Fire Analysis of The Walter F. Dexter Building

Building 34 of the California Polytechnic, San
Luis Obispo Campus

Jeff Jenkins

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JWJENKIN@hotmail.com

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Executive Summary

The purpose of this report is to provide a fire analysis of the Walter F. Dexter Building on the California Polytechnic State University, San Luis Obispo Campus. The report will detail egress analysis, notification systems, and building construction in a prescriptive approach. The report will also include a performance based analysis of the building with a designed fire scenario. This performance based analysis will show that in one of the most likely fire scenarios for the building, there is still ample time for the occupants to escape safely.

Introduction

The purpose of this report is to give an initial prescriptive and performance egress, notification and structural analysis relative to fire protection of the Walter F. Dexter Building (Building 34) located on the California Polytechnic State University, San Luis Obispo Campus. The building is a mixed occupancy and includes assembly, business, industrial, mercantile and storage occupancies as specified in NFPA 101 Chapter 6.1. This report will include floor plans of the building which will specify the occupancy type for each room as well as the occupant load factor per room. This report will also specify egress capacities and compare occupant load factors to the egress capacities in order to ensure there is sufficient egress capacity. Exit corridors, exit sign placement and the number of exits will also be discussed. All exits in this building were measured and all capacities were determined using prescribed formulas taken from NFPA 101 unless otherwise noted. For the notification system NFPA 72 was referenced. The 2009 International Building Code (IBC) was used for structural fire protection analysis.

For the performance based egress analysis, occupant characteristics, and pre movement times will be discussed. Building characteristics such as stairway and doorway widths taken from the prescriptive analysis are input into a proper hand calculation in order to give an approximate egress time. Finally, tenability performance criteria of the building will be discussed. A comparison of computer modeling (Pathfinder) results for egress and tenability criteria will be made to determine if the criteria for tenability will be met for a prescribed fire scenario.

Egress

Occupancy Classification

The Walter F. Dexter Building is a mixed occupancy building. The occupancies include art galleries, labs, classrooms, offices, storage rooms and a vending area. In order to classify these occupancies NFPA 101 – The Life Safety Code Chapter 6.1 was consulted. Occupancies were then determined to be Assembly, Industrial, Business, Storage and Mercantile respectively. Please see Figures 1.1-1.2 for floor plan and occupancy classification. Points of egress were located as well as exit stairs, exit corridors, elevators, restrooms and maintenance rooms are marked. This is to establish an overall view of the building and will be used to make analysis of the egress capacity for the building.

Occupancy Load, Exit Capacity and Exit Arrangement

The occupancy load was calculated for each space in the building. This was done in accordance with NFPA 101 Table 7.3.1.2. The occupant load gives the minimum amount of people that will occupy that particular space at any time. A comparison must then be made to determine if the exit capacity of the floor is sufficient for the occupant load of the floor. Table 1.1 gives the calculated occupancy load for each space on the floor. Each floor was then totaled to give the total occupant load. The total occupant load of the floor was then compared to the exit capacity of the same floor. Exit capacity of each egress (circled in red) was calculated using NFPA 101 Table 7.3.3.1. Each exit was measured and then divided by the factor given in the table. From this, the exit capacity from each egress can be determined. In order to determine if the number of

exits from each floor is sufficient, the occupancy load per floor is again reviewed and compared to NFPA 101 7.4.1 and 7.4.1.2. Being as the building has at least four exits from each floor, all criteria are met. In order to verify the arrangement of exits, NFPA 101 7.5.1.3.1 and 7.5.1.3.2 were referenced. The exits are in compliance as they are arranged to be separated from one another so in the event of an emergency not more than one is likely to be blocked. They are also located at not less than one half of the diagonal dimension of the building. Please see figure 1.1 -1.2 for details on the egress capacity per exit as well as exit arrangement.

Table 1.1

First Floor			
Room Number	Area (sq ft)	Occupant Load	Factor
111A	1215	41	30
111B	371	0.74	500
111	1338	3	500
111C	107	0.21	500
112	132	1	100
112A	241	2	100
112B	94	0.94	100
113	238	5	40
114A	87	1	100
114	161	0.87	200
115	374	4	100
115A	167	2	100
116	175	2	100
117	668	33	20
120	479	1	500
120A	130	0.25	500
122A	113	0.23	500
123	35	0.07	500
124	94	1	100
125	96	1	100

Second Floor			
Room Number	Area (sq ft)	Occupant Load	Factor
208	1464	29	50
209	1572	31	50
210	929	19	50
211	165	2	100
212	147	2	100
213	266	3	100
213A	26	0.05	500
214	305	3	100
214A	77	0.15	500
215	259	3	100
216	175	2	100
216A	174	2	100
216B	46	0.09	500
217	309	3	100
218	31	0.06	500
218A	30	0.06	500
219	297	3	100
220A	109	1	100
220B	108	1	100
220C	103	1	100

126	130	1	100
127	1128	23	50
128	1961	39	50
128A	2198	22	100
128E	2198	22	100
129	1904	19	100
129A	1898	18	100
130	104	1	100
131	104	1	100
132	104	1	100
133	102	1	100
134	1530	30	50
135	44	0.08	500
137	36	0.07	500
138	28	0.05	500
140	184	2	100
141	445	9	50
141A	78	1	100
142	111	1	100
143	103	1	100
144	1845	37	50
145	1361	27	50
145A	450	5	100
145B	221	2	100
146	96	1	100
147	98	1	100
148	1366	30	50
149	1504	30	50
150	1187	24	50
151	1255	25	50
152	1407	28	50
153	203	2	100
154	113	1	100
155	103	1	100
156	63	0.12	500
159A	640	32	15
159B	625	13	50
160A	399	4	100
160B	185	2	100
160C	83	1	100
161	121	1	100

