

ROLF JENSEN & ASSOCIATES, INC.
FIRE PROTECTION CONSULTANTS

PHASED EVACUATION FOR HIGH-RISE BUILDINGS

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Rolf Jensen & Associates, Inc.



Safety Design in Buildings



Bahrain Conference

Intercontinental Hotel Thursday, June 19, 2014



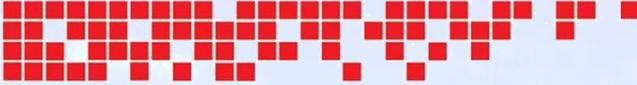
Learning Objectives

- Introduction or review of Area of Refuge Concept and associated requirements
- Understand the advantages of partial or selective evacuation in high-rise buildings
- Understand general aspects of fire alarm system design required for selective evacuation of high-rise buildings and avoidance of false alarms



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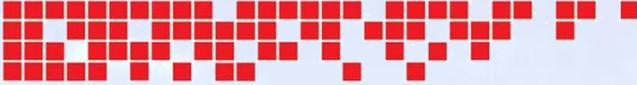
Presentation Summary

- Fire Safety Concepts Tree
- Problem Statement
- Phased Evacuation
- Refuge Floors and Elevator Evacuation
- Real World Examples
- Fire Alarm System Interface
- Conclusions



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Speaker Bio

- Vice President of Middle East Operations – RJA Dubai
 - Fire Protection Engineer and Graduate of University of Maryland
 - Professional Engineer (licensed in Delaware and Maryland) and LEED Accredited Professional
 - Project Experience includes Doha Convention Center and Tower, King Faisal Specialist Hospital, and Muscat International Airport
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Fire Safety Concepts Tree – NFPA 550

