

4 EVACUATION

Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.1.1
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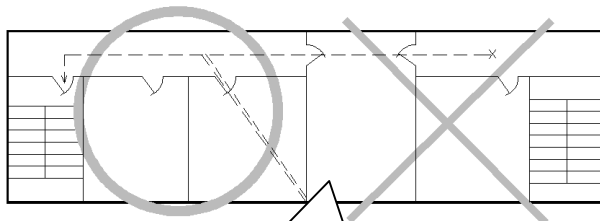
Principle of Evacuation Planning

The principle of evacuation planning is to provide a safe evacuation route from any point of a building to a safe area outside the building. A safe evacuation route is one that is:

- Same with path of flow in the daily route,
- Ready for evacuation at all times,
- Continuous with one or more exits and public ways,
- Resistant to fire and smoke,
- Of sufficient in capacity,
- Redundant by plural paths of travel, etc.,
- Not hindered by any obstructions,
- Suitable for the type of occupant's.

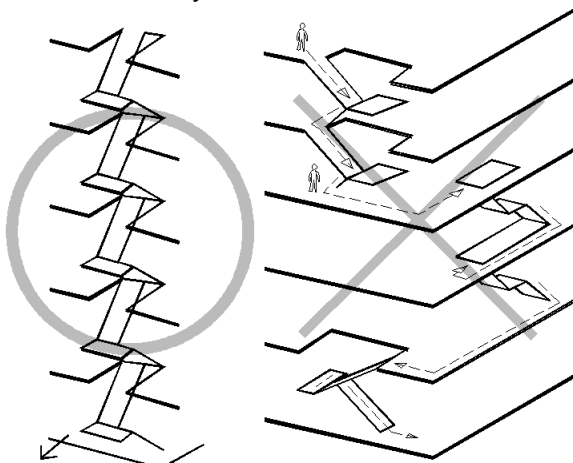
Continuity of Evacuation Route

Continuity of Horizontal Evacuation Route



Do not locate any room on the evacuation route.

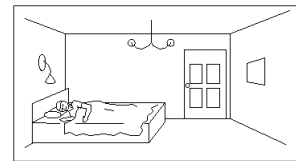
Continuity of Vertical Evacuation Route



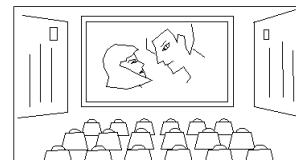
Evacuate to outside

Variety of Occupant's Characteristic

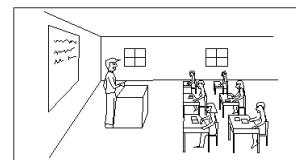
Sleeping in Hotel and Housing



High Density in Theater and Department Store



Trained in Offices School, and Factory



Disability of the Aged, Infant, and Handicapped in Hospital



4.1.2	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Basic Idea of Evacuation Planning

The basic idea of evacuation planning is to complete evacuation before smoke builds a hazardous level that the smoke descends to the particular height at which it obstructs evacuation. The evacuation time must be shorter than the time for the smoke descent.

$$T_{\text{evacuation}} \leq T_s$$

($T_{\text{evacuation}}$: Time to complete evacuation, T_s : Time for the smoke descent to the hazardous level)

1) Time to complete evacuation ($T_{\text{evacuation}}$)

T_{escape} is the sum of two periods; i) Time to start evacuation (t_{start}) and ii) Time to complete evacuation after the start ($t_{\text{evacuation}}$).

$$\square T_{\text{evacuation}} = t_{\text{start}} + t_{\text{evacuation}}$$

t_{start} and $t_{\text{evacuation}}$ have further subdivided periods.

1) Time to start evacuation (t_{start})

$$\square t_{\text{start}} = t_{\text{awareness}} + t_{\text{decision}}$$

$t_{\text{awareness}}$: Time until awareness of fire

t_{decision} : Time to decide to evacuate

2) Time to complete evacuation after the start ($t_{\text{evacuation}}$)

$$\square t_{\text{evacuation}} = t_{\text{travel}} + t_{\text{queue}}$$

t_{travel} : Time to walk through the evacuation route
 $= L/v$

(L: Length of egress travel, v: Walking velocity)

t_{queue} : Time to pass through the narrowest point of the evacuation route

$$= P/NB$$

(P: Number of occupants,

B: Narrowest net width of evacuation route (m),

N: Discharge coefficient (person/ms))

2) Time for the smoke to descend to the hazardous level (T_s)

T_s is the accumulated time in which smoke spreads to the space in front of escape stairways.

$$\square T_s = \sum t_i$$

(t_i : Time for smoke spillage in each room, located along the path from the fire origin to an escape stairway)

The verification method of evacuation planning in Japan specifies the formula of t_i ;

$$\square t_i = \{A_{\text{room}} (H_{\text{room}} - H_{\text{lim}})\} / \{\max(V_s - V_e, 0.01)\}$$

(A_{room} : Floor area,

H_{room} : Average ceiling height,

H_{lim} : Hazardous height of smoke from the floor surface level,

V_s : Volume of smoke generation,

V_e : Volume of smoke exhaust)

Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.1.3
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Components of Evacuation Route

The evacuation route is composed of three portions: exit access, exit, and exit discharge. Those three components are considered as:

1) "Exit Access" is the portion of an evacuation route from any occupied point in a building to an exit.

These include:

- Corridors: An enclosed path of the exit access,
- Aisles: Other paths of exit access, such as passageways in rooms and theaters.

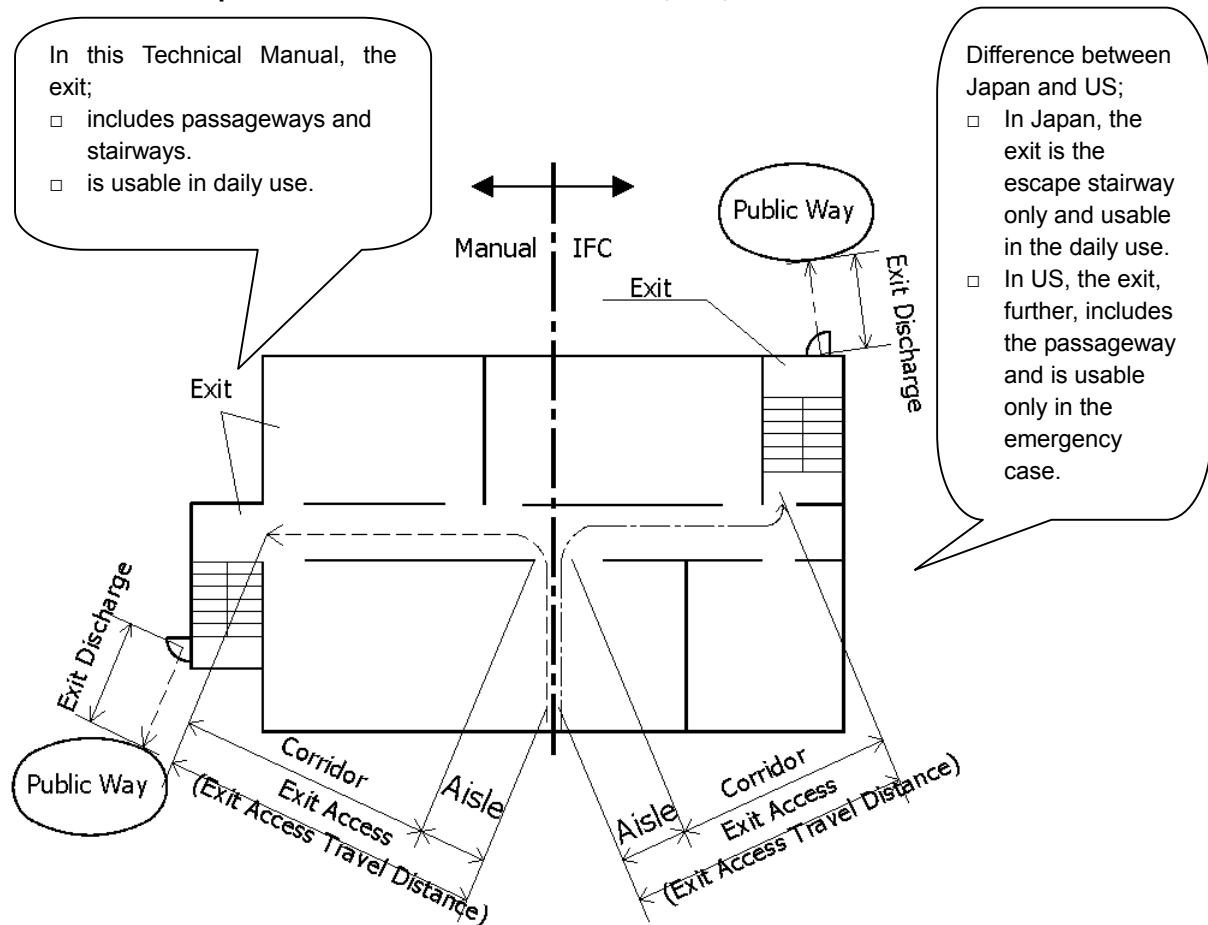
2) "Exit" is the portion of an evacuation route that is separated from other interior spaces of a building by fire resistance structure and opening protection. Such as;

- Exit passageways for evacuation in the horizontal direction,
- Escape stairways and outside escape stairways for evacuation in the vertical direction.

3) "Exit Discharge" is the portion of an evacuation route between the termination of an exit and a public way.

- A public way is a street, alley or other parcel of land open to the outside air leading to a street.

Component of Evacuation Route in BSL, IFC, and this Technical Manual



4.1.4	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Capacity of Evacuation Route (1/2)

The evacuation route must have sufficient capacity to allow smooth evacuation. The capacity is directly related to the width of the evacuation route. Fire codes in other countries usually regulate a minimum width for evacuation routes based upon the number of occupants. For example, the fire code in the United States specifies:

1) Width of stairway (B) should be not less than the unit width ($w=0.3\text{inch/occupant}$), multiplied by the number of occupants (P) to ensure complete evacuation within two minutes (T).

□ Time to discharge (T) = $P/(BXN_{\text{eff}}) = P/(PXwXN_{\text{eff}}) = 1/(0.3X45/22) = 1.63$ minutes

(whereby, $N_{\text{eff}}=45\text{occupants/unit/minute}$, 1unit=22inch)

2) Width of corridor (B) also allows occupants to pass through the narrowest point of the corridor within two minutes.

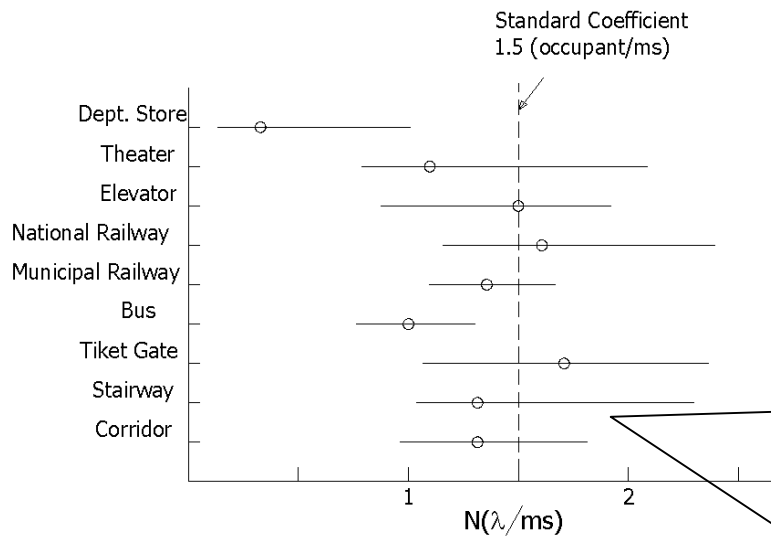
□ Time to discharge (T) = $P/(PwXN_{\text{eff}}) = 1/(0.2X60/22) = 1.83$ minutes

(whereby, $w=0.2\text{inch/occupant}$, $N_{\text{eff}}=60\text{occupants/unit/minute}$, 1unit=22inch)

Fire codes in Japan adopt the discharge coefficient:

- 80 occupants/m/minute for stairways,
- 90 occupants/m/minute for corridors.

Survey on Discharge Coefficient in Japan



There are no suitable survey data from other countries which clearly show the appropriate discharge coefficient, because surveys reflect occupant characteristics such as:

- Mental degree to hurry,
- Less crowded.

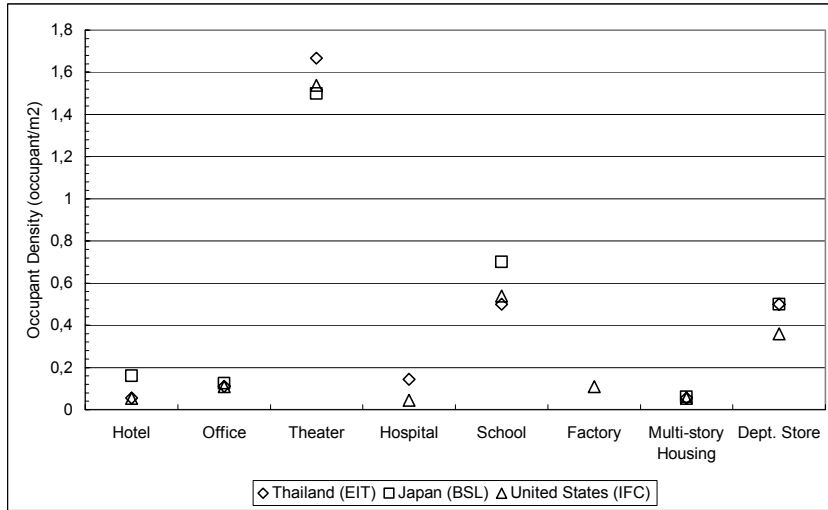
The standard coefficients used in Japan are:

- 1.5person/m/s in horizontal,
- 1.3person/m/s in vertical.

Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.1.4
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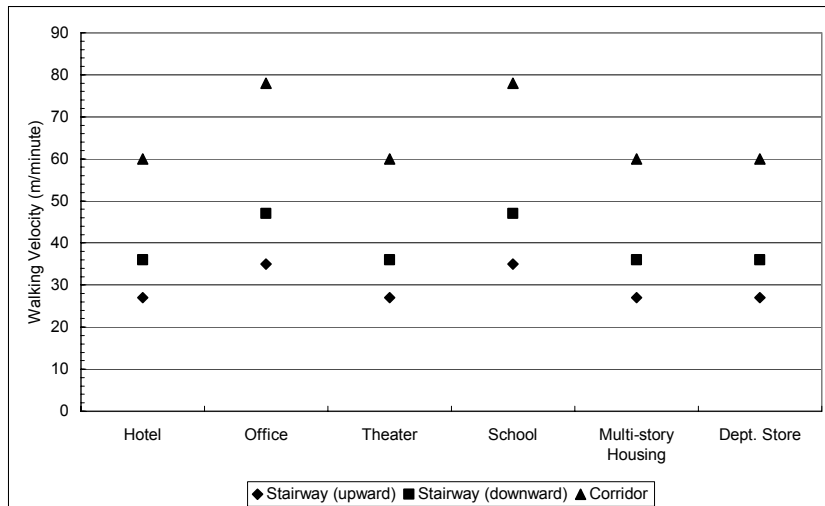
Capacity of Evacuation Route (2/2)

Occupant Density in Thailand, Japan, and United States



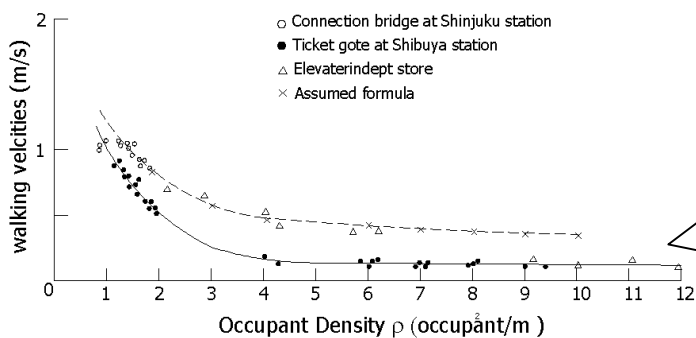
The occupant density of the three countries is similar except for theaters and department store.

