Second Floor

180 Seconds

ASET vs RSET Summary

Floor Level	RSET Time	Visibility	Temperature	Toxicity
Level 1	135 Seconds	Fail at 30 seconds	Pass	Pass
Level 2	161 Seconds	Pass	Pass	Pass

Design Fire 2- Project Integration Room

HRR of metal-frame, upholstered stacking chairs

HRR of office workstations

Design Fire 2- HRR from FDS

Visibility- First Floor

120 Seconds

Visibility- Second Floor

180 Seconds

Temperature- First Floor

180 Seconds

Temperature- Second Floor

180 Seconds

Toxicity- First Floor

180 Seconds

Toxicity- Second Floor

180 Seconds

ASET vs RSET Summary

Floor Level	RSET Time	Visibility	Temperature	Toxicity
Level 1	135 Seconds	Fail at 120 seconds	Pass	Pass
Level 2	161 Seconds	Pass	Pass	Pass

- Conservative design fire and visibility parameters were chosen
- Possible solutions need to be evaluated
- Smoke control system is not required for atriums that connect only two stories (CBC 404.5 Exception).

Possible Solutions

- Add 1 Hour Fire Barriers
- Reduce visibility tenability requirements to a minimum of 4 meters
- Design and implement a smoke control system
- Use growth and decay fire instead of steady state
- Justify use of lower soot yield

Growth and Decay instead of Steady State

Figure 3-1.96. *HRR of trash bags.*

Soot Yield

- Current Soot Yield 5%
- Estimate contents of typical trash can

Example

Assume 50% paper and 50% plastic contents.

According to SFPE Handbook Table 3-4.16, cellulosic materials have a soot yield of 1.5% while polyethylene has a soot yield of 6%. Assuming a 50/50 ratio, the combined soot yield estimated would be 3.75%.

Conclusion

- Occupancy classification change to reflect current usage of room
- Door swing of Room 104 changed to swing in the direction of egress
- 1 Hour Fire Barrier separating atrium spaces from adjacent spaces, or approved smoke control system

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