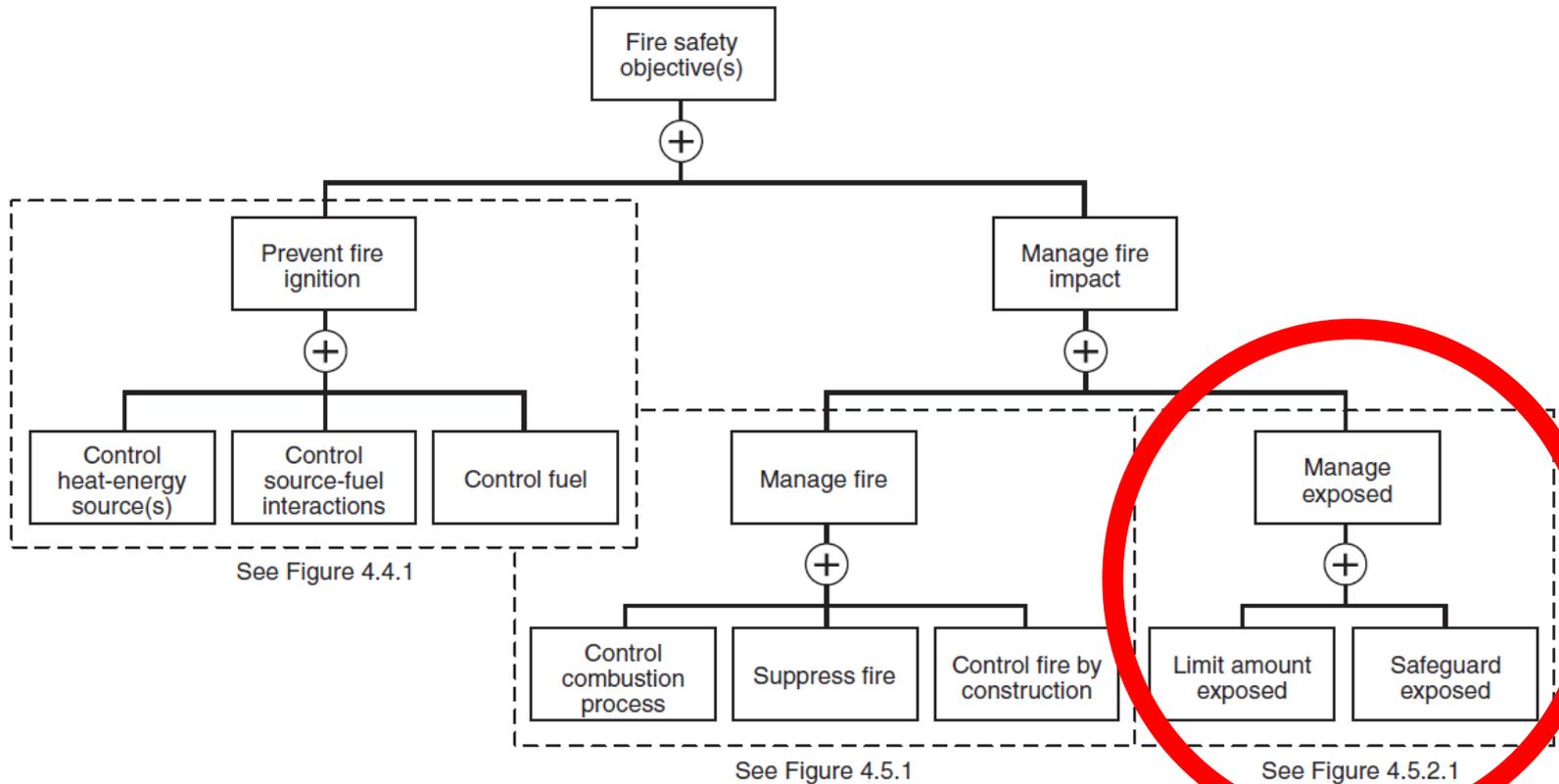


FIGURE 4.3 Top Gates of the Fire Safety Concepts Tree with Selected Lower-Tiered Gates.



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Fire Safety Concepts Tree – NFPA 550

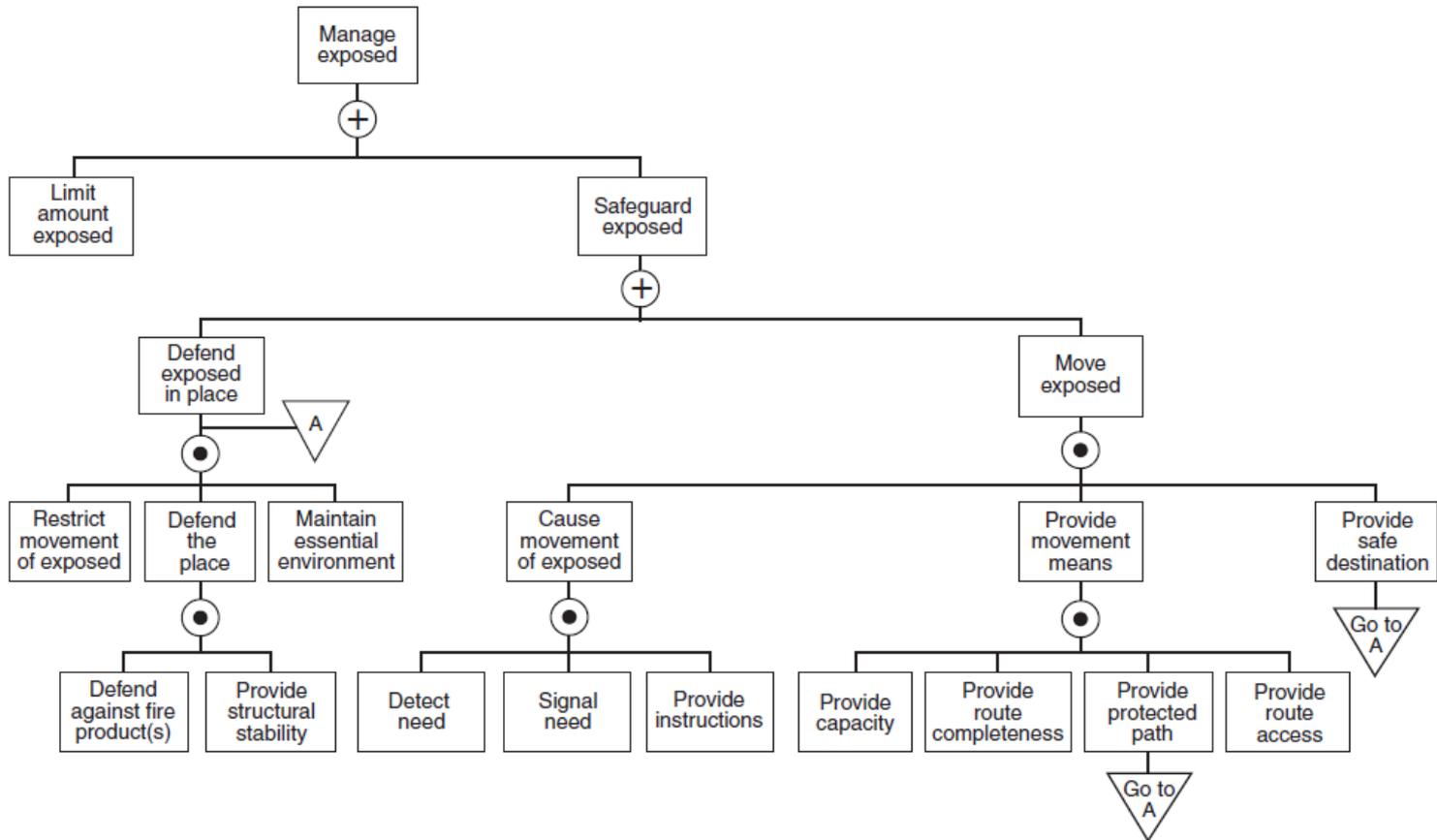
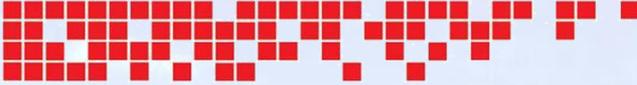


FIGURE 4.5.2.1 “Manage Exposed” Branch of Fire Safety Concepts Tree.