Walking Velocity by Classification of Building in Japan



The walking velocity in the horizontal direction is the fastest.

Survey on Walking Velocity by Occupant Density in Japan



The survey shows;
 □ Walking velocity decreases, as the occupant density increases,
 □ When the density exceeds 4.0 occupants/m², the walking velocity becomes stable.

4.1.5	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Multiple Evacuation Routes (1/2)

Fire can start in any part of a building, including evacuation routes. Therefore, any point in a building must have two or more evacuation routes.

Fire codes in other countries require the number of evacuation routes by floor area or the number of occupants:

1) Fire codes in United States require:

- two or more exits for a room or floor with 50 occupants,
- three or more exits for a room or floor with 500 occupants,
- four or more exits for a room or floor with 1,000 occupants,

2) Fire codes in Japan require two through stairways or more for a floor with:

- 50 m² for hospitals,
- 100 m² for hotels and multi-story housing,
- 200 m² or 400m² for offices, schools, factories, and department stores,

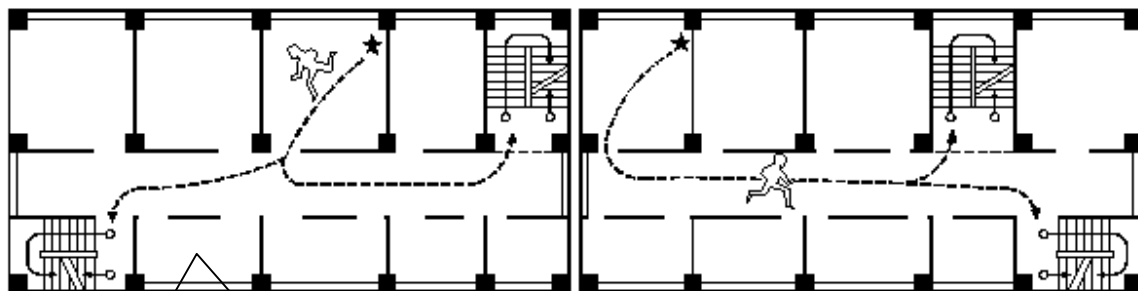
When the floor areas are converted to the number of occupants by occupant density, the numbers vary from 16 to 280 occupants.

Well-balanced Layout of Escape Stairways

Unbalanced Layout of Escape Stairways

(sample)

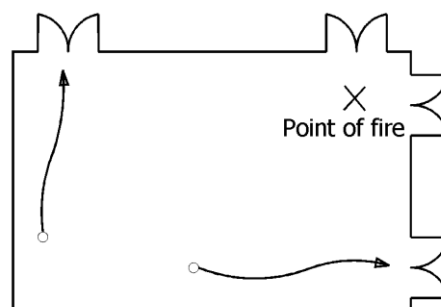
(sample)



Evacuation route should be;

- Simple,
- Well-balanced in their location,
- Connected with escape stairways at the end of its path.

Discounted Number of Evacuation Routes

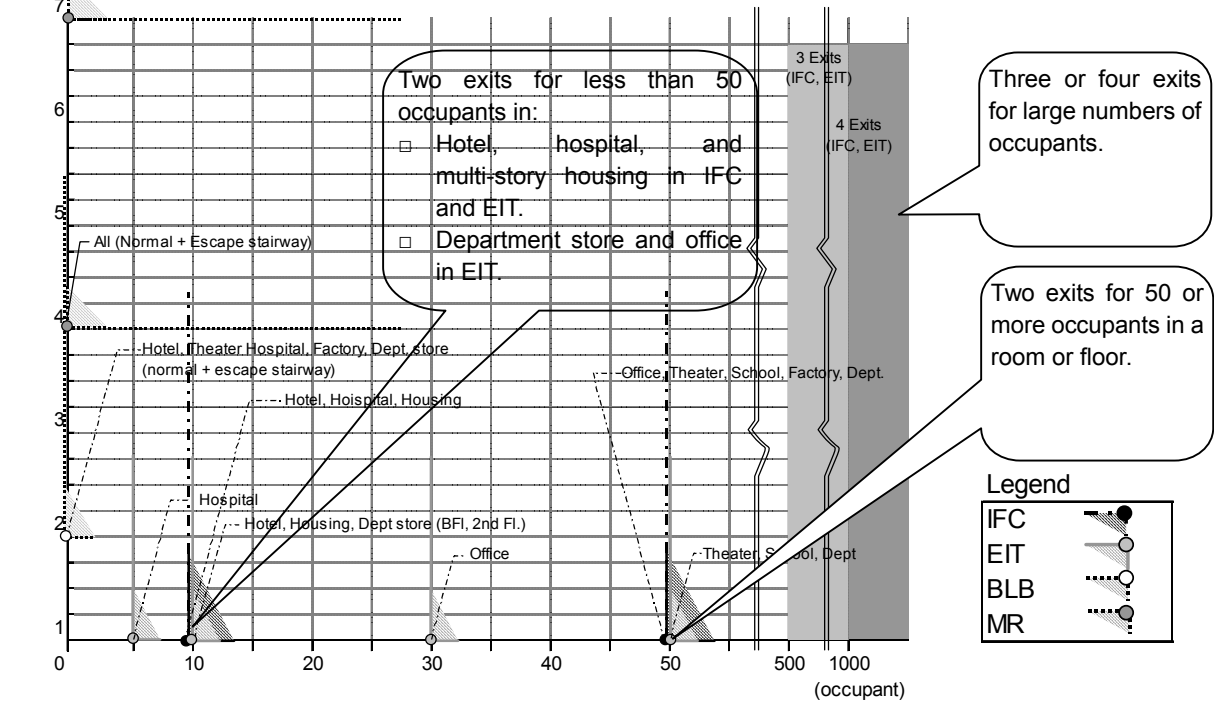


Closely located doors may be simultaneously blocked by fire. These two evacuation routes are counted as one route.

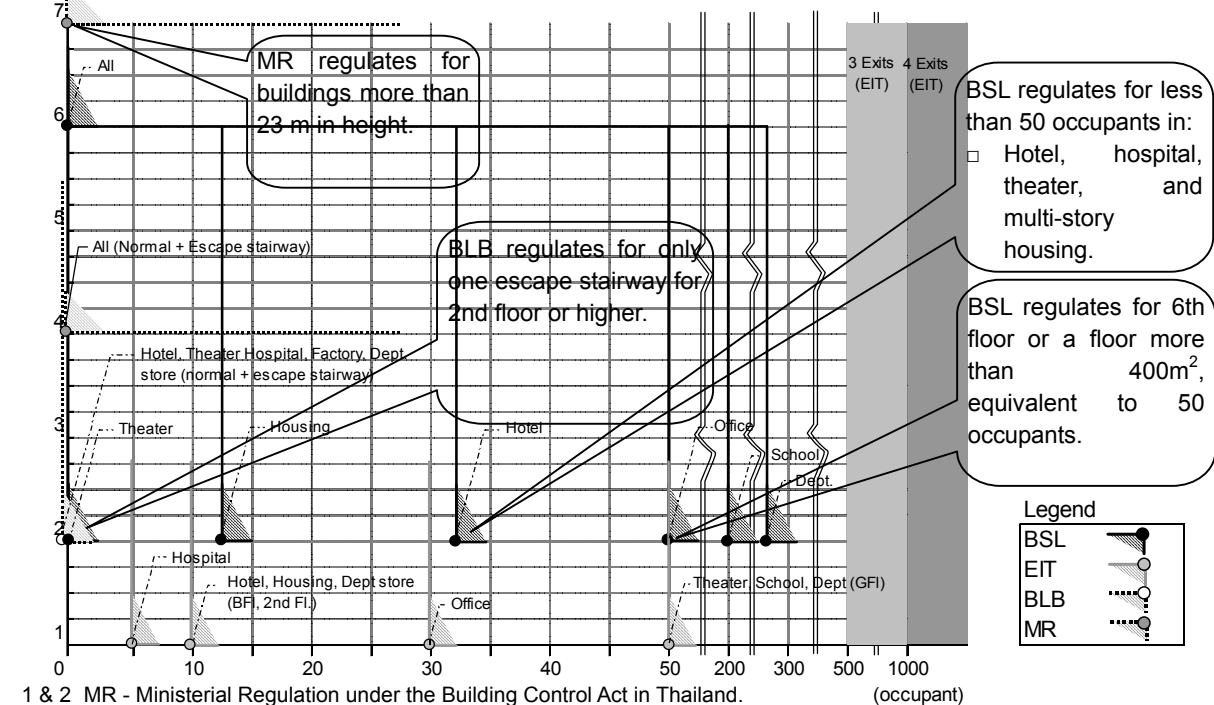
Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.1.5
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Multiple Evacuation Routes (2/2)

Rooms and Floors Requiring Two or More Evacuation Routes in IFC, EIT, BLB, and MR¹



Floor with Two or More Evacuation Routes in BSL, BLB, and MR²



1 & 2 MR - Ministerial Regulation under the Building Control Act in Thailand.

BLB - Bangkok By-Law in Thailand

EIT - Standard of the Engineering Institute of Thailand.

BSL - Building Standard Law in Japan.

IFC - International Fire Code in United States.

4.1.6	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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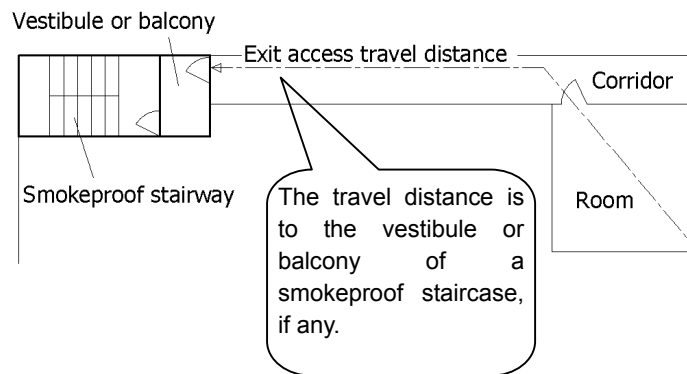
Maximum Exit Access Travel Distance (1/2)

When fire breaks out, occupants must reach an exit as soon as possible. The maximum exit access travel distance aims to regulate the maximum length from any part of a building to an exit. In other words, it aims for well-balanced layout of evacuation routes

The maximum exit access travel distance is generally;

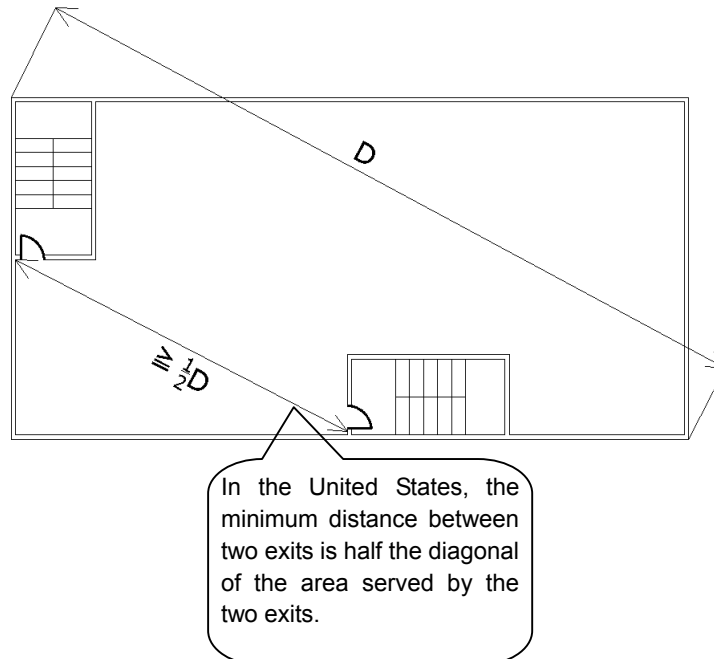
- 50 m for 15th floor or higher and 40 m for less than 15th floor in Japan,
- 61 m in United States.

Maximum Exit Access Travel Distance



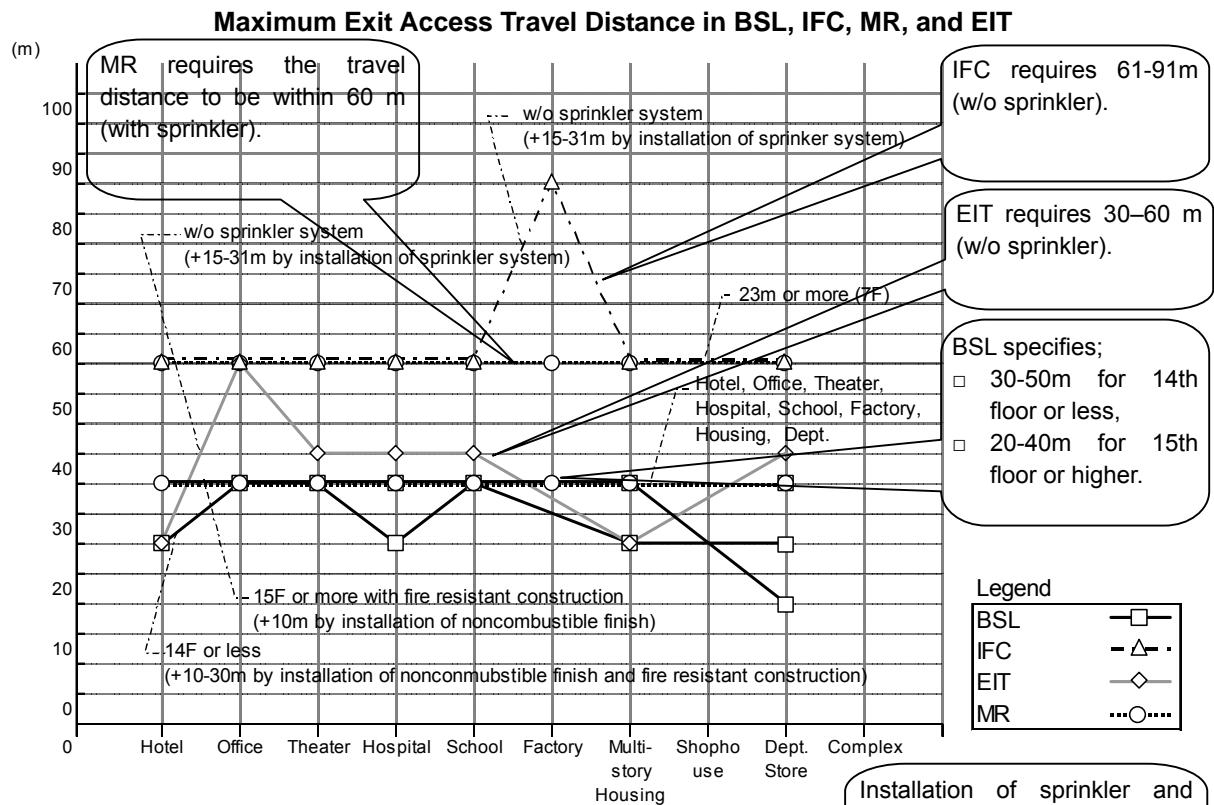
In the United States, the minimum distance between two exits is regulated to properly disperse the exits.