220D	105	1	100
220E	97	1	100
220F	102	1	100
220G	99	1	100
220H	105	1	100
220J	107	1	100
221	580	12	50
221A	580	12	50
222A-F	3659	37	100
223	92	1	100
224	94	1	100
225	94	1	100
226	93	1	100
227	993	50	15
227A	77	0.15	500
228	628	31	15
228A	73	1	100
230	40	0.08	500
231	25	0.08	500
232A	108	1	100
233	517	10	50
233T	53	0.1	500
234	105	1	100
235	105	1	100
236	105	1	100
237	105	1	100
238	105	1	100
239	106	1	100
240	103	1	100
241	105	1	100
242	105	1	100
243	105	1	100
244	105	1	100
245	105	1	100
246	105	1	100
247	1554	31	50
248	1527	31	50
249	1516	30	50
250	237	2	100
251	420	4	100
251A	154	2	100

162	117	1	100
163	117	1	100
164	113	1	100
165	113	1	100
166A	182	2	100
166	325	3	100
167	538	11	50
167A	45	0.45	100
168	152	2	100
169	194	2	100
170	161	2	100
170A	191	2	100
171A	559	28	20
171	1488	99	15
171B	102	1	100
171C	635	42	15
Max Occupany		738	
Exit Capacity		3025	
# of Exits		11	

251B	146	1	100
252	618	12	50
252A	1459	29	50
252B	1365	27	50
252C	1175	24	50
252D	1723	34	50
252E	1767	35	50
252F	1329	27	50
252G	48	0.09	500
253	107	2	50
254	107	2	50
255	111	2	50
256	76	1	100
Max Occupancy		578	
Exit Capacity		996	
# of Exits		4	

Occupancy Classification (1st Floor)

Figure 1.1

Occupancy Classification (2nd Floor)

Figure 1.2

Fire Resistance Ratings, Exit Signs and Interior Finish

Fire resistance ratings for exit corridors are shown in Figures 1.4 and 1.5, in accordance with NFPA 101 Table 8.3.4.2. There are elevators and stairways which require a 1 hour fire resistance rating. The exit corridors must have a 1 hour fire resistance rating.

Exit sign placement is shown in figures 1.4 and 1.5 as well, in accordance with IBC 2009 1011. They must be visible from any direction of egress travel. The exits are not more than 100 feet from any exit corridor. Paths of travel to the exits are clearly marked by the signs.

Interior finish requirements for this building must be Class A or Class B in exits and exit access corridors in accordance with NFPA 101 38.3.3. Class A finish shall have a flame spread index of 0-25 and a smoke developed index of 0-450 while Class B finish shall have a flame spread index of 26-75 and a smoke development index of 0-450. The interior finish of the walls and ceilings in the building are texture and paint. NFPA 101 10.2.1.2 states that materials applied directly to the surface of walls and ceilings in a total thickness of less than 1/28" shall not be considered interior finish if they meet the requirements of Class A requirements. Class A requirements must be tested by ASTM E 84 or ANSI/UL 723 which both test the surface burning characteristics of building materials. It is assumed that the surface finish meets the requirements of these tests.

Fire Resistance Ratings and Exit Signs (1st Floor)

Figure 1.4

Fire Resistance Ratings and Exit Signs (2nd Floor)

Figure 1.5

Occupant Characteristics

The main use of this building is labs/classrooms as well as professors' offices. The density in the labs should be relatively low as space is allotted for work areas. The offices are sized to be large enough for one person. The larger labs and classrooms have at least two exits therefore allowing a quick egress.

Since this building is located on a college campus, it is assumed that the age range of the majority of the occupants will be young adults. The occupants should be relatively familiar with the layout of the building as they visit it on a daily basis. Also, as college takes a while to complete, the occupants may visit the same building for a number of years. I would therefore expect the occupants to be very familiar with the building layout. I also expect the occupants of the building to be alert, as it is not used for sleeping.

The amount of responsibility of the occupants should be relatively low due to the fact that this is an office and classroom setting. Most of the belongings of the occupants should be relatively close to them and easy to gather. They will not have much responsibility for the building itself. In most cases I would expect the occupants to grab a backpack or laptop and then be ready to evacuate.

Social affiliation between classmates and teachers will likely have an effect on egress time. Friends will likely gather with each other before making egress. Teachers may also try to facilitate the evacuation of students, likely keeping them in a group as a means of accountability.

The commitment of the occupants will also likely add time to egress. Students will not react to an alarm immediately as they will likely be involved in lecture or lab

activity. An unwillingness to break from this activity and assumption that it is a false alarm can significantly delay egress.

I would expect the occupants to be physically able to get around on their own and require little assistance otherwise. They should be able to maintain an average walking speed of 1 meter/sec on flat ground and an average of .5 meter/sec on stairs. I would also believe that their cognitive ability would be above average as they are in college or teaching in a college.

Pre-Movement and Movement Times

Taking into account the occupant characteristics above I would expect a relatively quick evacuation time. It is necessary to take into account that all rooms will not be occupied at all times. This decreases the amount of people that may need to evacuate at any given time.

Time to detection in this building should be relatively short due to the fact that there are always people moving around in this building and it is not used for sleeping. Students and teachers are constantly entering and exiting classrooms, bathrooms and labs. From ignition of a fire, I would predict no more than thirty seconds for detection to occur.

Reaction time of the occupants is again something I would consider to be relatively short. Since the occupants are awake and alert, it should not take much time to decide to leave. I would estimate around 30 seconds maximum to take action. This is based on the SFPE Handbook where pre-movement times are taken from a large department store.

Pre-evacuation activity time may be longer than reaction time but still should be much less than occupants of a residence. Most of the occupants' valuables are kept in briefcases or backpacks that are easily packed and ready to go. Teachers and students may take time to gather and try to stay together while making egress.

Travel time in this building should be considered to be under normal conditions with density not being a factor. Most occupants will be young adults. Using this assumption, from Table 4.2.2 it can be gathered that the average walking speed is 1 meter/second on flat ground and .5 meter/second on stairs. Per Table 3-12.6 in the SFPE Handbook, I would expect 3.0 seconds to open doors.

Hand Calculation of Egress Time

The following will show a calculation of the amount of time it will take to fully evacuate the Walter Dexter Building (Building 34). Measurements of all stairwells as well as doorways were taken directly from the building. All assumptions are listed below. All equations were taken from the NFPA fire protection handbook.

Analysis of Building 34

Please see Figure 1.1 and 1.2 for exit locations. North is assumed to be at the right of the page. Exit stairwells are indicated with a red square and exits are indicated with a red circle.