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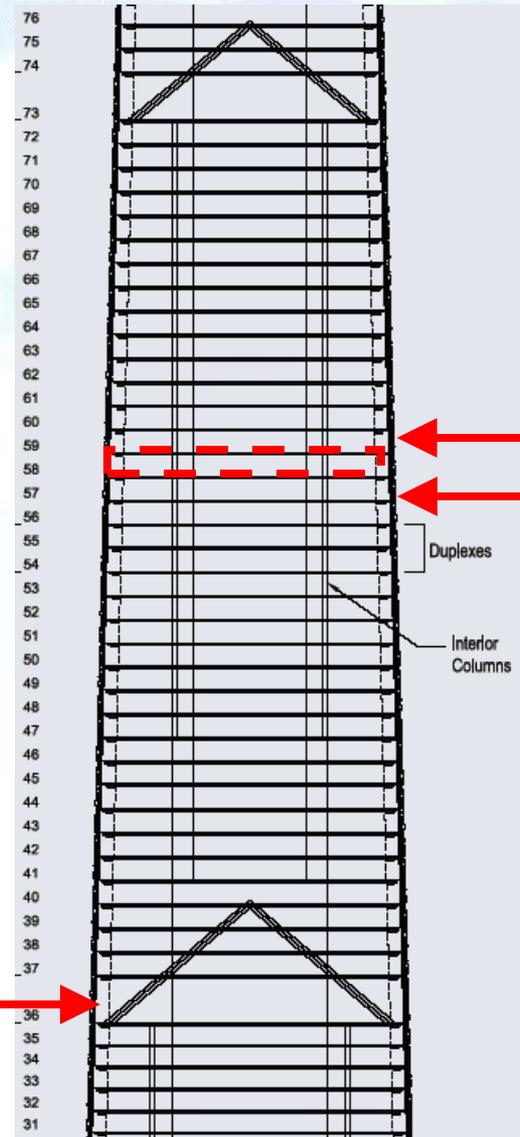
Problem Statement

*It's a **42°C** day in Bahrain. There is an **unconfirmed fire** incident in a residential **kitchen** on the **46th** floor of a 50 story mixed use tower. You are working in your office on the **18th** floor and you hear the fire alarm system indicating that you should evacuate the building.*

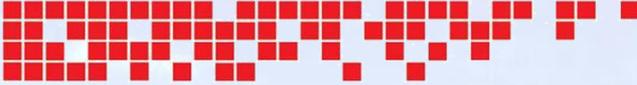


Phased Evacuation with Refuge Floors – NFPA 101

Area of Refuge. An area that is either (1) a story in a building where the building is protected throughout by an approved, supervised automatic sprinkler system and has not less than two accessible rooms or spaces separated from each other by smoke-resisting partitions; or (2) a space located in a path of travel leading to a public way that is protected from the effects of fire, either by means of separation from other spaces in the same building or by virtue of location, thereby permitting a delay in egress travel from any level.



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Refuge Floors

U.S. High Rise Design 1970's and 80's

- Active Suppression to Control Fire Growth
- Fire Rated Building Structure
- Each Floor is an Area of Refuge
- Evacuation Sequence – Fire Floor, 2 Above, 1 Below – Evacuate “4 Floors Down”

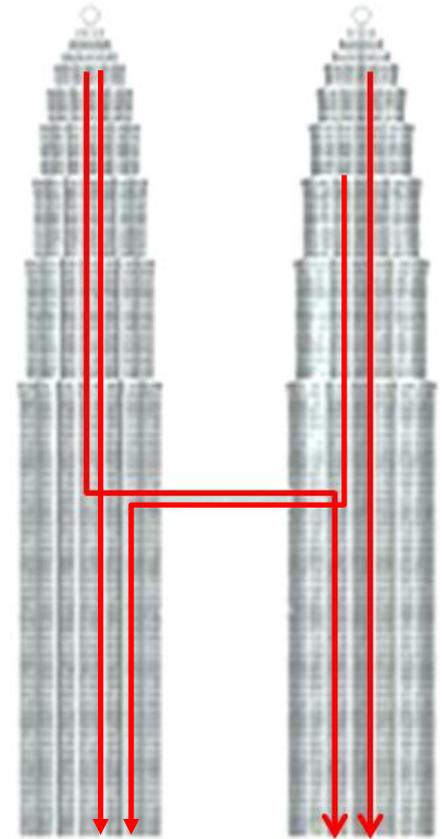


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Refuge Floors

Petronas Towers – 1998

- Active Suppression and Smoke Management Systems
- Use of Sky Lobby and Sky Bridge as Refuge Areas
- Evacuation Sequence – Occupants could exit from either tower by means of sky bridge