Minimum Distance between Exits in the United States



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.1.6
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Maximum Exit Access Travel Distance (2/2)



Installation of sprinkler and noncombustible interior finish alleviates the travel distance in Japan and US regulations.

Details of Maximum Exit Access Travel Distance in BSL, IFC, MR, and EIT

Building Type	MR		EIT		BSL				IFC		
	23m or more (with sprinkler)	60	w/o sprinkler	with sprinkler	14th Fl. or less		15th Fl. or more		w/o sprinkler	with sprinkler	
			30	60	FPB with NCIF	Others	FPB with NCIF	50	76		
Hotel	40	60	30	60	50	60	30	40	50	61	76
Office	40	60	60	91	50	60	40	40	50	61	91
Theater	40	60	45	60	50	60	40	40	50	61	76
Hospital	40	60	45	60	50	60	30	40	50	61	76
School	40	60	45	60	50	60	40	40	50	61	76
Factory	40	60	-	-	-	-	-	-	-	91	122
Multi-story housing	40	60	30	60	50	60	30	40	50	61	76
Shophouse	-	60	-	-	-	-	-	-	-	-	-
Dept. store	40	60	45	60	30	40	30	20	30	61	76
Complex	-	60	-	-	-	-	-	-	-	-	-
Subjects of Distance	normal stairs	fire escape stairs	exits		through stairs				exits		

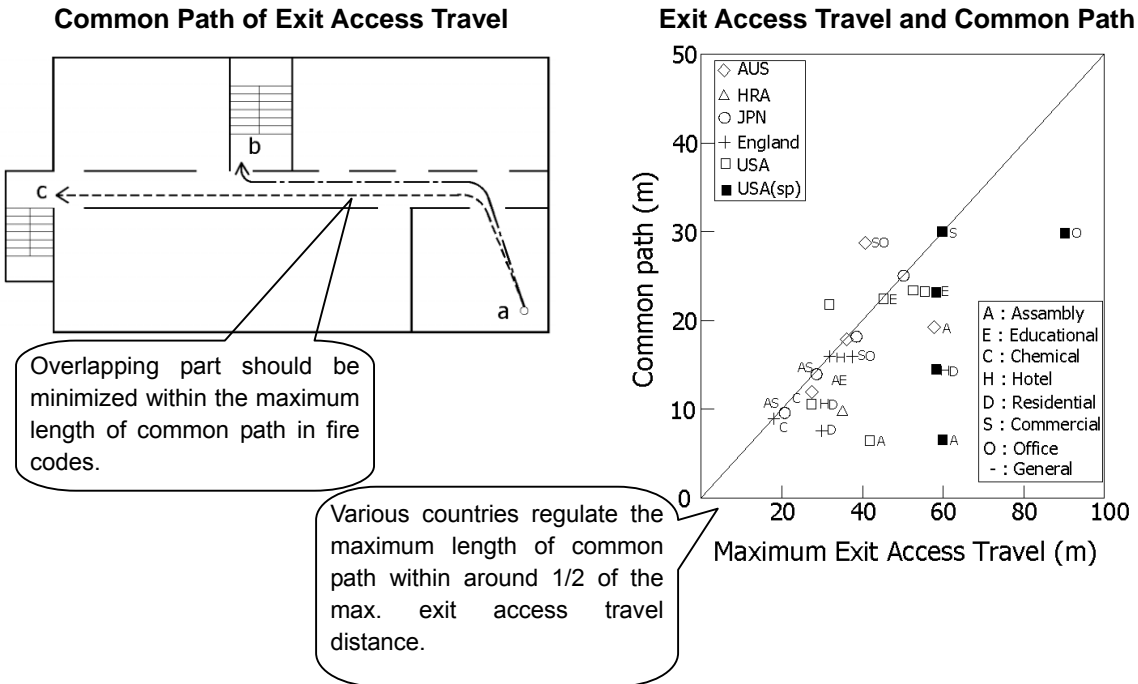
- Note: 1) MR - Ministerial Regulation under the Building Control Act in Thailand.
 2) EIT - Standard of the Engineering Institute of Thailand.
 3) BSL - Building Standard Law in Japan
 4) IFC - International Fire Code in United States.
 5) NCIF means Noncombustible Interior Finish, while FPB is Fireproof Building.
 6) BSL and MR regulate the distance to escape stairways, while EIT and IFC regulate to exits.

4.1.7	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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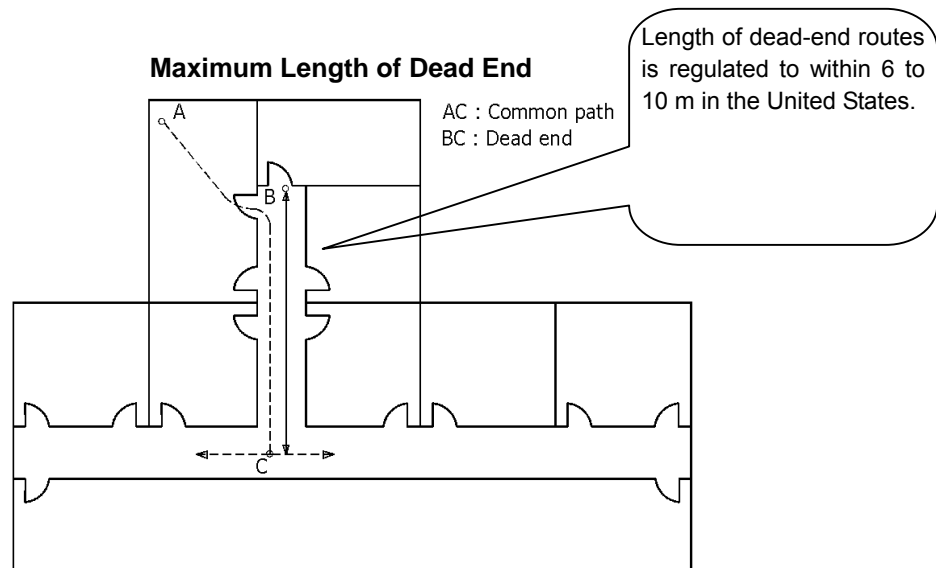
Common Path of Exit Access Travel (Maximum Length of Dead End)

The common path of exit access travel aims to regulate the length of overlapping parts of two evacuation routes. Allowance for overlapping is effective for the flexibility of the evacuation routes, while it ensures redundancy of the evacuation routes.

Generally speaking, the regulated maximum common path of exit access travel is within around a half of the maximum exit access travel distance.



The maximum length of the dead-end is to regulate the length of path in dead-ends. An occupant often enters dead-ends by mistake. By the time he or she returns to the correct evacuation route, heat and smoke may have closed the evacuation route. Therefore, dead-end routes should be eliminated or minimized



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.2.1
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Form of Corridors and Aisles (1/2)

The corridors and aisles form the horizontal part of the evacuation routes. Those horizontal parts are connected to an escape stairway and exit discharge. Firstly, the corridors and aisles must be safe and secure through provision of:

- Flat and slip-resistant surface,
- Fire and smokeproof construction,
- Noncombustible interior finish,
- Fire protection at openings.

In addition to safety, the corridors and aisles require sufficient capacity for the occupants who evacuate through these parts. Fire codes in Thailand, Japan, and United States regulate the minimum width of corridors as:

- 150 cm, uniformly in Thailand,
- 120 cm for corridors serving only one side and 160 cm for corridors serving both-sides in Japan,
- 91.4 cm for 50 occupants or less, and 111.8 m for more than 50 occupants in the United States.

Width of corridors is uniform in Thailand and Japan, while it proportionally changes by the number of occupants in US.

Minimum width for corridors proportionally increases by 0.508 cm/occupant in the US. On the other hand, fire codes in the US specify uniform width for aisles.

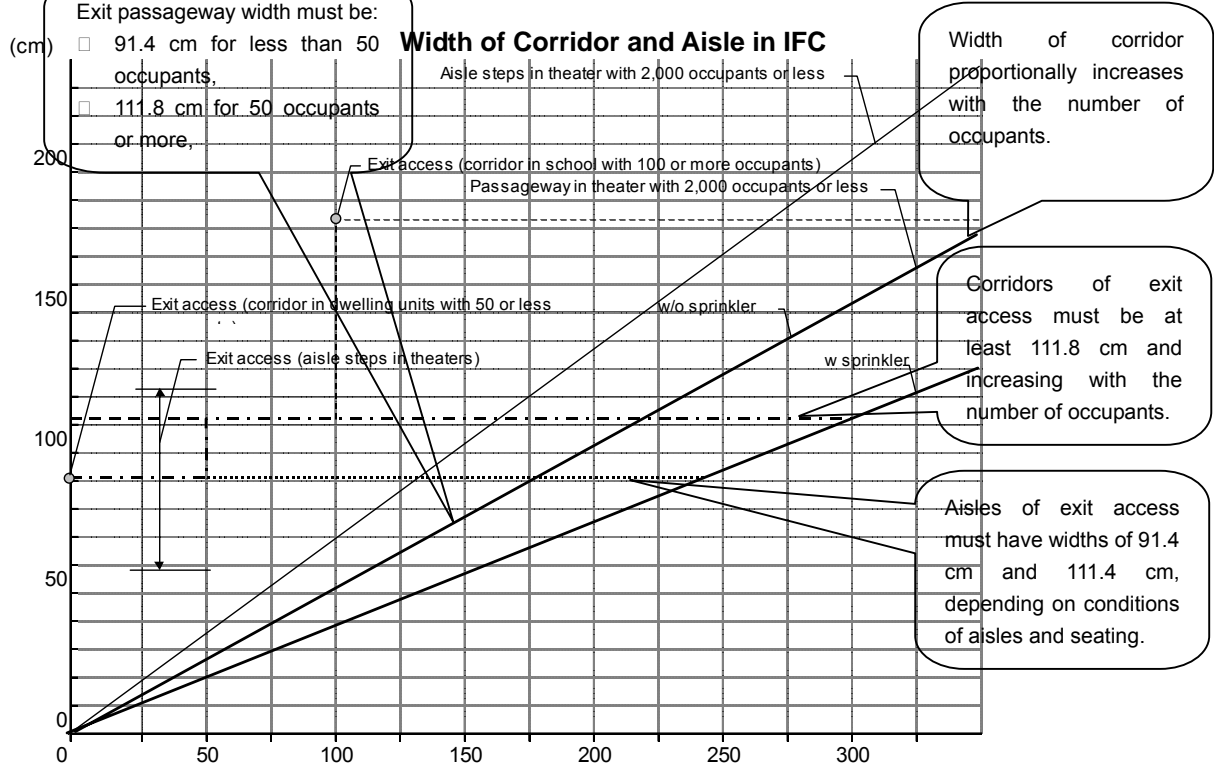
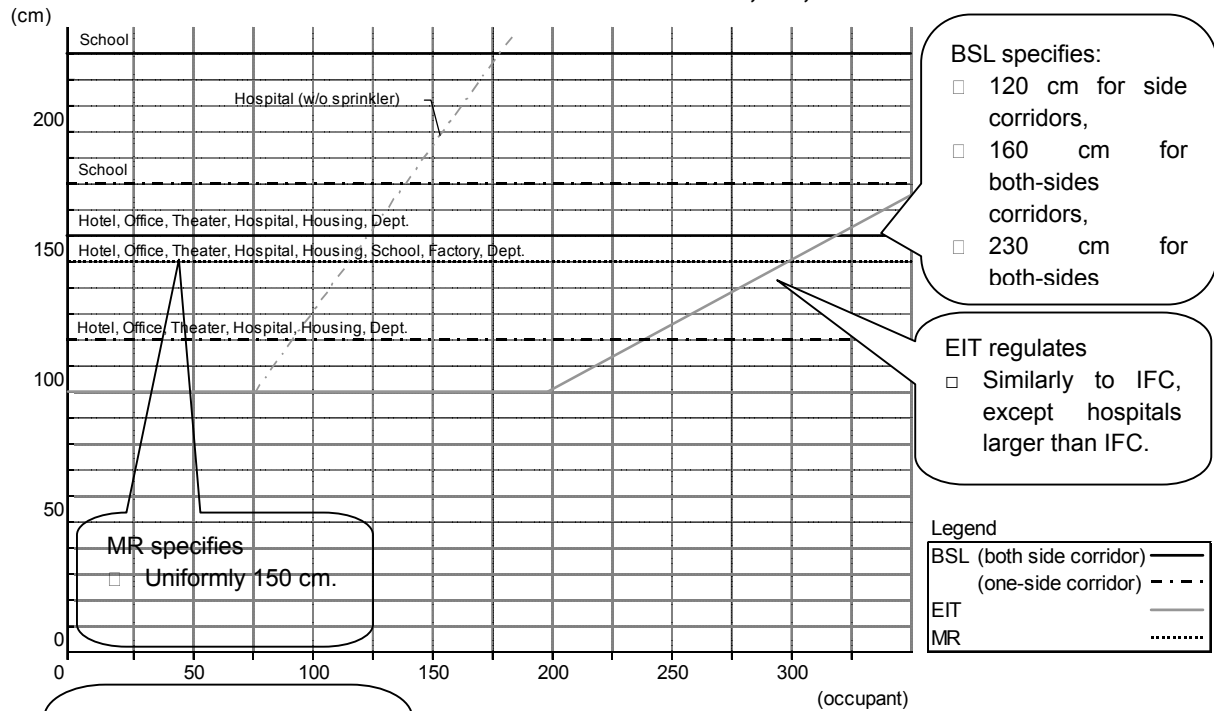
- 91.4 cm and 111.8cm, depending on the layout of table and chairs along the aisle.

The fire code in the United States specifies the total width of corridors. It also regulates, when one exit is out of use, the remaining exits must maintain 50% or more of required capacity.

4.2.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Form of Corridors and Aisles (2/2)

Width of Corridor and Aisle in BSL, EIT, and MR



Note:

- 1) MR: Ministerial Regulation under the Building Control Act.
- 2) EIT: Standard of Engineering Institute of Thailand.
- 3) BSL: Building Standard Law in Japan.
- 4) IFC: International Building Code in United States.