2nd Story - Stairwell widths from North and going clockwise to West are 44", 59", 60" and 58". The respective door widths are 59", 59", 63" and 41".

Two exits give access to the ground floor and have no stairs. Their widths are 66" and 59".

1st Story – Exit widths from North and going clockwise to West are 70", 72", 36", 41" 36", 36" and 72".

Assumptions

All occupants start egress at the same time. They will use all facilities in optimum balance. Stair risers are 7" tread is 11". $F_s = F_{smax}$. Floor area = 39000 sq ft. 12ft ceilings. Occupants = 650 per floor. 4' x 8' landing on floor. Density = .175 persons/sq ft

Flow of Stairways

Boundary Layer = 6" on each side (Table 4.2.3)

Stairway effective width = 32", 47", 48" and 46" respectively

Doorway Effective width (stairwells) = 47", 47", 51" and 29" respectively

$F_s = F_{smax} = 18.5$ people/min/ft (Table 4.2.7)

$F_c = F_s * W_e$ (Eqn. 4)

$F_c = 18.5 * 2.67' = 49.3$ people/min for 44" stairs

$F_c = 18.5 * 3.91' = 72.4$ people/min for 59" stairs

$F_c = 18.5 * 4.0' = 74$ people/min for 60" stairs

$F_c = 18.5 * 3.8' = 70.3$ people/min for 58" stairs

Flow of Doors

Boundary Layer = 6" on each side (Table 4.2.3)

Doorway effective width (2nd Story) = 54" and 47" respectively

Doorway effective width (1st Story) = 58", 60", 24", 29", 24", 24" and 60" respectively

$F_s = F_{smax} = 24$ people/min/ft (Table 4.2.7)

$F_c = F_s * W_e$ (Eqn. 4)

2nd Story

$F_c = 24 * 4.5' = 108$ people/min for 66" door

$F_c = 24 * 3.9' = 93.6$ people/min for 59" door

1st Story

$F_c = 24 * 4.8' = 115$ people/min for 70" door

$F_c = 24 * 5.0' = 120$ people/min for 72" door

$F_c = 24 * 2.0' = 48$ people/min for 36" door

$F_c = 24 * 2.4' = 57.6$ people/min for 41" door

$F_c = 24 * 2.0' = 48$ people/min for 36" door

$F_c = 24 * 2.0' = 48$ people/min for 36" door

$F_c = 24 * 5.0' = 120$ people/min for 72" door

Speed of Stairway Flow (stairways limiting flow)

$S = k - akD$ (Eqn 1) $k = 212$ for stairs and 275 for corridors, $a = 2.86$ (Table 4.2.4)

$S = 196 - (2.86 * 212 * .175) = 90$ ft/min for travel speed down stairs

Travel Distance (stairways limiting flow)

Between floors = $12' * 1.85$ (Table 4.2.5) = 22.2' on stairs + 8' = 30.2'

Travel Time

$$30.2 \text{ ft} / 90\text{ft/min} = .33 \text{ min/floor}$$

Building Evac Times

$$\begin{array}{rcl}
 2^{\text{nd}} \text{ Floor} - & 49.3 \text{ people/min for } 44'' \text{ stairs} & \\
 & 72.4 \text{ people/min for } 59'' \text{ stairs} & \\
 & 74 \text{ people/min for } 60'' \text{ stairs} & \\
 & 70.3 \text{ people/min for } 58'' \text{ stairs} & \\
 + & 70.3 \text{ people/min for } 58'' \text{ stairs} & \\
 & 108 \text{ people/min for } 66'' \text{ door} & \\
 & \underline{93.6 \text{ people/min for } 59'' \text{ door}} & \\
 & 537.9 \text{ people/min can evacuate from second floor} &
 \end{array}$$

$$650 \text{ people} / 537.9 \text{ people/min} = 1.20 \text{ min}$$

$$1.20 \text{ min} + .33\text{min} = 1.53 \text{ min to evacuate}$$

$$\begin{array}{rcl}
 1^{\text{st}} \text{ Floor} - & 115 \text{ people/min for } 70'' \text{ door} & \\
 & 120 \text{ people/min for } 72'' \text{ door} & \\
 & 48 \text{ people/min for } 36'' \text{ door} & \\
 + & 57.6 \text{ people/min for } 41'' \text{ door} & \\
 & 48 \text{ people/min for } 36'' \text{ door} & \\
 & 48 \text{ people/min for } 36'' \text{ door} & \\
 & \underline{120 \text{ people/min for } 72'' \text{ door}} & \\
 & 557 \text{ people/min can evacuate from } 1^{\text{st}} \text{ floor} &
 \end{array}$$

$$650 \text{ people} / 557 \text{ people/min} = 1.16 \text{ min to evacuate}$$

$$1.16 + 1.53 + .5 \text{ (premovement)} + .5 \text{ (detection)} = 3.7 \text{ min} = \text{total evac time}$$

Pathfinder

The evacuation simulator Pathfinder yields the following results.

$$2.63 \text{ minutes} + .5 \text{ (premovement)} + .5 \text{ (detection)} = 3.63 \text{ min} = \text{total evac time}$$

This is based on 1300 occupants spread at random throughout the building. Features such as fixed seating and exit only rooms were added to classrooms where applicable. This figure compares well with the hand calculation yielding a difference of only four seconds.

Uses and Limitations

This analysis of the evacuation time of this building is based on loose figures. It is near impossible to calculate the population density due to many factors. It is impossible to determine where people will go when an emergency occurs. Most will often try to exit the way they entered. This can greatly increase the density at this exit and therefore decrease the density at other exits.

Given the use of this building as classrooms, offices and labs, it makes it more difficult to determine the density as not all rooms will be occupied at all times. The occupant load of the room cannot be accurately determined because students tend to skip class and classes can be canceled or held at other locations. Office hours can be canceled as well.

One major assumption made by this calculation is that all exits will be available in the event of an emergency. A fire is likely to shut down at least one or more exits due to

location and the presence of the products of combustion. Again, this will change the density of the population using exits.