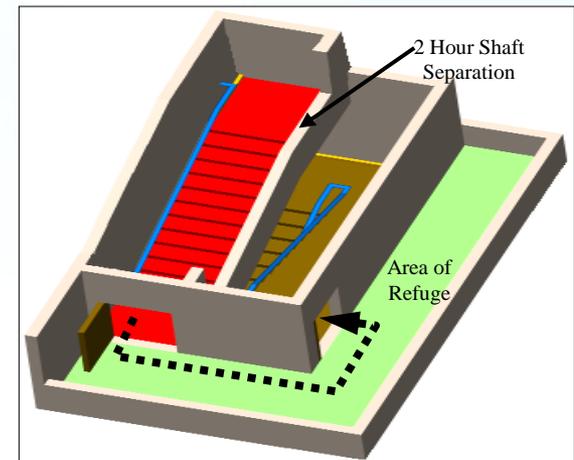
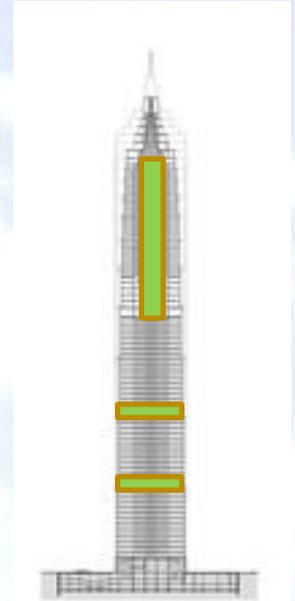


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Refuge Floors

Jin Mao Tower – 1999

- Active Suppression and Smoke Management
- Refuge Floors required by China Code every 15 floors
 - Office – Refuge Areas on Office Floors
 - Hotel – Refuge Areas Every Floor
- Stairs are Interrupted at Refuge Floors – Office Floors

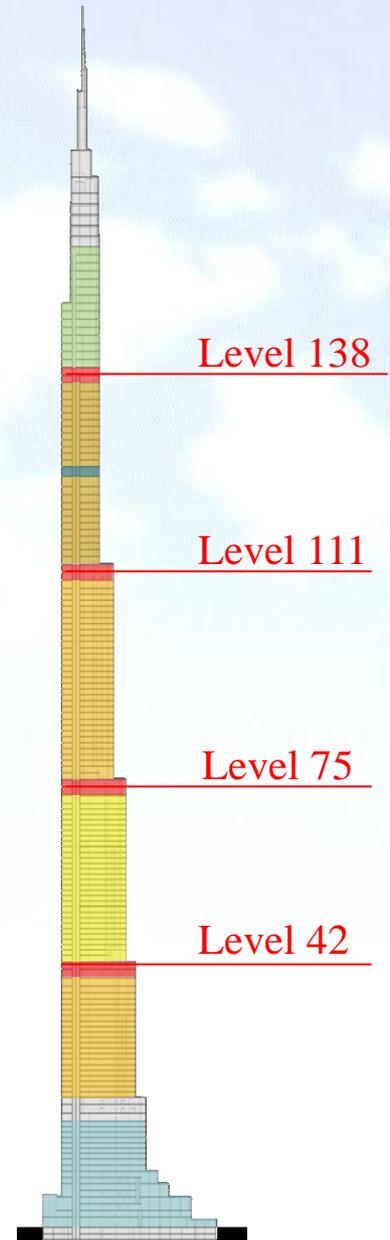


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Refuge Floors

Burj Khalifa – 2010

- Active Suppression and Smoke Management Systems
- Fire Rated Building Structure
- Refuge Areas coordinated with MEP floors
- Refuge Areas sized for Partial Occupant Load
- Stairs are Interrupted at Refuge Floors



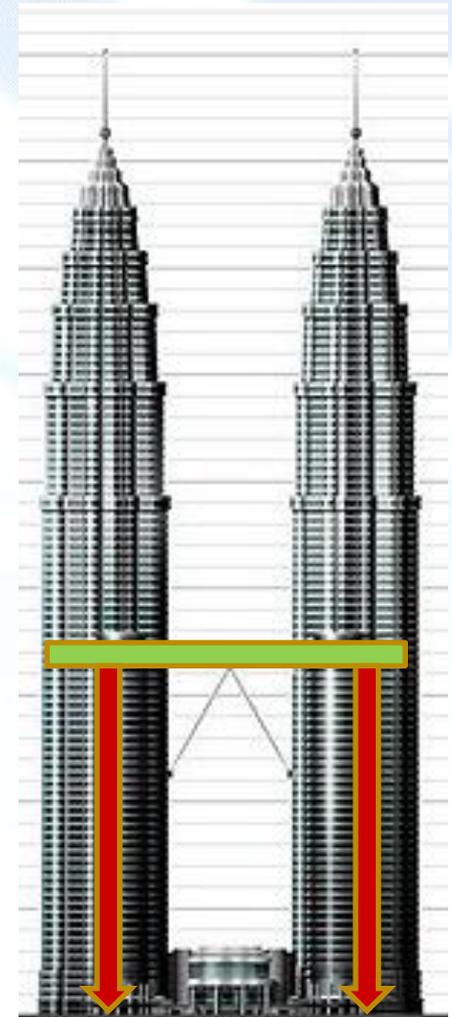
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Evacuation Elevators