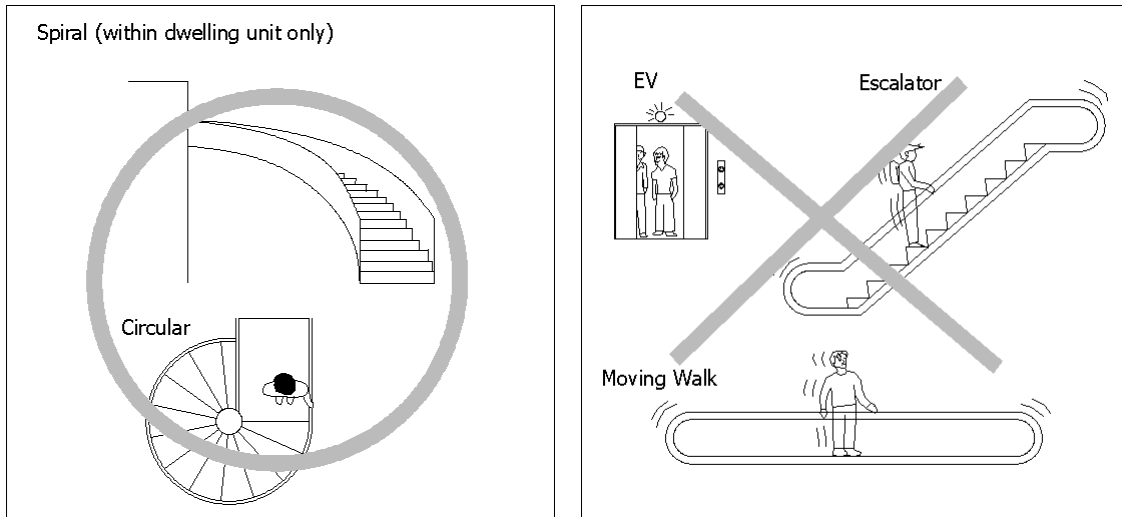
Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.2.2
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Type of Escape Stairway (1/3)

The stairway forms a main structure in the vertical path of an evacuation route. It has to provide safe passage as well as easy travelling.

From the point of view of safe passage, elevators, escalators, and moving walkways are not suitable for exit access, while a spiral-type stairway is usable only within a dwelling unit.

Appropriate and Inappropriate Types of Stairways for Exit Access



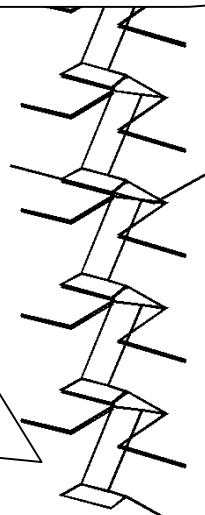
Escape stairways are classified into four types: 1) through stairways, 2) escape staircases, 3) smokeproof staircases, and 4) outside escape stairways.

Types of Escape Staircase

Through Stairway

Through stairway can reach a safe floor, that has an access directly to the outside, without any interruption and change of path. This is the common requirement of all kinds of escape stairways.

At the safe floor, a stoppage is necessary to prevent an occupant from wrongly passing by the safe floor.



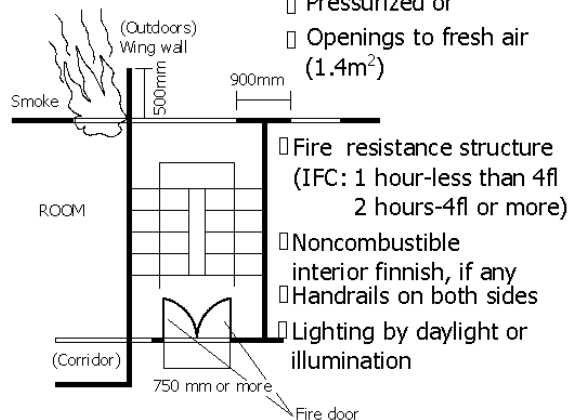
Escape Staircase (inside buildings)

(Openings to outside, if any)

- Wing wall >50 cm or
- Distance >90 cm from another windows

(BSL)

- Pressurized or
- Openings to fresh air (1.4m²)



- Fire resistance structure (IFC: 1 hour-less than 4fl, 2 hours-4fl or more)
- Noncombustible interior finish, if any
- Handrails on both sides
- Lighting by daylight or illumination

(Opening to inside, if any)

- Fire preventive devices at any openings, i.e. BSL:fixed-sash type with wired glass within 1 m², IFC:3/4hour fire resistance

4.2.2	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Type of Escape Stairway (2/3)

Types of Escape Stairway

Smokeproof Staircase (inside buildings)

Requirements for smokeproof staircases in Japan are:

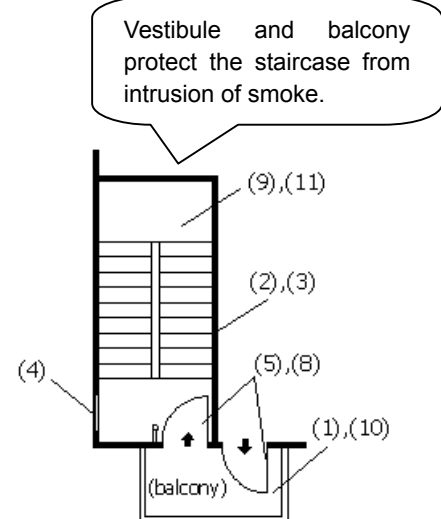
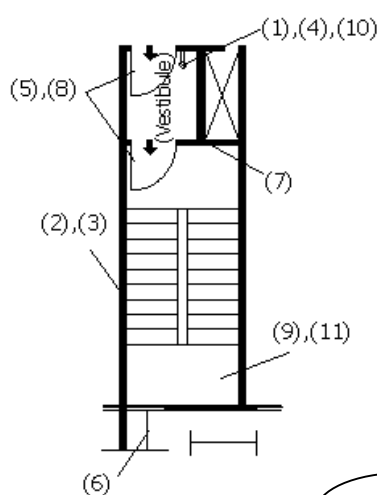
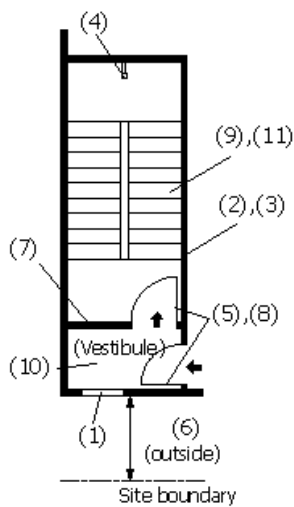
- (1) vestibule with opened window to outside or exhaust system, or balcony
- (2) fire resistance for walls and stairs, (IFC, EIT: 2 hours)
- (3) noncombustible interior finish, if any
- (4) lighting in staircase by daylight or illumination
- (5) fire doors for staircase, vestibule, and balcony (IFC, EIT: 1 hour)
- (6) openings to outside: sufficient distance from site boundary, wing wall of 50 cm, distance of 90 cm from other openings
- (7) openings of staircase to inside: only to balcony and vestibule with fix-sash type with glass
- (8) openings of vestibule/balcony to inside: only for entrance
- (9) area of staircase and vestibule/balcony > floor area X 3/800 (8/100 for theaters, dept. stores)
- (10) area of vestibule and balcony >5m²
- (11) both sides handrails

(Vestibule Type)

(Balcony Type)

(Natural Exhaust Type)

(Mechanical Exhaust Type)

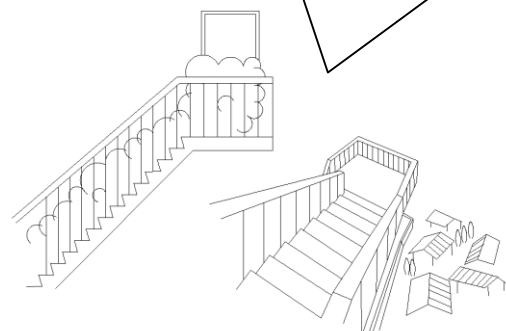
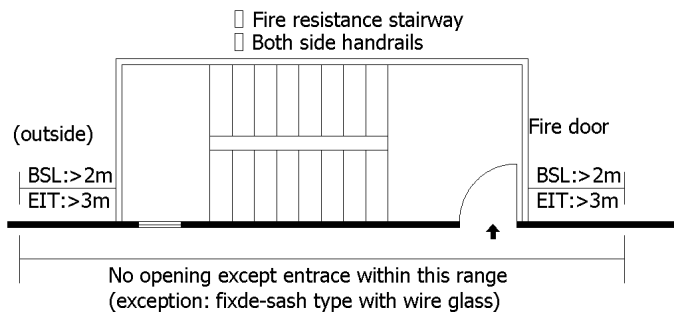


Vestibule and balcony protect the staircase from intrusion of smoke.

An outside escape stairway has the advantage of being protected from smoke spread, while it has the disadvantage of;

- Freezing and snow weather,
- Extremely high place. IFC specifies up to 22.86 m or 6th floor.

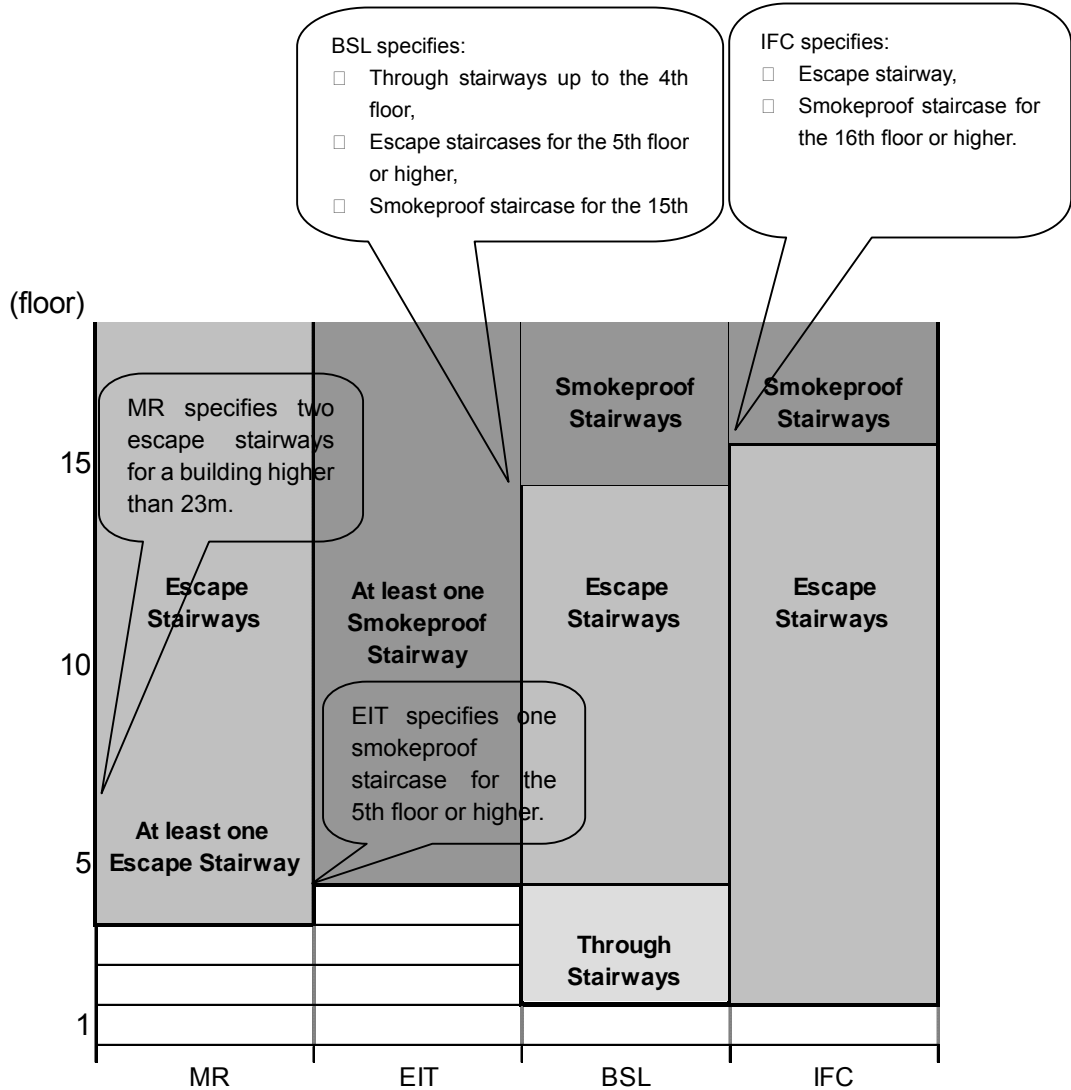
Outside Escape Stairway



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.2.2
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Type of Escape Stairway (3/3)

Type of Escape Stairway by Number of Floor in BSL, IFC, MR, and EIT



Note:

- 1) MR: Ministerial Regulation under the Building Control Act in Thailand.
- 2) EIT: Standard of the Engineering Institute of Thailand.
- 3) BSL: Building Standard Law in Japan.
- 4) IFC: International Fire Code in United States.

The figure assumes the following conditions;

- 5) IFC: A building has required number of occupants for escape stairways. Smokeproof staircases are required for floors located more than 22.86 m higher than the height of a ladder truck.
- 6) EIT: An escape stairway is not specified in the standard, while the smokeproof staircase is specified.
- 7) BSL: A building has the required floor area for the through stairway.
- 8) MR: An escape stairway is required for a floor higher than 23 m.

4.2.3	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Width of Escape Stairway (1/2)

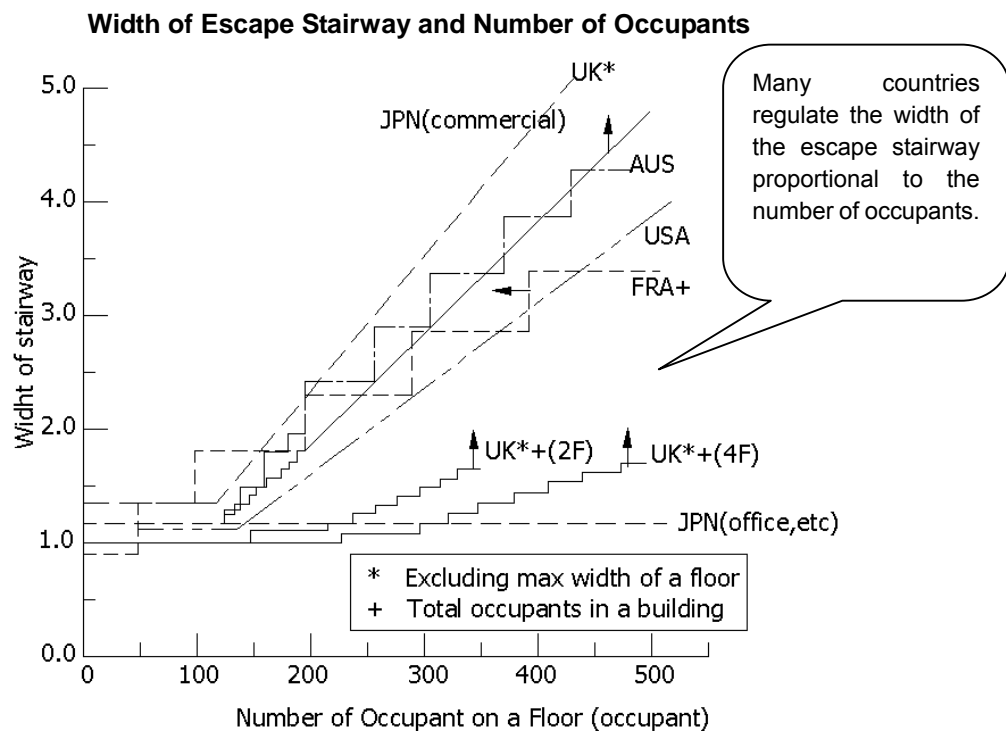
Sufficient width of the escape stairway is essential to secure smooth evacuation. The width of escape stairways must be sufficient for the occupants:

- On each floor,
- On floors above and below an intermediate floor, if the escape stairway connects to the intermediate floor.