The use of this gives the designer an opportunity to calculate the effective widths of doors and stairways. It also gives an estimation of evacuation times. By factoring different densities, a designer can see how their design will play out in evacuation times. It can be used as a basis to determine stairway and exit widths base on expected occupant loads. This gives the opportunity to increase or decrease the widths and see what the calculated egress time will be.

It should be noted that in this building the first floor and second floor exits do not coincide with each other. Second floor exits (for the most part) cannot be used by first floor occupants. This is due to the fact that a majority of the exits are stairwells that are located outdoors. The midline of the building is located approximately six feet above ground level at the front of the building. This makes a couple of the exits accessible to the outside with the use of a ramp. The rear of the building takes on a true two story above ground level stance.

Tenability Performance Criteria

The objectives summarized in the Life Safety Code Section 4.2 state that:

- 1) A structure shall be designed, constructed, and maintained to protect occupants who are not intimate with the initial fire development for the time needed to evacuate, relocate or defend in place.
- 2) Structural integrity shall be maintained for the time needed to evacuate, relocate or defend in place occupants who are not intimate with the initial fire development.
- 3) Systems utilized to achieve the goals of #1 shall be effective in mitigating the hazard or condition for which they are being used, shall be reliable, shall be

maintained to the level at which they were designed to operate and shall remain operational.

It has been calculated that it will take approximately three minutes to evacuate the Walter Dexter Building given normal occupant loading. This time serves to show that the building is designed with the adequate number of exits and exit capacities to allow occupants to escape. The building is designed with all rooms and offices located directly off of main exit corridors. This is the design feature that allows for quick egress from the building in the event of an emergency. Rooms with larger occupant capacities offer at least two exits.

The Walter Dexter Building's (Building 34) most noticeable design feature is the long corridors leading to exits. Construction along these corridors must be at least one hour fire resistive construction according to LSC Table 8.3.4.2. It was calculated that the egress time for the entire building is approximately three minutes. This design feature meets the requirements of #1 above. Also, all stairways must be of 1 hour fire resistive construction. Again this exceeds the requirements for the safe egress time as calculated.

There are no suppression or smoke evacuation systems installed in this building. Being as such, the only items that must be maintained are the clear corridors and stairways. As long as no obstructions are introduced (ex. displays, trash cans etc.), egress times should not be hampered.

A difficulty with this building is determining the path that smoke will take and how it will affect the occupants. The location of a fire will determine how smoke travels through the building. If it starts near a stairwell, for instance, the smoke will likely travel to the second floor and have an effect on occupants there faster than occupants on the

first floor. A fire that starts near the end of a corridor on the second floor will likely have no effect on the first floor occupants for a long period of time.

Smoke will have a large impact on egress time as it can cause a decrease in vision and an increase in breathing difficulty thereby reducing walking speed and increasing exposure time. Although the long corridors allow for easy paths of travel, they also act as channels for smoke. The long corridors may cause occupants to become confused or disoriented and unable to distinguish which exit is closest to them or which direction will lead them to safety. As stated before it is difficult to account for all scenarios such as fire size and location. This will determine which occupants are affected first and how they will respond. Fire modeling is the best way to deal with a majority of scenarios.

For the simulation, tenability criteria that must be met are a temperature not exceeding 65 C, visibility must remain above 10 meters and CO concentration must not exceed 1200 parts per million. These properties will be evaluated later in this report.

Notification

Fire Alarm System

The Dexter building is currently protected by a Digital Monitoring Products Inc. system. The issue number of the system is AH-9874. The system consists primarily of manual pull stations connected to audible alarms. This is due to the fact that the building was constructed during the 1940's. However, heat detectors have been added to room 111A. This is a mercantile occupancy which is currently occupied by Subway Restaurant. These heat detectors were installed there as the room used to house vending machines. The fire detection system relies primarily on occupants sounding the alarm.

The fire alarm control panel is located on the ground floor of the building, adjacent to the electrical room (Room 157). The main keypad behind the enclosure is a Fire Command 690F model. Cal Poly is currently in the process of updating all alarm systems to a Notifier system. This building is one of a few remaining with a Digital Monitoring Products system.

Detection Devices

As previously mentioned, the only fire detection devices in the building are spot type, ordinary heat detectors (assumed, 135-174F). They protect the Subway Restaurant, located on the first floor of the building. These detectors are listed as a one-time use detector and therefore are not inspected. They are built with a fusible link which is designed to melt when the temperature is increased. When this link melts, the alarm will be set off inside the building. Subway currently occupies the only room with the heat

detectors. This seems to be a good fit as refrigeration equipment as well as ovens maybe in operation when the building is unoccupied.

There are no other detection devices in the building. This is likely due primarily to the fact that the building is rarely occupied to capacity due to varying class times. It is also likely due to the fact that the cost of renovating the alarm does not make economic sense. The goal is to have the entire campus monitored by one system manufacturer. I was informed by the risk manager that this is one of the few buildings that is not under a Notifier system. They are hoping to renovate it and switch the fire alarm system over to a Notifier system in the next 5 to 10 years. The following figures (1.6 – 1.7) give the locations of fire alarm pull systems as well as the signal device locations.

Figure 1.6

F=Pull Station	H=Heat Detector
AV=Speaker/Strobe	FACP= Fire Alarm Control Panel

Figure 1.7

Detection Device Placement

According to NFPA 72 Chapter 17.4, the initiating devices shall not be installed in inaccessible areas, and shall be installed in a manner that provides accessibility for periodic maintenance. The heat detectors that are installed in room 111A are easily accessible with a ladder for maintenance. However, these are a one time use device so no maintenance is required. Chapter 17.5 forbids the detectors to be recessed into the mounting surface. Upon inspection, it is evident that these detectors are not recessed into the mounting surface.

Since this is the only room covered by detection devices, Chapter A17.5.3.2 of NFPA 72 applies. This states that if there are no detectors in the room or area of fire origin, the fire could exceed the design objectives before being detected by remotely located detectors. When coverage other than total coverage is required, partial coverage can be provided in common areas and work spaces such as corridors, lobbies, storage rooms, equipment rooms and other tenantless spaces. The intent of selective coverage is to address a specific hazard only.