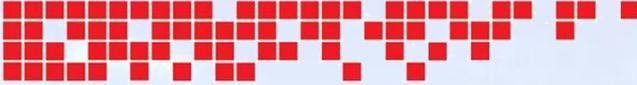
- Petronas Towers- 1998

- How can Elevators Be Used for Evacuation
- Refuge Areas Combined with Sky Lobbies
- Elevators could be Used Safely from Sky Lobbies
- Time Evacuation Calculation Including Elevators



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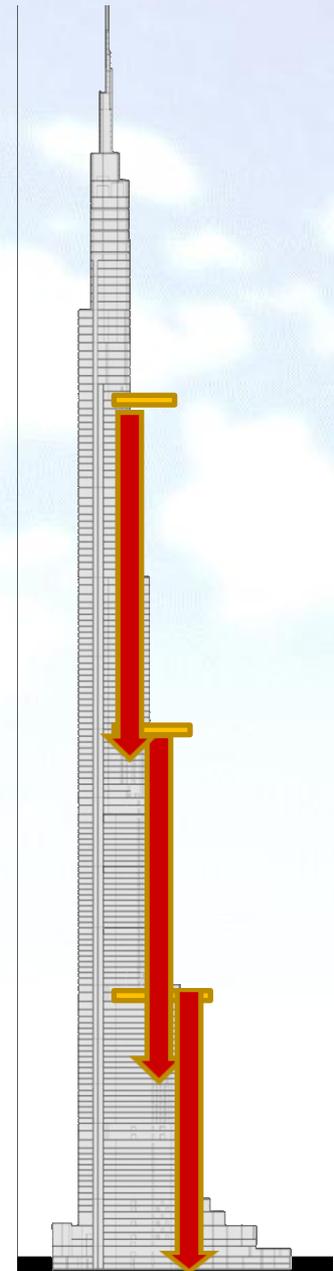


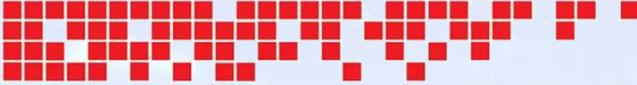
Evacuation Elevators

- Burj Khalifa- 1999
- Shanghai Tower- 2004
- Wuhan Tower- 2012
 - Shuttle Elevators with Protection Features
 - Resistant to Water Infiltration
 - Emergency Power
 - Limited stops – Lobby to Refuge Floor or Sky Lobby
 - Operated by Trained Staff



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Evacuation Elevators

- First Codified into Building Regulations in IBC 2012
- Provisions for Self Evacuation Elevators as an Alternative to Additional Stairway.
 - Self Evacuation – For Occupant Use with No Attendant
 - Available Prior to Phase 1 Recall
 - Signage to Notify if Elevators are Available for Egress
 - Applies to “All” Elevators in High Rise Building
- Implemented Selectively in U.S.



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Contemporary Design: Kingdom Tower

- Located in Jeddah, KSA
- Part of Kingdom City Development
- Mixed-Use
 - Office
 - Hotel
 - Residential
 - Observation Levels
- GFA: 320,000 SM
- Height: 1,000+ Meters



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Kingdom Tower – Building Program

LEVELS	PROGRAM	AREA
LEVEL 157 – 159	Observatory & Sky Terrace	1,583 m ²
LEVEL 126 – 153	Void Space – No Occupancy	1,618 – 1,167 m ²
LEVEL 99 - 120	Residential – Group 4	1,552 – 1,143 m ²
LEVELS 87 – 94	Residential – Group 3	1,572 – 1608 m ²
LEVELS 73 – 83	Residential – Group 2	1,841 – 1,698 m ²
LEVELS 44 – 67	Residential – Group 1	2,094 – 1,893 m ²
LEVELS 27 – 37	Service Apartments	2,057 – 2,120 m ²
LEVELS 20 – 26	Hotel Guest Rooms	2,148 – 2,269 m ²
LEVELS 7 – 14	Office	2,756 – 2,682 m ²
LEVELS B2 - 6	Lobbies, Hotel Function Spaces, Spa	14,992 – 2,757 m ²
LEVELS B3 – B1	Parking	47,718 - 20,511 m ²