Fire codes specify the width of escape stairways as:

- 91.4 cm for less than 50 occupants and 111.4 cm for 50 or more occupants in the United States,
- Uniformly 140 cm except department stores in Japan.

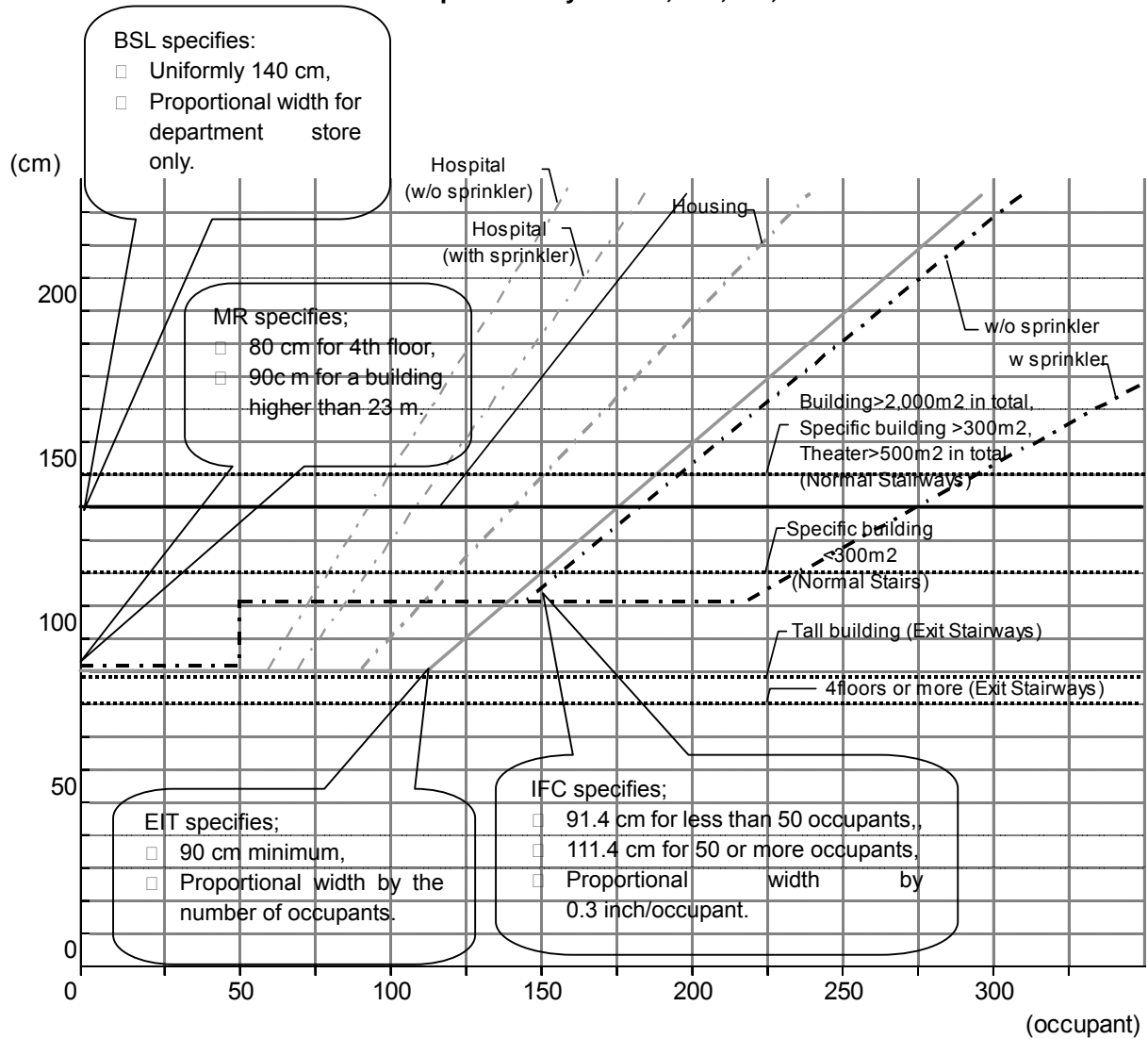
The fire code in the United States proportionally regulates the minimum width of escape stairway by 0.762 cm/occupant (or 0.3 inch/occupant), while the fire code in Japan regulates the width of the escape stairway of department store proportional to the floor area. In effect, both countries partially or wholly specify the width by the number of occupants, because the floor area can be converted into the number of occupants by the occupant density.



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.2.3
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Width of Escape Stairway (2/2)

Width of Escape Stairway in BSL, IFC, EIT, and MR



Legend

— BSL	— EIT
— BSL ((Special) Fire escape stairs: Dept. store > 1,500m ² in total)	- - - EIT (exception)
- - - IFC MR

Note:

- 1) MR: Ministerial Regulation under the Building Control Act in Thailand.
- 2) EIT: Standard of the Engineering Institute of Thailand.
- 3) BSL: Building Standard Law in Japan.
- 4) IFC: International Fire Code in United States.

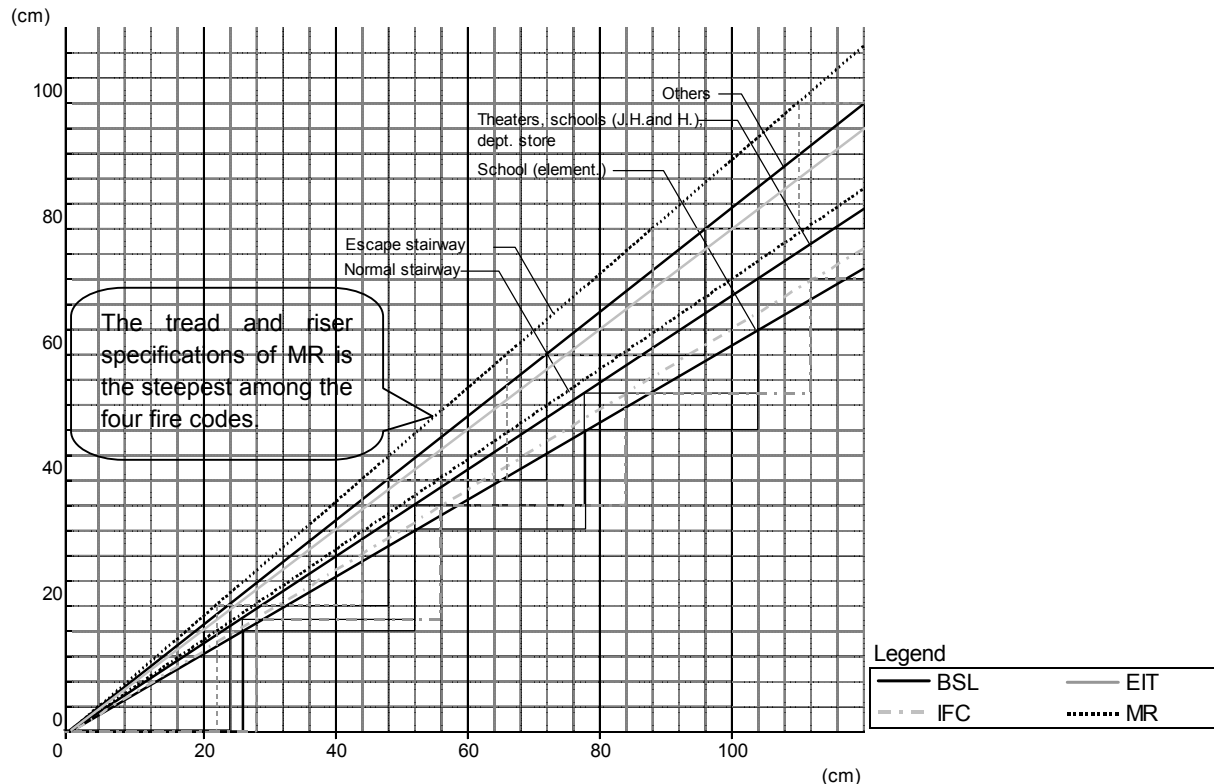
4.2.4	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Form of Miscellaneous Facilities of Stairway and Corridor (1/2)

In a crowded evacuation route, occupants cannot move with complete control. They may not be able to see their feet. Sudden changes in stair configuration can cause people to lose control and fall down.

Tread and riser has to be consistent from the top to the bottom of an escape stairway. This consistency aims to provide the steady movement for the occupants.

Treads and Rises in BSL, IFC, and MR



Handrails in an escape stairway help prevent occupants from falling down and support occupants who have impaired mobility. Handrails should be installed:

- At both sides of the escape stairways preferably to either dominant hands,
- In the middle of the stairway, if the width of the escape stairway is large.

Landings take the roles of;

- Controlling the distance that occupants can fall,
- Providing a resting space for occupants who have difficulties to walk through.

The landing is necessary at the certain height, normally 3 to 4 m in flight height.

- Fire codes in Japan and US specify;
- Maximum flight height within 3 to 4 m in Japan, and 3.7 m in US,
 - Width of the landing to be larger than the escape stairway.

Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.2.4
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Form of Miscellaneous Facilities of Stairway and Corridor (2/2)

Doorways along the path of an evacuation route are important for controlling the passage of occupants and the intrusion of smoke and fire. The doorways should have:

- Fire resistance,
- Automatic closing system,
- Opening direction the same as the direction of evacuation. When the opening direction is opposite to the evacuation direction, occupants will not be able to open the door, due to crowd in front of the door.

Preferred types of doorway are:

- Single door,
- Double doors,
- Sliding door,
- Automatic type with manual operating mechanism in case of power supply cut.

Revolving type doors are unsuitable to conduct large numbers of occupants.

Preferred conditions of the doorway are:

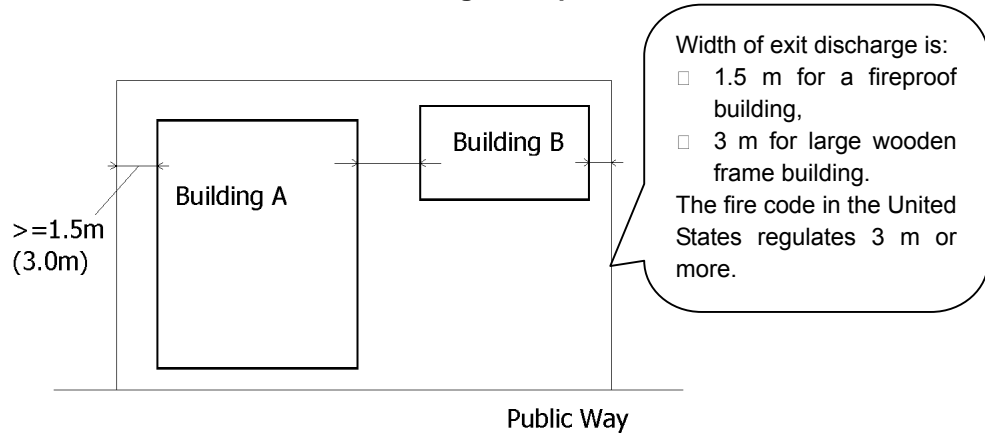
- Sufficient number and well-balanced location for rooms with many occupants,
- Appropriate level of opening power requirement so the doorway can be opened by infants, aged, and disabled occupants,
- Appropriate level of opening power requirement where pressurized and/or exhaust smoke control systems cause a gap of air pressure in front and behind a doorway,
- Able to be opened at all times from the inside without any special device.

4.2.5	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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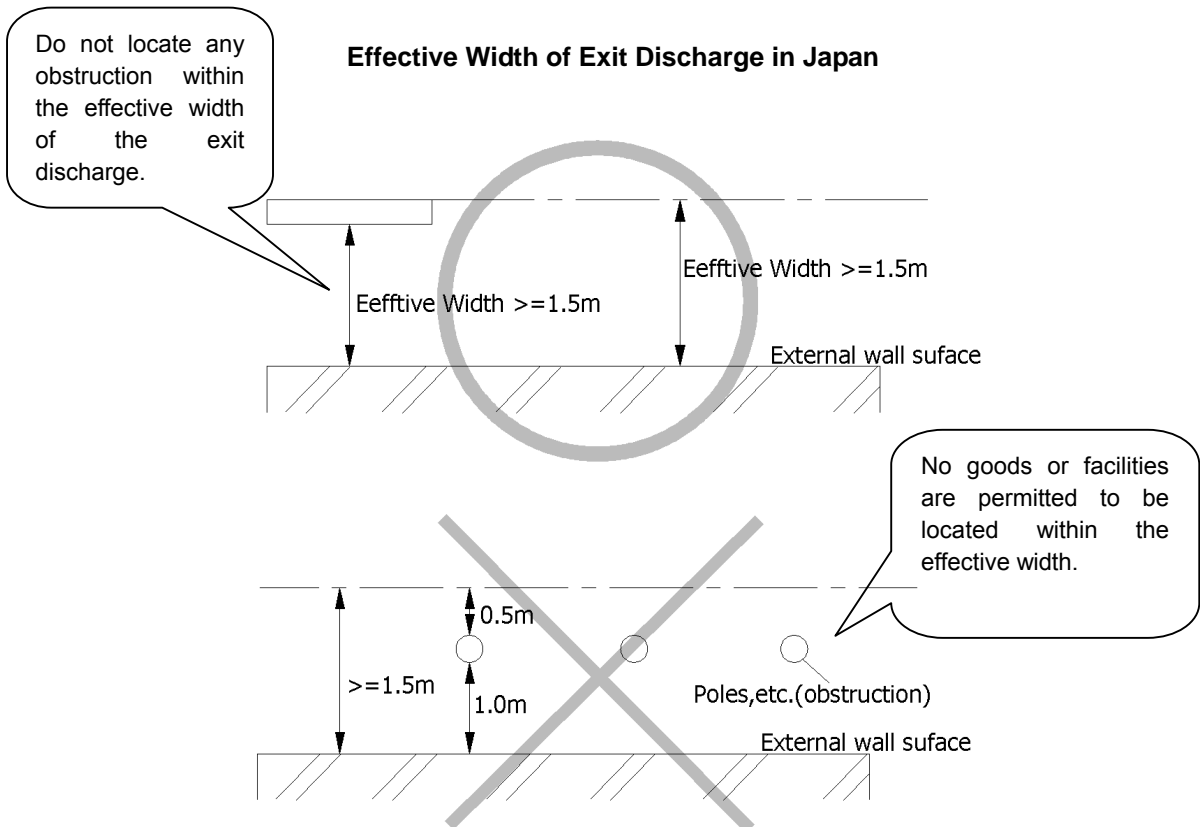
Exit Discharge

The exit discharge is the portion of an evacuation route from the termination of an exit to a public way. The exit discharge has to have sufficient width and fire protection to at least the same fire safety standard as the exit connecting to the exit discharge.