Where a specific area is to be protected, all points within that area should be within $.7 \times$ the adjusted detector spacing for spot-type detectors as required by 17.6.3. The ceiling height of room 111A is approximately 12 feet. There are no projections coming down from the flat ceiling and no partitions in the room. In accordance with Chapter 17.6.3.5.1 which states on ceilings 10 feet to 30 feet high, heat detector spacing shall be reduced in accordance with Table 17.6.3.5.1 prior to any additional reductions for beams, joists, or slope where applicable. Based on this chart, a ceiling height up to and including 12 feet has a factor of .91 to be multiplied by the listed detector spacing. It is

assumed that these detectors have a listed spacing of 30 feet. This means that $30 \times .91$ gives a spacing of 27.3 feet. There are three detectors that cover a length of approximately 65 feet. So based on the fact that $27.3 \times 3 = 81.9$ the coverage area is approximately 82 feet. This gives an adequate amount of detectors to cover the length of the room. The width of the room is approximately 20 feet so again the number of detectors is adequate based on a spacing of 27.3 feet.

As previously mentioned, the building is mostly outfitted with manual actuated alarm initiating devices. According to NFPA 72 Chapter 17.14 manual pull stations should be red in color and the background should be of a contrasting color. They should be mounted between 42 and 48 inches above the floor and be unobstructed. They are to be mounted within 60 inches of each doorway that exits the building. They will be located within 200 feet of each other on the same floor. A walkthrough and measurement of the building provided all of the aforementioned criteria to be true.

Scenario

Since there are only detection devices in the occupancy which is now a Subway restaurant, a fire would have to propagate there for the detection devices to most quickly respond to a fire. In this example, we will assume a polyethylene wastebasket filled with 12 milk cartons (Table B.2.3.2.6.2d) that is against the wall on the edge of the room. The room measures approximately 20 x 65 feet. Ambient temperature is assumed to be 20 C and the height is 12 feet or 3.65 meters.

Heat Release Rate Equation B.1

$$Q_m = qA \text{ where } q = 35 \text{ kW/m}^2 \text{ and } A = 3.08 \text{ ft}^2 = .286 \text{ m}^2 \text{ (assumed)}$$

$$Q_m = 10 \text{ kW}$$

Fire Growth Rate Equation B.6a

$$Q = (1055/t_g^2)t^2 \text{ where } Q = 10 \text{ kW and } t^2 = 40000 \text{ s (table B.2.3.2.6.2d)}$$

$$t_g = 2054 \text{ s}$$

$$\text{Alpha} = 1055/t_g^2$$

$$\text{Alpha} = .00025 \text{ kW/s}^2$$

Design Example

RTI

Spacing of 9.14m and temp of 62.8 C from Table B.3.2.5

$$\text{RTI} = 61 * (1.5^{1/2}) = 74.7$$

Spacing

$$30 \text{ ft} * (.91) = 27.3 \text{ or radial distance of } .707 * 27.3 = 19.3 \text{ ft or } r = 5.8 \text{ m}$$

Fire Detection and Analysis Worksheet [28]

Design Example

Ambient Temperature and Height	T=20C or 293K H=3.65m
A	Alpha=.00025kW/s ²
Detector Characteristics	T _s =27 +273 =300K RTI=74.7
Analysis	S=1.41*5.8=8.18m Q=10kW
Time when heat reaches detector	t* _{2f} = .861(1+r/H)= 2.23
A factor	A=(9.81m/s ²)/(1.005kj/kg x20C x1.2 kg/m ³)=.40
t* ₂	t _{cr} /(A ^{-1/5} x α ^{-1/5} x H ^{4/5}) = 17.8
t* ₂ >t* _{2f}	Yes
u/u* ₂	A ^{1/5} x α ^{1/5} x H ^{1/5} = .44
Δ T/Δ T* ₂	.023
Δ T* ₂	210.3
u* ₂ / Δ T* ₂ ^{1/2}	.44
Y	2.38
T _d (t)	21.2
T _d (t) ≈ T _s	21.2≈20

The following values were calculated by following directions from Figure B.3.3.4.4 and input into the respective equations in the above worksheet.

$$t^*_2 = 17.8 \quad t^*_{2f} = 2.23 \quad \Delta T^*_2 = 90.52$$

After the calculations are complete, it can be concluded that the heat sensors installed are adequate. This is due to the fact that the temperature of the detector came

out slightly larger than the ambient temperature, but only marginally. One would expect to see a much larger difference in $T_d(t)$ and T_s if the current spacing was clearly inadequate. However, this can be attributed to rounding errors while solving the problem.

Disposition, Supervisory and Trouble Signals

In order to reset the system the COMMAND key followed by 4 and 7 must be pressed. The system will reset any smoke detectors and stop the flashing fire zone light if it returns to normal. A user code must be entered in order to silence the alarm.

NFPA 72 3.3.240.6 defines a supervisory signal as a signal indicating the need for action in connection with the supervision of guard tours, the fire suppression system or equipment, or the maintenance features of related systems. Per the manufacturer's literature, there are three supervisory signals that this alarm system can generate. They are Power Trouble, Phone Line and Battery. Power Trouble has two options one is the type of trouble that occurred with your system and the second is an AC power problem. Phone line will indicate a problem with either phone line 1 or 2. A battery signal will indicate a problem with a low battery or the battery exceeding its life expectancy.

A trouble signal is displayed as a LED on the control panel. It will turn on when there is a problem trying to communicate with the central system. It will also turn on when there is a problem with the phone line. It will pulse (1 second off and 1 second on) when there is a problem with the system. When this happens, it is advised to call for service.

Notification Devices

As previously mentioned, the building alarm system primarily relies on the occupants using the alarm system to alert others of a fire. The notification devices are a Simplex Grinnell combination horn and strobe (Figure 1.8) similar to a 4903-9356 model number. Their locations are noted on Figures 1.6 and 1.7 of this report.

This building consists of both audible and visual notification devices. According to NFPA 18.4.1.1 an average ambient sound level greater than 105dB shall require the use of a visual notification appliance. The building consists mostly of classrooms and offices. It would be a rare occasion where the sound level would reach 105dB. However, the visual notification can help with those who are hearing impaired. Business occupancies have an average ambient sound level of 55dB according to Table A.18.4.3. The audible warning device must have a sound level at least 15dB above the average

ambient sound level or 5dB above the maximum sound level having a duration of at least 60 seconds, whichever is greater, measured 5 feet above the floor in the area required to be served by the system in order to be in compliance with 18.4.3.1.