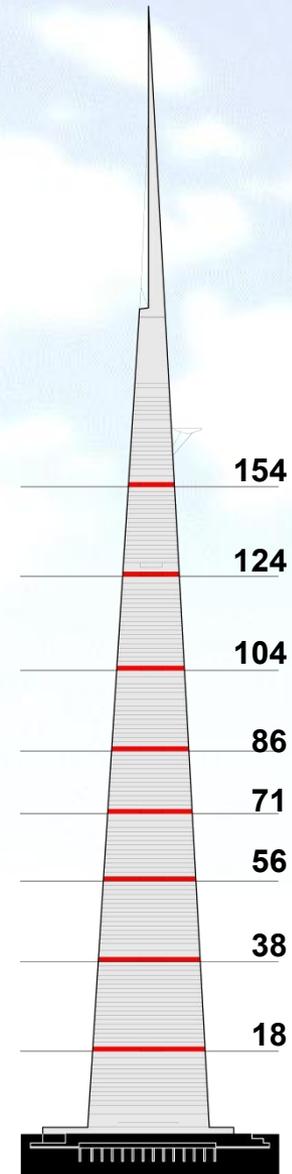


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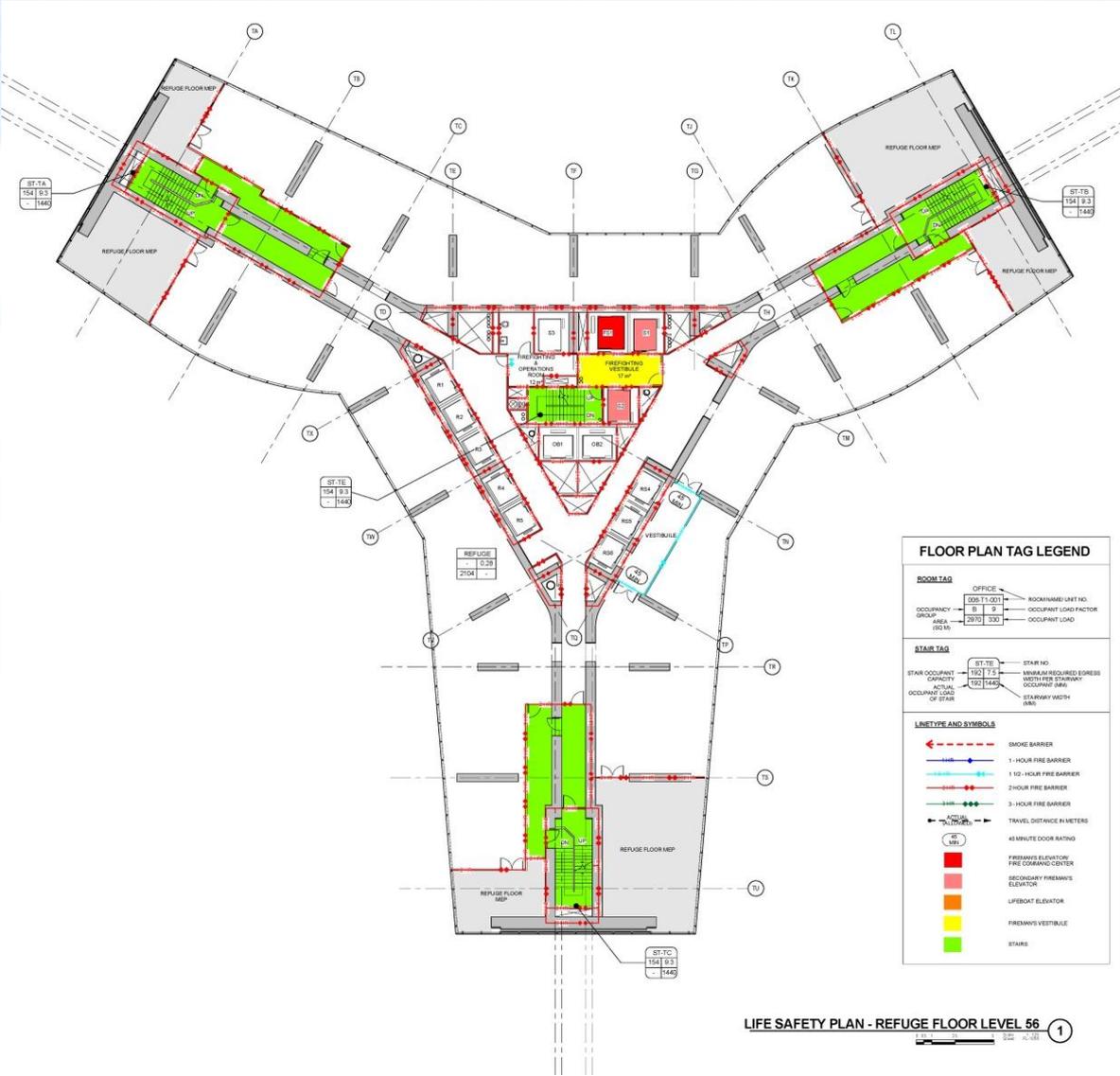
Refuge Floors

- Located Every 20 Floors
- Full Floor Refuge Areas
- Stairs are Discontinuous at Refuge Floors
- Refuge Floors are Mechanically Pressurized
- A Fire Officer is Resident in Each Refuge Floor
- Queuing Point for Evacuation Elevators