Width of Exit Discharge in Japan



Effective Width of Exit Discharge in Japan



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.3.1
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Horizontal Exit

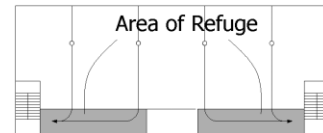
The horizontal exit aims to provide temporary storing space for occupants in large and high-rise buildings. It is difficult to evacuate a large number of occupants in a short time. They need a safe area to wait for smooth evacuation. The horizontal exit is formed as a compartment by:

- Fire resistant structures with noncombustible interior finish,
- Fire protection equipment at openings with automatic closing,
- Smoke exhaust system within the compartment.

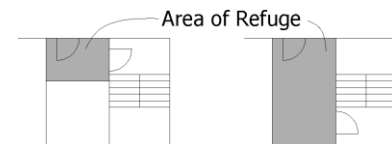
The preferable type of horizontal exit depends on the conditions of the building:

- Safe compartments of corridors and a vestibules of smokeproof stairways are useful for safely storing occupants in the initial stages of evacuation,
- Horizontal exits are useful for large numbers of disabled occupants. They allow occupants to horizontally evacuate to a fire and smoke resistant compartment in a short time.
- Confined method is preferable for the occupants who are not able to move. This type is used for surgery rooms and intensive care units.

Safety Compartment (Corridors)



(Vestibules)

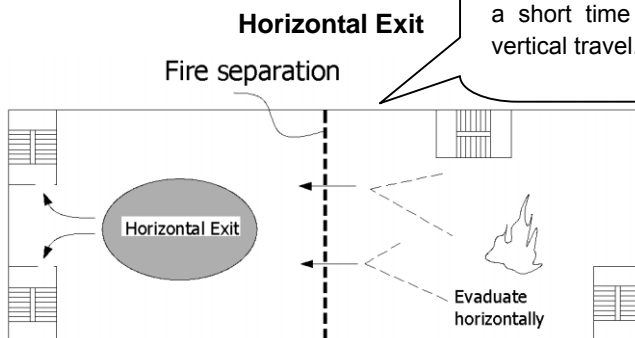


Disabled occupants include:

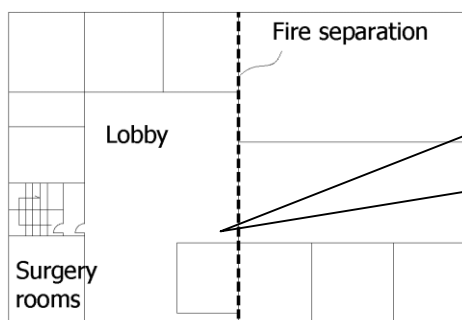
- Infants and the aged
- The physically impaired, such as those with difficulty in walking
- Those with visual and hearing impairments

Easily able to evacuate in a short time without any vertical travel.

Access for rescue is necessary to every compartment because horizontal exit is used for temporarily storing occupants.

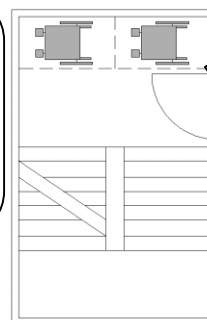


Confine Horizontal Exit



Patients stay in a compartment until arrival of rescue.

Area of Refuge with Lots for Wheelchairs



The fire code in the US specifies the area of refuge must have;

- One wheelchair lot per 200 occupants,
- A communication system.

4.3.2	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Rooftop Safety Area

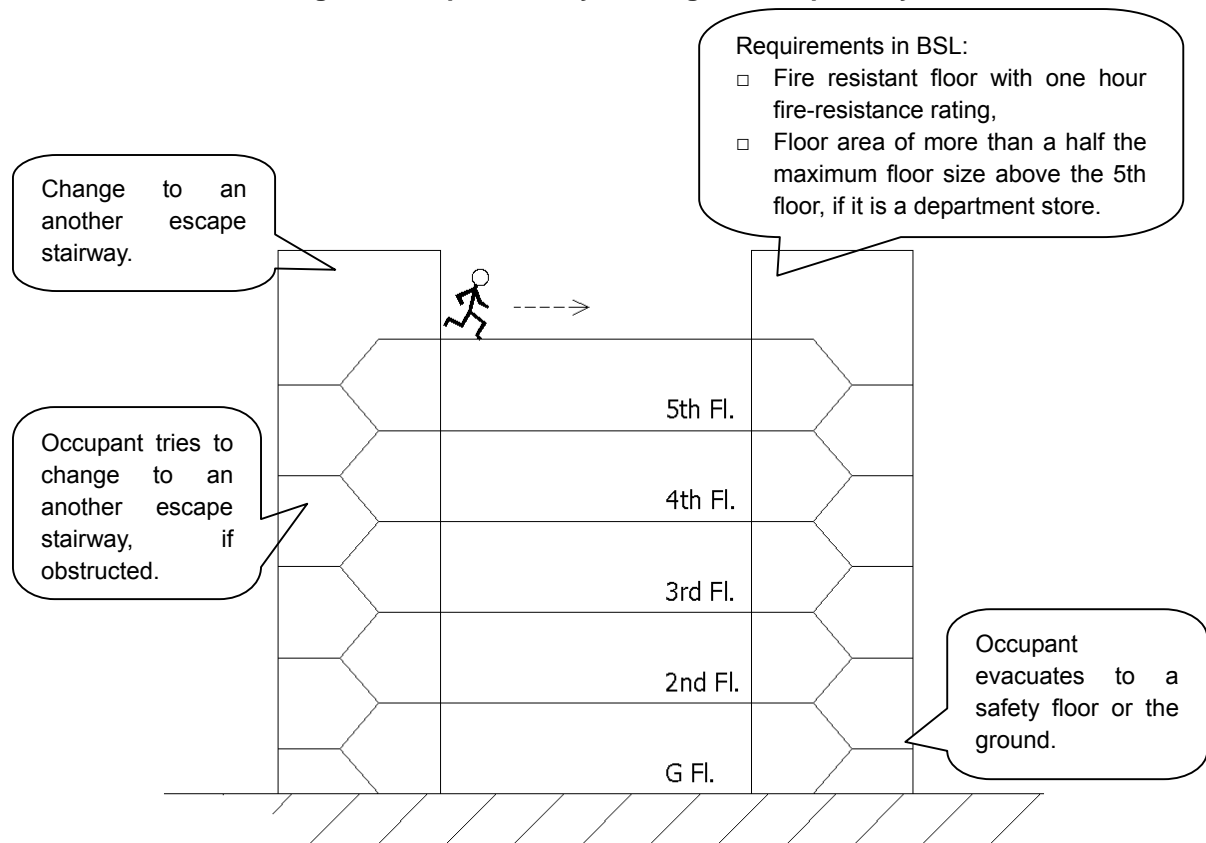
The aim of the rooftop safety area is to ensure an alternative evacuation route. It provides a route to change to an alternative escape stairway. If an occupant faces an obstruction in one escape stairway, he or she can shift to another escape stairway via the rooftop safety area.

The rooftop safety area is necessary for four-story buildings in the United States and five-story department stores in Japan

The rooftop safety area has the advantage of resistance to smoke due to being fully open to the air. It requires:

- Access from the escape stairways,
- Fences or railings to protect occupants from falling,
- Locks which are unlocked in an emergency,
- Sufficient floor area to allow occupants to temporarily stay on the rooftop safety area.

Change of Escape Stairways through Rooftop Safety Area



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.3.3
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Balcony Linking

Balcony linking provides an alternative evacuation route for an occupant who is late to start evacuation. The balcony linking has the advantage of resistance to smoke by being fully open to fresh air.

On the other hand, it has the disadvantage of:

- Lack of security and privacy between neighboring balconies,
- Limitation on design of exterior wall.

Partition board is necessary to ensure privacy. It should be designed to be easily broken by an occupant willing to pass through.

Balcony linking is not a principle evacuation route. It is only additional route for redundancy.

Balcony linking is preferable for buildings having occupants in sleeping conditions and with disability to evacuate, such as:

- Hospitals,
- Hotels,
- Multi-story housings.

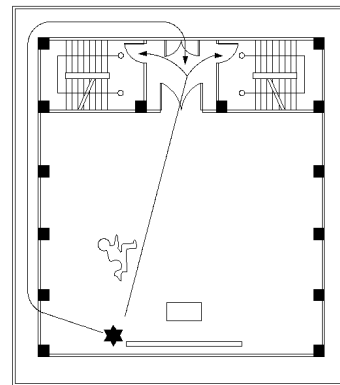
There are three types of balcony linking:

- Surrounding type having direct access to escape stairways,
- Partial type in which occupants re-enter into neighboring rooms,
- Isolated type in which occupants wait for rescue from outside.

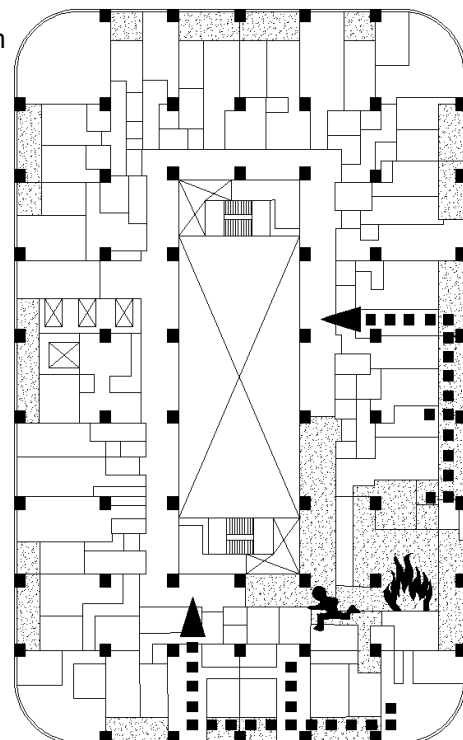
Requirements of the balcony linking in BSL:

- At least one side faces to a public way or on-site road,
- Larger than 2 m² and 75 cm or more in depth,
- Doorways to balconies larger than 75 cm in width and 180 cm in height,
- Well-opened to fresh air,
- Fire resistant floor and wall.

Partial Type



Surrounding Type



4.4.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Exit Sign Illumination (1/2)

Exit sign illumination is designed to lead occupants to an exit discharge by showing the direction of the evacuation route.

Exit Sign Illumination in Japan

At Exits

At Corridors

(at corridor/aisle)

(at indoor aisles)

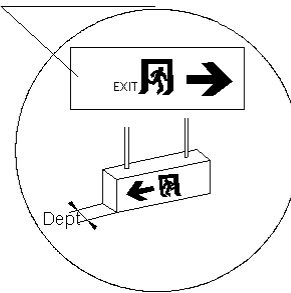
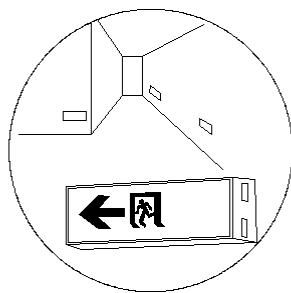
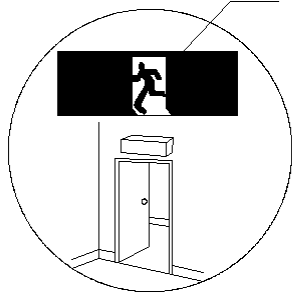
Visible from any point at a distance of more than 30 m.

Visible to occupants obstructed by smoke

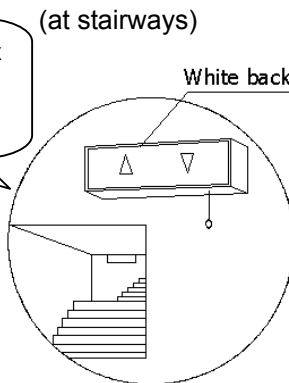
- Appropriate for large corridor in dept. store and underground mall,
- hanging at 0.5 m or more from ceiling and 2.5 m or more above the floor surface.

Green background

White background

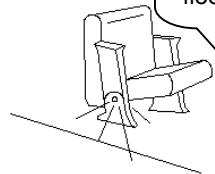


Intensity of at least 1lux at the floor surface.



(at aisles in seating)

Intensity of at least 0.2 lux at the floor surface.



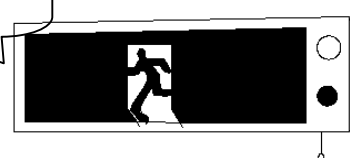
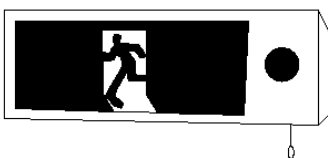
Special Types of Exit Sign Illumination for Occupants with Disability

Blinking Type

Blinking and Sounding Type

Blinking with high brightness.

Blinking with sounds to guide deaf and blind people.



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.4.2
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Exit Sign Illumination (2/2)

Exit sign illumination is:

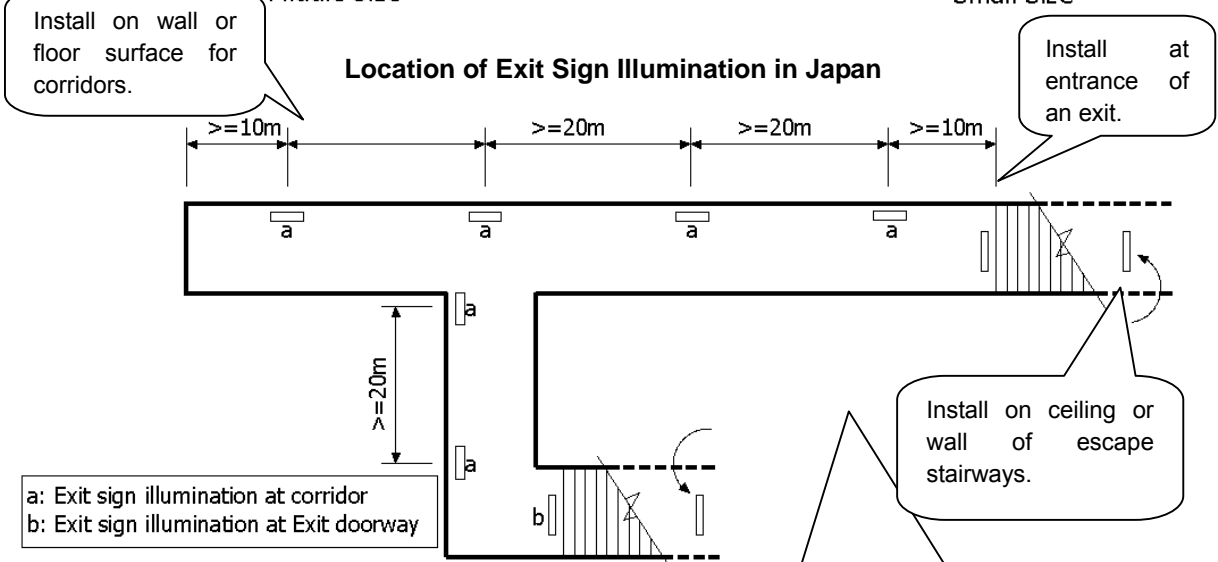
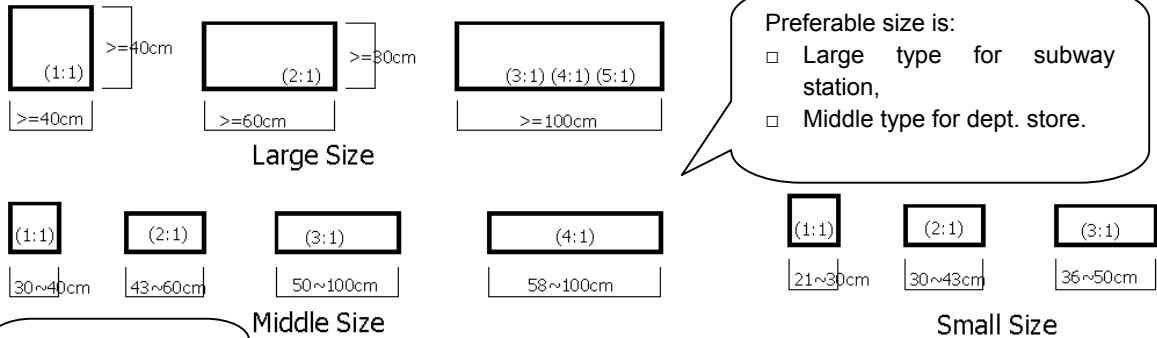
- Lit at all times for easy maintenance,
- Immediately switched to battery or power generator in case of power supply cut.
- Switched back to power supply when the power supply is back.