NFPA 18.4.8.1 states that wall mounted audible appliances shall have their tops above the finished floors at heights of not less than 90 inches and below the finished ceilings at distances of not less than 6 inches. These devices installed in this building are combination audio visual appliances so this code does not apply to them. 18.4.8.3 states that if combination audible/visible appliances are installed, the location of the installed appliance shall be determined by the requirements of 18.5.4 which is described below.

The visual requirements for these combination devices are given in 18.5. They must be located and must be of a type, size, intensity and number so that the operating effect of the appliance is seen by the intended viewers regardless of the viewer's orientation. The flash rate shall not exceed 2 flashes per second and have a duration of .2 seconds. The lens for the light must be mounted between 80 and 96 inches above the finished floor.

All of the appliances in the building met this requirement. However, it is important to note that most signaling devices are located in the main corridors of the building. This means that there should be a strobe mounted approximately every 40 feet in the corridor in accordance with 18.5.4.3 which sets the standard for spacing in rooms. There is an appliance located approximately every 60 feet. The alternative to this spacing in the corridor is that a minimum illumination of .0375 lumens/ft² is provided where visible notification is required in accordance with 18.5.4.5. For the purposes of this

report, it is impractical to measure the intensity of light in the corridor with the alarm functioning.

As far as the notification in rooms that do not contain a combination notification device, the only means occupants will be alerted is through audible tones. This violates the ADA Advisory 215.1 which states that unlike audible alarms, visible alarms must be located within the space they serve so the signal is visible. Occupants will have to be warned by others that there is an emergency.

Power Supply

Power supply requirements are made using literature from current Simplex combination notification devices. Due to the age of the building and the system, it was not possible to find requirements for the installed devices without physically removing them from the wall. The combination device used is a Simplex TrueAlert wall mount with a speaker and strobe combination. The maximum voltage and current are 24 VDC and 63mA respectively. The speakers draw $\frac{1}{2}$ W of power for a decibel rating of 81 at 10 ft. Total current drawn per device is based on similar combination notification devices.

SILENT KNIGHT

5495 Power Expander Calculations
Version 02.18.09

Global Project Values:

Project Name: <input type="text" value="Building 34 Dexter Building"/>	Standby Hours: <input type="text" value="24"/>
Project ID: <input type="text" value="FPE 522"/>	Alarm Mins: <input type="text" value="15"/>
Prepared By: <input type="text" value="Jeff Jenkins"/>	Derating Factor: <input type="text" value="1.2"/>
Date: <input type="text" value="4/1/2013"/>	Voltage Drop Warning Threshold %: <input type="text" value="10"/>

Panel ID: <input type="text" value="5495"/>	Model: 5495 Power Expander	Max NAC Current: 3.0 Amps
Location: <input type="text" value="Entryway North of Room 157"/>	Volts: 24 VDC	Max Panel Current: 6.0 Amps

Ckt #	Circuit Name		Current Draw Standby	Alarm	Wire AWG & Type	Ohms Per 1000 Ft.	Length(ft) One-Way	Actual Ohms	Volts @ EOL	%Drop
5495	Pwr Module	1	0.075	0.205						
NAC #1	Circuit 1	cfg.	0.000	1.512	#12 Stranded	1.59	300	0.95	18.96	7.07%
Total Standby Current (Amps)			0.075	1.717	#12 Stranded	(Amps)				
Standby Time In Hours			24	0.250	Alarm Time In Minutes / 60		(15 Mins)			
Total Standby AH Required			1800	0.429	Total Alarm AH Required					
Total Combined AH Required			2.23							
Multiply By The Derating Factor			1.20							
Minimum Battery Amp-hours Required			2.68							

Wire resistances are based upon an ambient temperature of 72 degrees F. Because of the minimal difference between solid and stranded wire no differential was made.

Figure 1.9

Circuit Configuration

Print Circuits Detail

Project Information

Project Name: Building 34 Dexter Building	Project ID: FPE 522
Prepared By: Jeff Jenkins	Date: 4/1/2013

Ckt. Number: NAC #1		Panel ID: 5495	
Ckt. Name: Circuit 1		Max Circuit Current: 3 Amps	
Qty	Device	Current Draw Each Standby	Current Draw Total Standby
24	Simplex Truealert 4903-9356	0.000	0.063
0	Unused	0.000	0.000
	Unused	0.000	0.000
	Unused	0.000	0.000
			0.000
			0.000
		Totals	0.000

<Return To Power Supply Config
Edit Device Database

Figure 2.0

In total, there are 24 devices in the building. Current draw for the devices in both standby and alarm mode is shown in Figure 4. The maximum length of wire from the fire alarm control panel to the furthest device (1 way) is approximately 300 feet. The

resistance is calculated in Figure 3. It is assumed that the secondary system must alarm for 15 minutes and have a 24 hour standby time. The minimum battery amp hours required was found to be 2.68.

The DMP Fire Alarm Control Panel requires 24 volts and 4 amps maximum. It is backed up by two 12 volt batteries each rated at 7.5 amp hours. The secondary power supply for the simplex devices consists of two 12 volt batteries with a capacity of 24 amp hours. Being as the requirement for the system has been calculated to be a minimum of 2.68 amp hours the 24 amp hour capacity more than meets this requirement.

A reason for the possible discrepancy between these two values is that neither the alarm standby time in the event of a power failure nor the alarm times are actually known. At the time of installation, these requirements may have varied from the values used for this calculation. Also, the actual amperage drawn for the combination devices has been approximated based on other similar devices.

Maintenance and Testing

The alarm system in the Dexter building undergoes annual testing by Deep Blue Integration. This is in compliance with NFPA 14.2.1.1. Deep Blue provides a testing schedule of each building as 14.2.5.2 states that all occupants must be notified. An inspection report of the findings is given back to the EHS office when the testing is complete.