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Refuge Floors



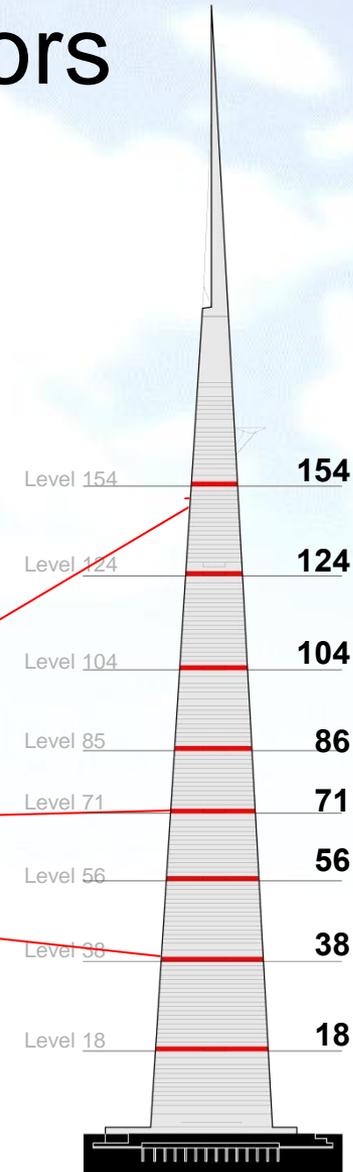
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Evacuation Elevators

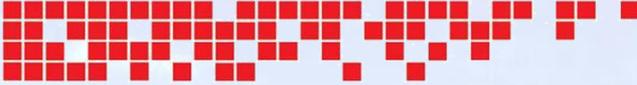
Kingdom Tower “Lifeboat” Elevators

- High Speed Shuttle Elevators For Evacuation
- Emergency Power & Protection Features
- Lifeboat Elevators Serve Refuge Floors
- Reduce Total Building Evacuation to < 2 Hours

Lifeboat Shuttle	Service
Observation Shuttles OB1, OB2	Floors 154, 104
Residential Shuttles R4, R5, R6	Floors 86, 71, 56
Residential Shuttles R1, R2, R3	Floor 38, 18



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Operational Aspects

Building Operation and Maintenance

- Adequate Staffing and Training

- Maintenance of Life Safety Systems

Crisis Management Plan

- Define Threats

- Pre-Planned Response Procedures

- Training

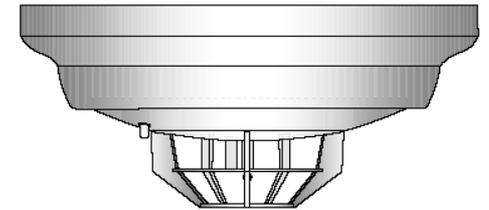
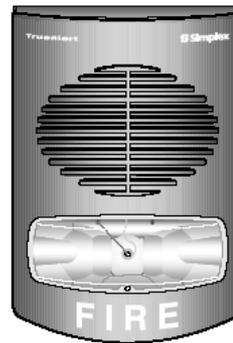
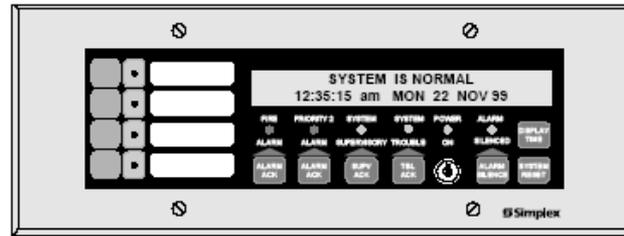
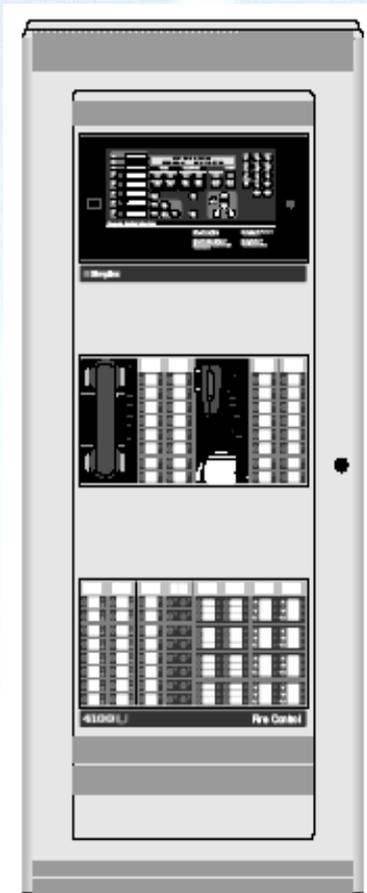
Security Issues



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Interface with Fire Alarm System



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Smoke Detectors – General Rules for Spacing and Installation

The location and spacing of smoke detectors result from engineering evaluation based on the guidelines detailed in NFPA 72 and engineering judgment. Some of the conditions included in the evaluation are the following:

1. Ceiling shape and surface
2. Ceiling height
3. Configuration of contents in the area to be protected
4. Burning characteristics of the combustible materials present
5. Ventilation
6. Ambient environment
7. Early Warning