Emergency power supply has:

- capacity for 20 minutes or more duration,
- an automatic recharging system within a specified period.

Fire code in US specifies 90 minutes.

Dimension of Guide Lamp in Japan



Exit sign illumination is basic type, while exit sign without illumination is used for specific spaces;

- With daylights or emergency lighting,
- In a building used in the daytime only, such as office, factory, and school,
- At a floor between 1st and 10th floor.

4.4.3	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Emergency Lighting

Emergency lighting illuminates evacuation routes only in the case of a power supply cut.

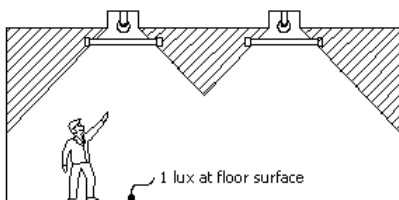
Fire codes in Japan provide specifications for emergency lighting with respect to;

- Fire retardant materials,
- Illumination intensity of 1lux or more at the floor surface,
- Automatically switching to emergency power supply within 10 seconds after power supply cut,
- Automatically switching back to normal power supply when the power supply is back,
- Working duration for thirty minutes or more.
- Wiring with fire resistance.

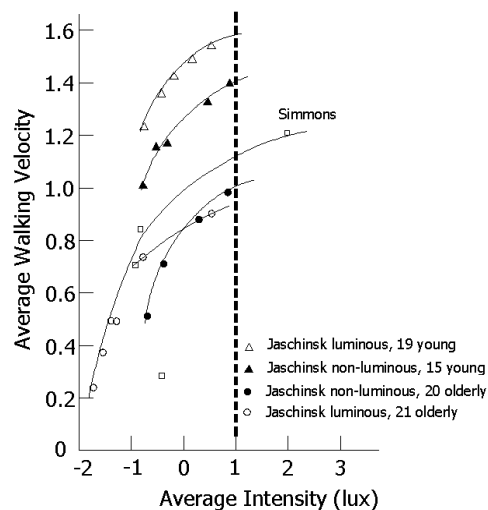
Fire code in US regulates 11 lux at the floor surface and ninety-minutes duration.

Intensity of Illumination

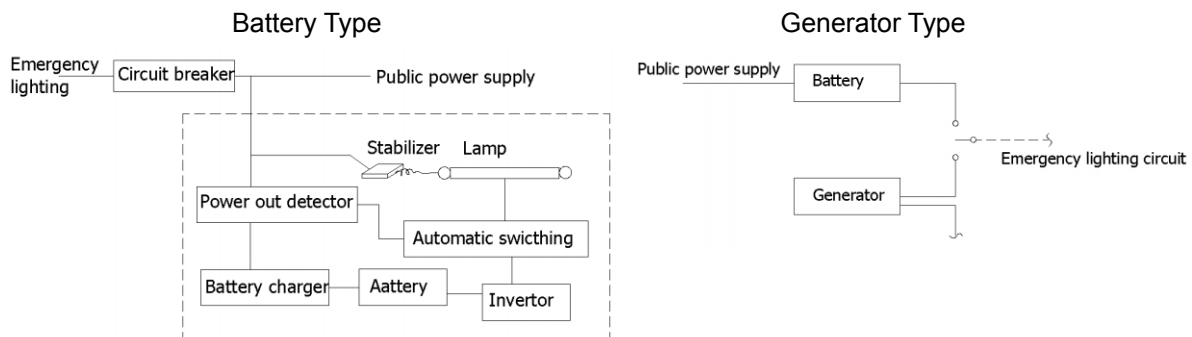
Illumination Intensity of the Floor Surface



Avg. Illumination Intensity and Walking Velocity



Power Source of Emergency Lighting



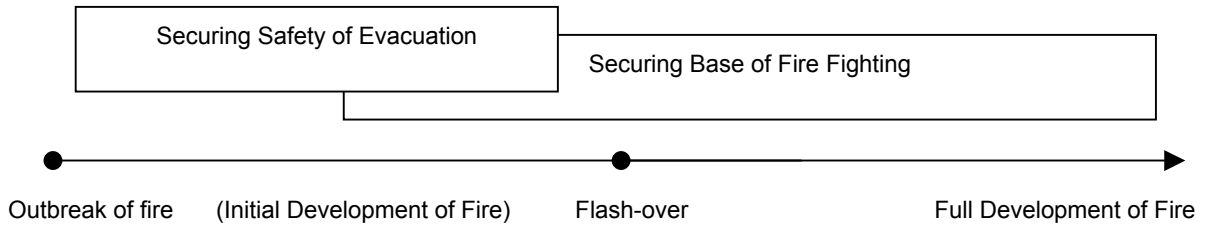
Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.5.1
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Principles of Smoke Control System (1/2)

The smoke control system has a different role in different stages of a fire:

- Safety of evacuation in the initial stage of fire,
- Safety of base for fire fighting in the later stages of the fire.

Roles of Smoke Control System by Stage of Fire



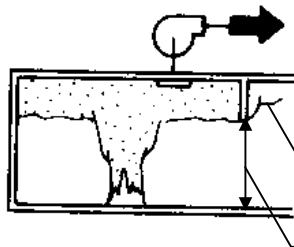
The smoke control system is effective for:

- Delaying the descent of smoke,
- Reducing smoke discharge from a room under fire.

Effectiveness of Smoke Control System

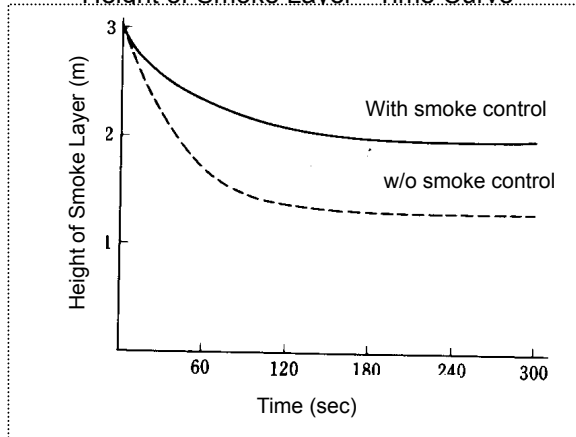
Conditions for Testing of Smoke Control System

- Floor Area: 20 m × 20 m
- Ceiling Height: 3.0 m
- Capacity of smoke exhaust: 400 m³/m

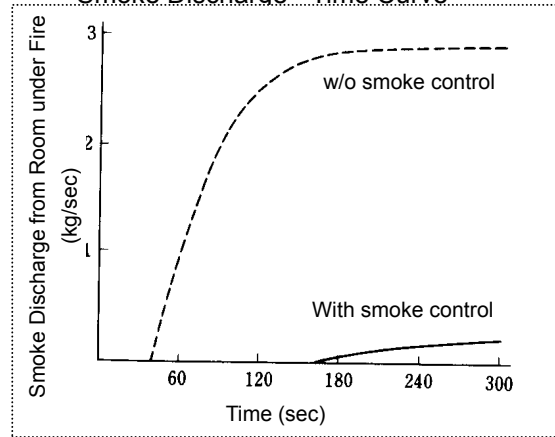


The testing of smoke control systems clearly shows that they delay smoke descent and smoke discharge.

Height of Smoke Layer - Time Curve



Smoke Discharge - Time Curve

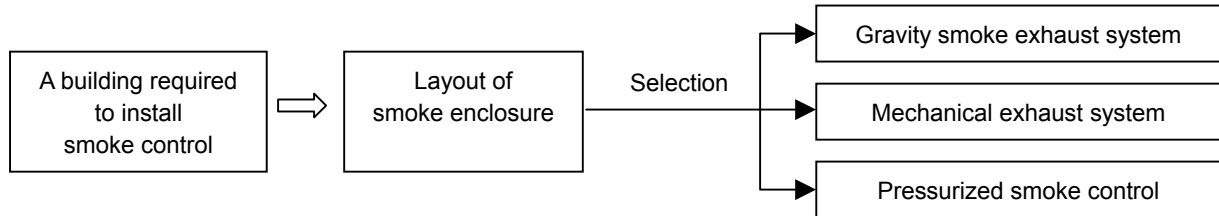


4.5.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Principle of Smoke Control System (2/2)

The first step of planning smoke control is to select a suitable type of the smoke control system. The spatial conditions and type of occupancy should be taken into account for the selection.

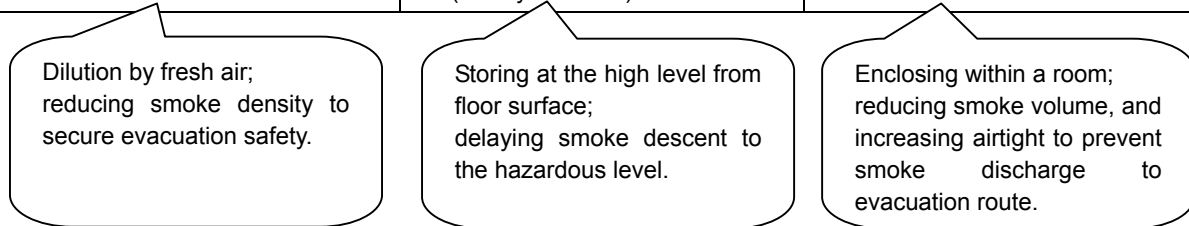
Selection of Appropriate Type of Smoke Control System



Parts of building that are not subject to the hazards of smoke spread are not required to have a specific smoke control system.

Parts of Building where Smoke Control System is not required

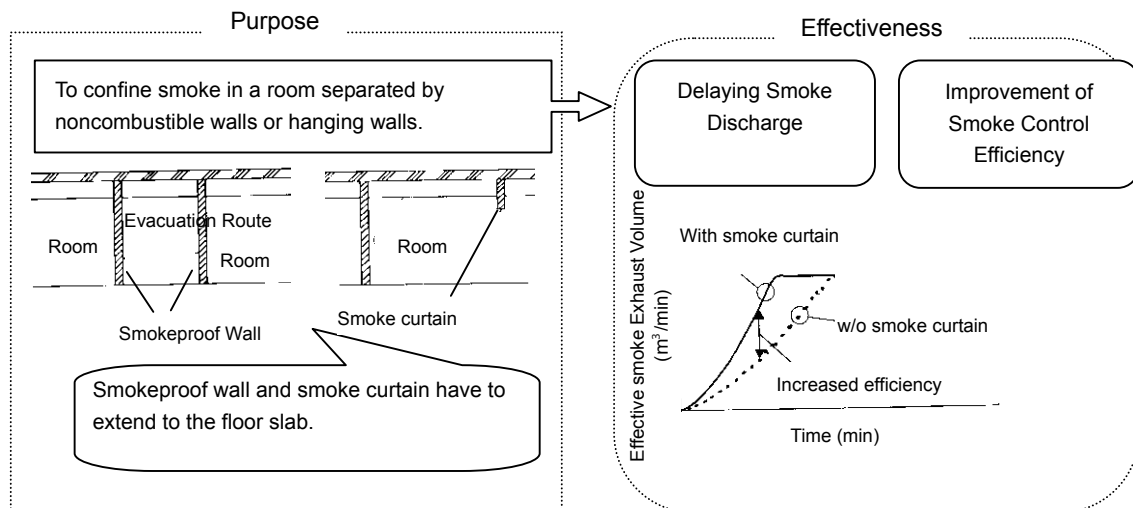
<input type="checkbox"/> Directly opened to air (i.e. balcony)	<input type="checkbox"/> Large spaces with high ceilings and few combustible materials (i.e. Gymnasium)	<input type="checkbox"/> Small and having noncombustible material only
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Smoke enclosure plays basic roles of the smoke control systems to;

- Delay smoke discharge from a room or compartment,
- Increase efficiency of smoke exhaust system in the initial development stage of the fire.

Effectiveness of Smoke Enclosure



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.5.2
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Types of Smoke Control Systems

Smoke control systems are classified into three types based on the air intake and exhaust methods.

Types of Smoke Control Systems

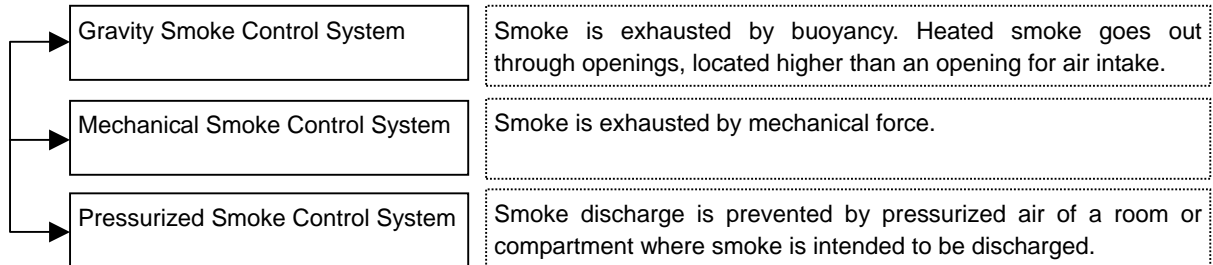
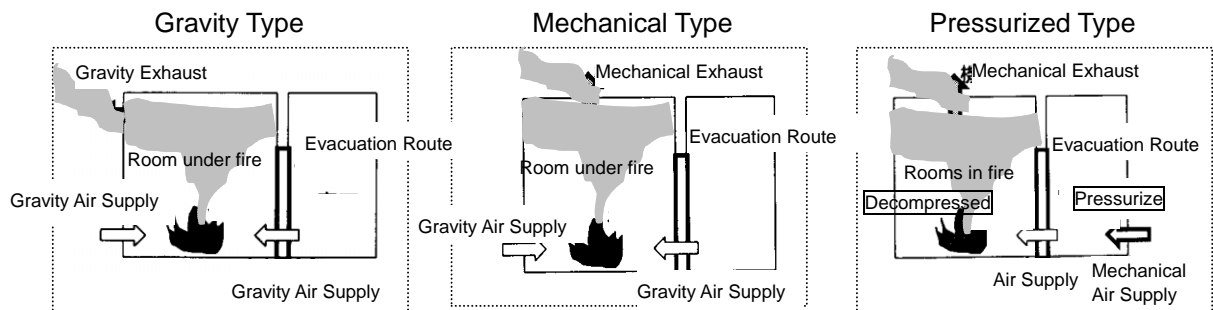


Diagram of Smoke Control System



Fire codes in Thailand and Japan specify the types of smoke control system by the part of building.