The device's name, location and serial number (if applicable) is posted on this report. Each device is judged as either passing, failing or not tested. Any discrepancies are listed at the end of the report. The name of the tester and signature is required at the

end of the report. The report states “all tests performed in accordance with California Code of Regulations Title 19, Section 1.09(a); NFPA 72 CH 7, Sect. 7-2; NFPA 72, Table 7-8.2; and NFPA 72, Table 7-3.2.”

Testing procedures involve testing the batteries with a load tester. Audio and visual alarms are tested by activating the alarm notification devices. Confirmation of proper operation of the audible and visual alarms must then be obtained. The audible alarms are to be verified that they are at least 15db above the ambient sound levels. The tester must then verify the reporting at the panel. Correct operation of the speakers and reporting to the panel must also be tested. The manual pull stations must be checked for proper operation and checked for reporting at the panel. The heat detectors in this building are one time use and therefore are not tested.

Construction

Classification

The building is a mixed occupancy building and is two stories in height. The total area of the first floor is 39,062 square feet and the total area of the second floor is 31,716 square feet (See Table 1). Based upon Table 503 in the International Building Code, the building can be either Type I A or B construction for all occupancy classes. An assembly occupancy makes up the greatest portion of the building. This sets the standard for building size (508.2.1, 508.2.3). It also precludes the structure from being typed as anything other than a Type I A or B construction classification in accordance with the 2009 International Building Code (Table 503). There are uninsulated steel I beams that are used for roof rafters in the construction of this building. Typically this would cause the structure to be typed as Type II or III. However, there is a steel lath and plaster which makes up the ceiling of the second story.

Construction Materials

The building is composed primarily of reinforced concrete. Upon inspection, all exterior and interior load bearing walls are made of concrete. Columns were not found to be present in the structure. This is likely due to the fact that it is only two stories in height. Floors were found to be of concrete.

The structure is of tilt up construction. The main load bearing walls and floors were installed first. Divisions between classrooms and offices were likely added after. The construction materials of these partitions (non- load bearing walls) is drywall (5/8" gypsum) over either steel or wood studs. It is assumed that standard stud spacing at

sixteen inches on center was used and stud size is approximately 2" x 4". Stud material could not be determined while inspecting the building.

The roof of the building is composed of concrete tile. There is a wood supporting structure underneath consisting of plywood. The supports for the roof are made up of steel I beams. The interior of the second story ceiling consists of a steel lathe and plaster. Please see figure 2.1. The interior of the building consisted of concrete and gypsum walls. The concrete and gypsum walls were both painted while the gypsum walls had an added textured finish. The floor consists of tile over a concrete floor. The exterior of the building was covered with a painted concrete finish.

Fire Resistance Ratings

The fire resistance ratings for a Type 1 A structure are as follows. The primary structural frame must be of 3 hour fire resistance. There were no structural elements with a sprayed on fire resistive coating located in the building. Interior and exterior bearing walls must have this same 3 hour rating. The concrete construction should easily provide for this rating. There were no exterior non load bearing walls in the structure. If I have unknowingly miscategorized an exterior wall as load bearing, a fire resistance rating of one hour would be required for the non-load bearing exterior wall. This is based on a separation distance from adjoining structures of 10 to 30 feet and a group A occupancy in accordance with Table 602. All interior non-load bearing walls and partitions are not required to have a fire resistance rating. Floor construction must have a 2 hour rating. The roof construction and secondary members must have a 1.5 hour rating. However, in a group A occupancy, fire protection of structural members are not required but fire treated wood must be used.

The fire resistance ratings for a Type 1 B structure are as follows. The primary structural frame must be of 2 hour fire resistance. Interior and exterior bearing walls must have the same 2 hour rating. Non-load bearing exterior walls must be one hour rated based on Table 602, a group A occupancy and a 10 to 30 foot separation distance from adjoining structures. Non-load bearing walls and partitions are not required to have a fire resistance rating. The floor construction must have a 2 hour fire rating. The roof and secondary members are allowed to have a 1 hour rating. However, in a group A

occupancy, fire protection of structural members is not required but fire treated wood must be used.

Based upon the requirements for the structure to fall into either the Type I A or B category, I would call this building a Type I B. The distinguishing feature between I A and B is the fire resistance rating of the structural members of the roof. The steel lath and plaster provides a one hour rating not a one and a half hour rating. The problem with determining the construction type is that the building was constructed in 1948. There were no codes around at the time. Therefore, the building most closely resembles a Type IB. Although the members in the roof are not rated, they seem to be consistent with at the time would be a noncombustible construction type.

The walls being of concrete, are relatively thick in size. This should increase their fire resistance rating. It provides greater protection for the reinforcing steel members inside the walls than would thinner walls. Even though no fire resistance rating is required for the interior walls, they are comprised of 5/8" gypsum which should provide at a minimum a one hour fire resistance rating. Any kind of fire in this structure would be room contents. It would be difficult to foresee any part of the structure itself becoming involved with fire. Failure of the non-load bearing walls can be expected but a collapse of the structure due to fire would be highly unlikely.

Performance Based Tenability Analysis

Introduction

For the performance based design and three criteria will be considered. The three criteria are visibility, temperature, and carbon monoxide exposure. Based upon various sources the temperature for tenability is approximately 65° C. The visibility for tenability must remain above 10 meters. Carbon monoxide exposure must remain below 1200 parts per million.

Fire Scenario

After a walkthrough of the building and a review of the Pathfinder results, a likely location for a fire was determined to be in room 252. Based on NFPA 101, a combination of design fire scenario five and six are used. Design scenario five is a slowly developing fire in close proximity to a high occupancy area. It addresses the concerns regarding a relatively small ignition source causing a significant fire. Design fire scenario six is the most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the building. It should also be noted that through the use of Pathfinder, this room requires the longest time for exit of all occupants when both exits were available. The location of this fire makes one exit inaccessible to the occupants. This provided a unique opportunity to see how a fire in a room with the longest egress time would affect the occupants. They should be noted that using Pathfinder even with both exits the available only 2-3 occupants exited through the now blocked exit.