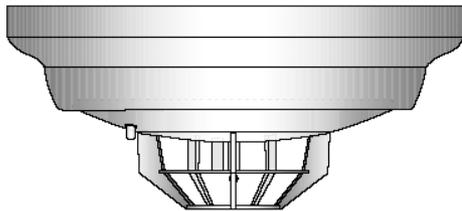
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Detection – Other Considerations

- *Smoke Detection vs. Heat Detection.* Smoke detection likely not appropriate for kitchens, mechanical rooms, or dusty/ humid/ outdoor environments.
- *Supervisory Signals.* Not all initiating devices cause alarm , e.g. duct smoke detectors, fire pump running, smoke detector missing, etc.



Cause and Effect Matrix – NFPA 72

System Inputs		System Outputs																																				
		Control Unit Annunciation								Notification								Required Fire Safety Control								Supplementary												
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG				
1	Manual fire alarm boxes – 1st floor	●	●				●				●			●				●																	●	1		
2	Manual fire alarm boxes – 2nd floor	●	●						●			●			●				●																●	2		
3	Manual fire alarm boxes – 3rd floor	●	●							●			●						●																●	3		
4	Smoke detectors – 1st floor	●	●				●				●			●					●				●													●	4	
5	Smoke detectors – 3rd floor	●	●						●			●			●				●					●												●	5	
6	Smoke detectors – 1st floor	●	●						●			●			●				●					●												●	6	
7	Smoke detectors – 1st floor elev. lobby	●	●					●			●			●					●					●												●	7	
8	2nd floor computer rm. smoke det.-zone 1	●	●						●			●			●				●					●												●	8	
9	2nd floor computer rm. smoke det.-zone 2	●	●						●			●			●				●					●												●	9	
10	In-duct smoke detector – supply fan 1	●	●						●			●			●				●					●												●	10	
11	In-duct smoke detector – supply fan 2	●	●						●			●			●				●					●												●	11	
12	In-duct smoke detector – 1st floor return	●	●						●			●			●				●					●												●	12	
13	In-duct smoke detector – 2nd floor return	●	●						●			●			●				●					●												●	13	
14	In-duct smoke detector – 3rd floor return	●	●						●			●			●				●					●												●	14	
15	Heat detectors – 1st floor mech. rm.	●	●					●				●			●				●					●												●	15	
16	Heat detectors – 2nd floor storage room	●	●						●			●			●				●					●												●	16	
17	Heat detectors – 3rd floor janitor's closet	●	●						●			●			●				●					●												●	17	
18	Waterflow – 1st floor	●	●					●				●			●				●				●													●	18	
19	Waterflow – 2nd floor	●	●						●			●			●				●					●												●	19	
20	Waterflow – 3rd floor	●	●						●			●			●				●					●												●	20	
21	Sprinkler control valve – 1st floor			●	●							●			●				●					●												●	21	
22	Sprinkler control valve – 2nd floor			●	●							●			●				●					●												●	22	
23	Sprinkler control valve – 3rd floor			●	●							●			●				●					●												●	23	
24	Fire pump running	●	●									●			●				●					●												●	24	
25	Fire pump power failure/phase reversal			●	●							●			●				●					●												●	25	
26	Fire alarm ac power failure					●	●								●				●					●													●	26
27	Fire alarm system low battery					●	●								●				●					●													●	27
28	Open circuit					●	●								●				●					●													●	28
29	Ground fault					●	●								●				●					●													●	29
30	Notification appliance circuit short					●	●								●				●					●													●	30

FIGURE A.14.6.2.4 Typical Input/Output Matrix.



Avoiding False Alarms

- *Positive Alarm Sequence*

- Smoke detector activation followed by 15 second acknowledgement period.
- After acknowledgement, staff have 180 seconds to investigate and confirm fire conditions.
- After 180 seconds, fire alarm panel sounds alarm signal.
- If a second detector or an automatic sprinkler activates at any point in the interim, the fire alarm panel sounds alarm signal.

- *Alarm Verification*

- Smoke detector activation followed by period of 1 minute where the panel checks to see if the smoke condition is still present. If at 1 minute smoke is still present at the detector, the fire alarm panel sounds an alarm signal.
- If a second detector or an automatic sprinkler activates at any point in the interim, the fire alarm panel sounds alarm signal.

- *Selective Evacuation*

- *Alarm to the floor or zone of fire origin, floor above and floor below. Alert to adjacent zones.*





Conclusions – Reconsider our Problem Statement

- *42°C day.* Do not evacuate the entire building unless essential to safety of building occupants. Utilize refuge floors if possible.
- *Unconfirmed fire incident in residential kitchen on upper floors.* Apply detection devices appropriate for the hazard (heat detection, etc.) Program the fire alarm system for positive alarm sequence.
- *Unaffected occupants on lower floors of the tower.* Program the fire alarm system for selective evacuation.



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Thank You

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