Design Fire

In room 252 there are three 30 gallon trash containers located near an exit. There is a dropped power supply outlet located in close proximity to these trash containers. Ignition of the trash in these containers occurs because of a malfunction of this dropped power supply outlet. Please see figure 2.2.

NIST Test FR 4018 – Heat Release Rate of Plastic Trash containers provides a heat release rate for one 30 gallon trash container at 300 kW. The material in the trashcan consists of wood, plastics, paper and other materials typical of construction site rubbish. A fire consisting of these materials is well suited to his room as it is used as a lab for landscape architecture. The test showed a peak heat release rate reached at 750 seconds. This can be seen in figure 2.3. The room was then created and, using Pyrosim, the design fire was added to this room. Polyurethane was the chosen material for the design fire as it would create the greatest amount of smoke production when compared to materials such as wood and paper. The yields for CO and soot are .042 and .198 respectively. This information comes from the SFPE Handbook and is stored in the Pyrosim library of materials.

Figure 2.3

It should be noted that an anomaly during extinguishment caused a spike in the heat release rate of the fire of trash container one. Since container one provided the highest heat release rate, it was chosen for the design fire.

Temperature

The temperature of the room was evaluated using slice files. These slice file are used to create a box at the egress point of the room. This box shows the temperature from floor to ceiling of the room. Based on figure 2.4 it is apparent that temperature remains below 65° C for a simulation time of 1000 seconds. This is much larger than the calculated required safe egress time (RSET) of the building. Thus temperature does not play a factor in the tenability of the room in this fire scenario.

Figure 2.4

Carbon Monoxide

The critical concentration for carbon monoxide is 1200 parts per million. A concentration at this level is known as an IDLH atmosphere. OSHA defines an IDLH atmosphere as any environment that can cause death, great bodily harm or hampers escape. At 1200 parts per million, a 30 minute exposure can cause death while adverse health effects could take place during a much shorter exposure time. Slice files at 6 feet in height as well as 3 feet in height were created to measure carbon monoxide concentration. The slice file was created at 3 feet in order to account for occupants who may be crawling low under the smoke. This behavior would be expected by those who are enduring fire conditions. As evidenced from figures 2.5 and 2.6, carbon monoxide concentration does not reach 1200 parts per million and even after 1000 seconds. As with temperature, this is much longer than the required safe egress time. Therefore

carbon monoxide concentration is not a factor in the tenability of this room in this fire scenario.

Figure 2.5

Figure 2.6

Visibility

In order to meet the criteria for tenability, the visibility of the room must remain at 10 meters. In this scenario visibility was again measured at a height of 6 feet and a height of 3 feet from the floor through the use of slice files. Again, this is to account for occupants who likely crawl low under smoke while enduring fire conditions. The results of the simulation yielded that visibility at 6 feet from the floor decreased to 10 meters at a time of 330 seconds. This is now the available safe egress time. Visibility at 3 feet from the floor decreased to 10 m at a time of 340 seconds. These results can be seen in figures 2.7 and 2.8. Thus visibility becomes the limiting factor for tenability when compared to carbon monoxide concentration and temperature. However, it should be noted that even at 330 seconds (or 5.5 minutes) the required safe egress time is 222 seconds (or 3.7 minutes).

Figure 2.7

Figure 2.8

Conclusion

In this prescriptive egress analysis, it is found that the Walter P. Dexter Building meets the necessary NFPA 101 requirements that were discussed in this report. The most critical factor is egress capacity exceeding the occupant load. As calculated, the egress capacity exceeds the occupant load for each floor. Paths of egress are clearly defined, the arrangement is appropriate and the number of exits is sufficient.

The building seems to clearly meet the criteria for available safe egress time being larger than required egress time. It is clear in the hand calculation above that it will take approximately 3 minutes to evacuate the building. Based on this number the tenability of the structure in the event of a fire seems adequate. Although the building is lacking automatic sprinklers and smoke removal systems, the exit capacity and size of both stairwells and doorways seem adequate to allow for safe egress. Another factor affecting the tenability is the familiarity of the occupants with the building. It is frequented by students and faculty who have repeat visits to the structure. This increases their familiarity with the structure and therefore their ability to make quick egress in the event of an emergency. They will be able to quickly locate the nearest exit and likely guide others who are less familiar with the building.

The fire alarm system in the Dexter is a fairly old system relying on the occupants for activation. There are no automatic suppression devices installed in the building. The only detection devices in the building are located in one room which is currently a Subway Restaurant. Spacing of these devices is adequate for the size of the room. The number of heat detectors for the one room in which they are installed was found to be accurate. The rooms are lacking visual notification devices. This is in conflict with

ADA Advisory 215.1 which states that unlike audible alarms, visible alarms must be located within the space they serve so the signal is visible. Based on assumptions made regarding notification device power requirements and wiring, the secondary power supply was found to be ample. The system is tested annually in accordance with NFPA 72. All devices are checked for proper operation and reporting at the panel.

The Dexter Building on the Cal Poly, San Luis Obispo campus falls into the category of Type 1 B construction based on the 2009 International Building Code. The size and type of construction materials used are sufficient to give it the fire resistance ratings required by the code. It is a mixed occupancy building but a group A occupancy comprises at least 90% of it. Lecture halls compose the bulk of the occupancies within the structures. Also, group A occupancies provide the highest requirements for fire resistance. This is in accordance with life safety being a priority.

Performance based tenability criteria for the designed fire scenario is met by the building. The designed fire scenario combines scenarios 5 and 6 from the NFPA Life Safety Code. It is a slowly developing fire in the largest fuel load of the building in close proximity to a high occupancy area. Three thirty gallon trash cans filled with materials typically found on a construction site were used.

The required safe egress time from the hand calculation as well as the Pathfinder simulation was found to be approximately 3.7 minutes. These values differed by only 4 seconds from each other. The fire does not hit a peak heat release rate for 12.5 minutes. This allows the occupants plenty of time to escape. Of the three tenability criteria, visibility is the only one that presents a problem at 330 seconds. This is the available safe egress time. However, it is still well beyond the required safe egress time. A slowly

developing fire coupled with a large room area are the reasons why temperature change and carbon monoxide concentrations are minimal. This also accounts for the visibility change at the opposite end of the room as smoke travels across cools and descends.