Smoke control systems are necessary for vestibules, EV shafts for firefighters, and habitable rooms in Japan. Thailand regulates at escape staircases and EV shafts for firefighters' elevators.

Required Smoke Control System by Part of Building

Part of Building	MR	EIT	BSL
Escape staircase	G or P	P	X
Vestibule of smokeproof staircase	X	X	G or M or P
EV shaft of elevator for firefighters	G or P	P	G or M or P
EV hall of elevator for firefighters	X	X	X
EV shaft	X	X	G or M or P
Corridor	X	X	G or M or P
Habitable room	X	X	G or M (over 100m ²)

Note:

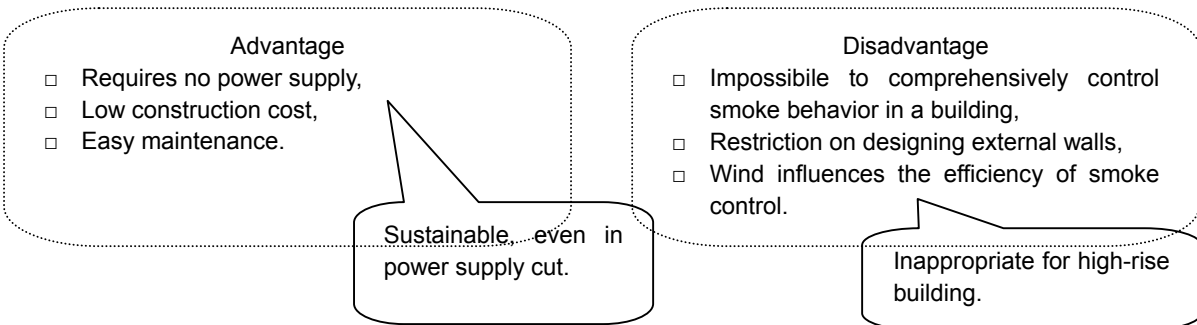
- 1) Capital of G, M, and P means the required type of smoke control system. G: Gravity smoke control, M: Mechanical smoke control system, and P: Pressurized smoke control system.
- 2) X: Smoke control system is not required.
- 3) MR: Ministerial Regulation under the Building Control Act in Thailand, EIT: Standard of the Engineering Institute of Thailand, BSL: Building Standard Law in Japan

4.5.3	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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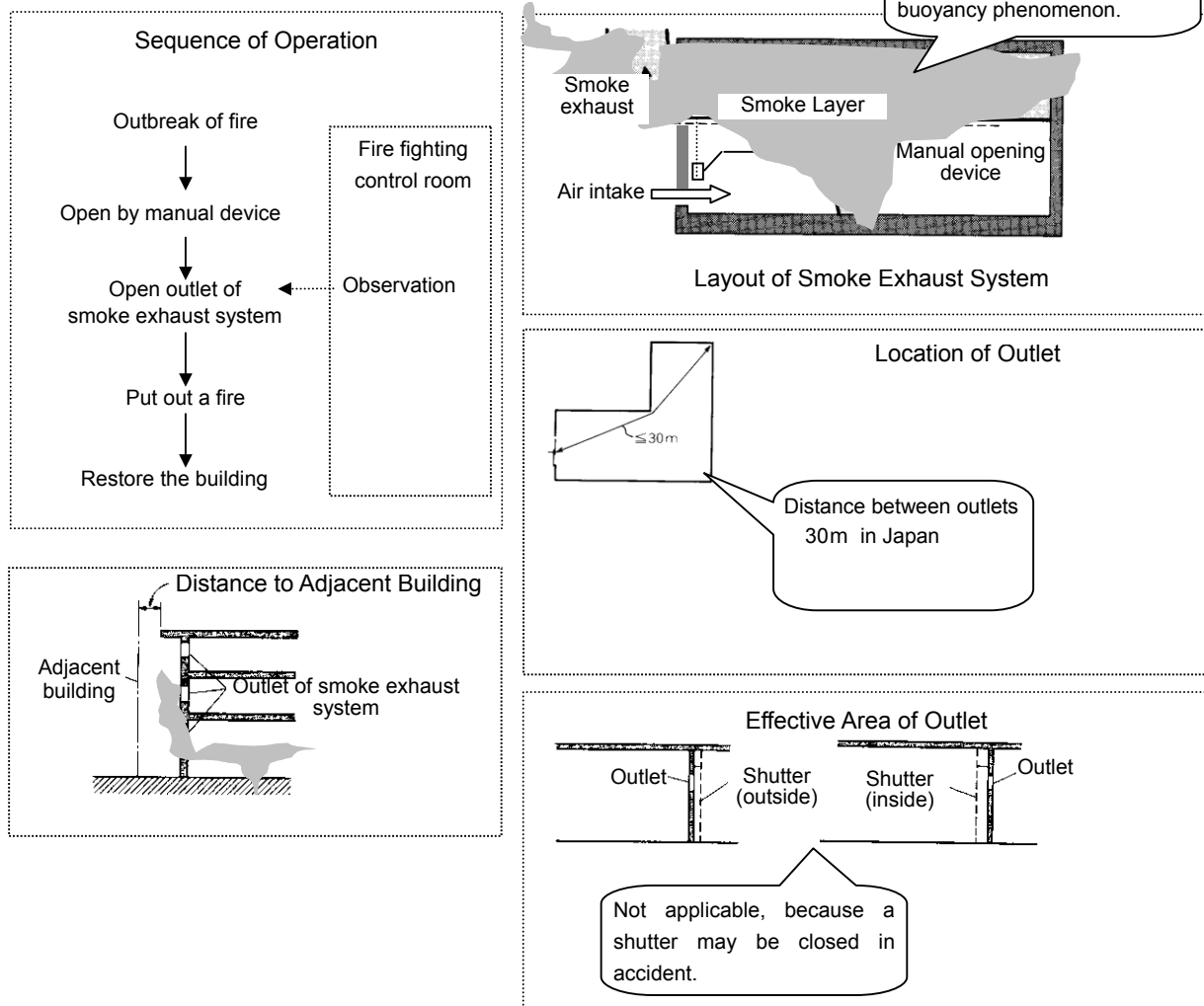
Gravity Smoke Exhaust System

The gravity smoke exhaust system exhausts smoke by buoyancy. The heated smoke rises and goes out through an opening which is located higher than an opening for air intake. This system has the advantage of easy maintenance, and low construction cost, but it is not possible to comprehensively control smoke behavior in a building.

Advantage and Disadvantage of Gravity Smoke Exhaust System



Typical Points for Planning of Gravity Smoke Exhaust System



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.5.4
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Mechanical Smoke Exhaust System (1/2)

The function of a mechanical smoke exhaust system is to exhaust smoke by mechanical force. The system offers the advantages of comprehensive control of smoke behavior in a building, while it requires periodical maintenance and an emergency power supply.

Advantage and Disadvantage of Mechanical Smoke Exhaust System

Advantage

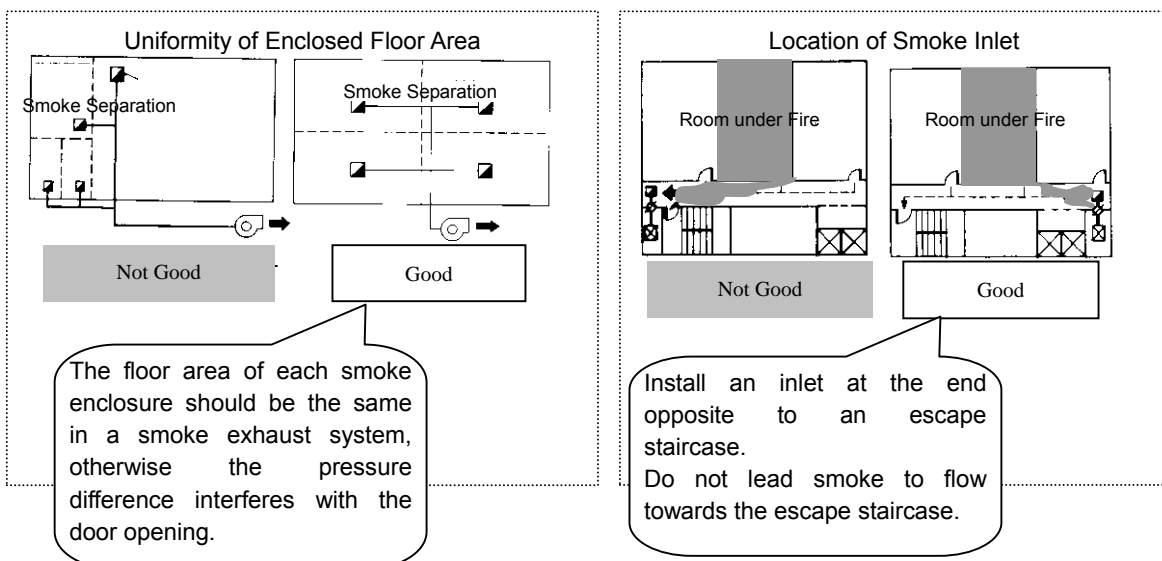
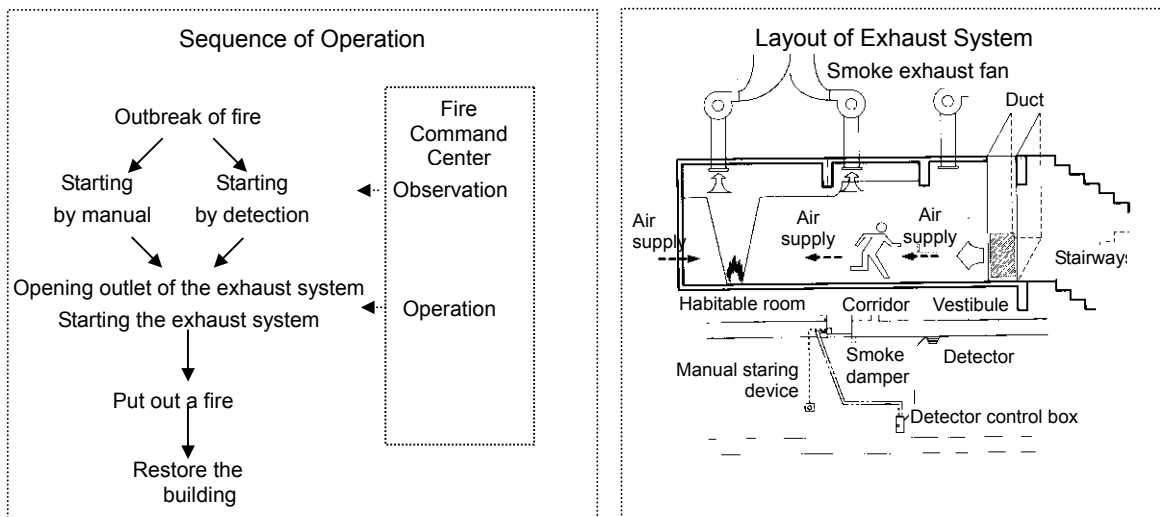
- Prevention of smoke spread from a room under fire,
- Comprehensive control of smoke behavior in a building,
- Less influence by wind.

Disadvantage

- Need for an emergency power supply,
- Suspension of smoke control, when the temperature rises excessively,
- Necessity of periodical maintenance.

Close fire damper of smoke control system to prevent further smoke spread.

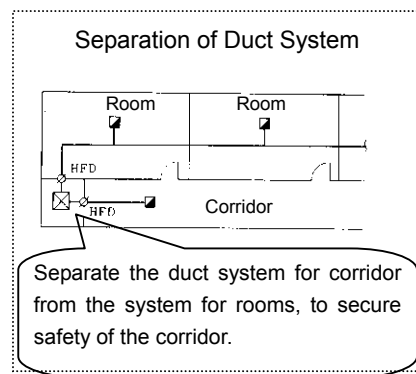
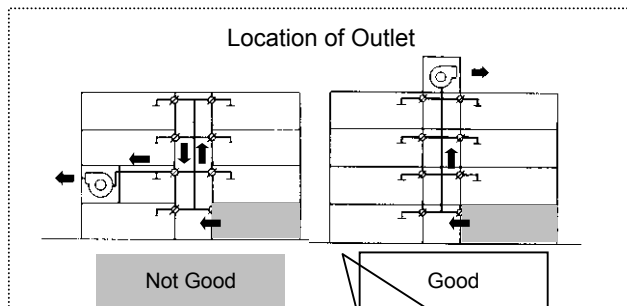
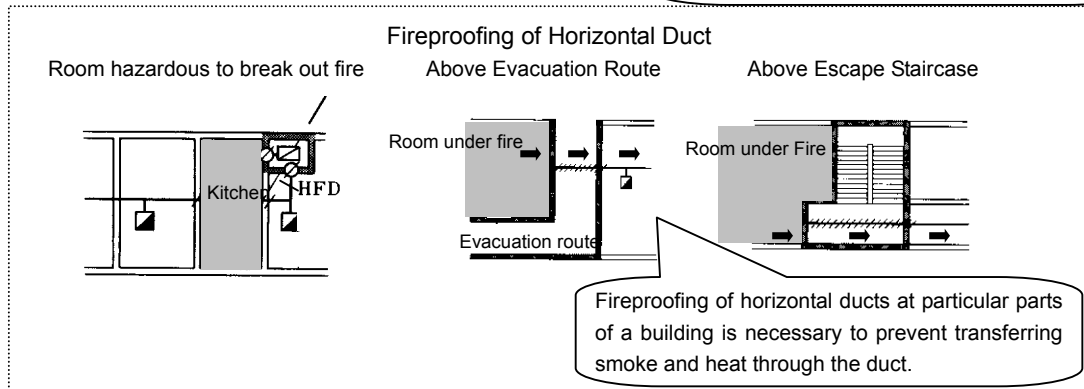
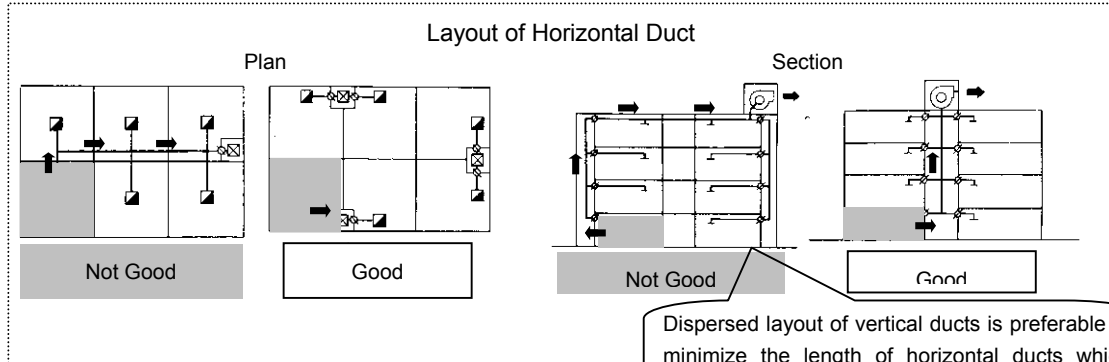
Typical Points for Planning of Mechanical Smoke Exhaust System



4.5.4	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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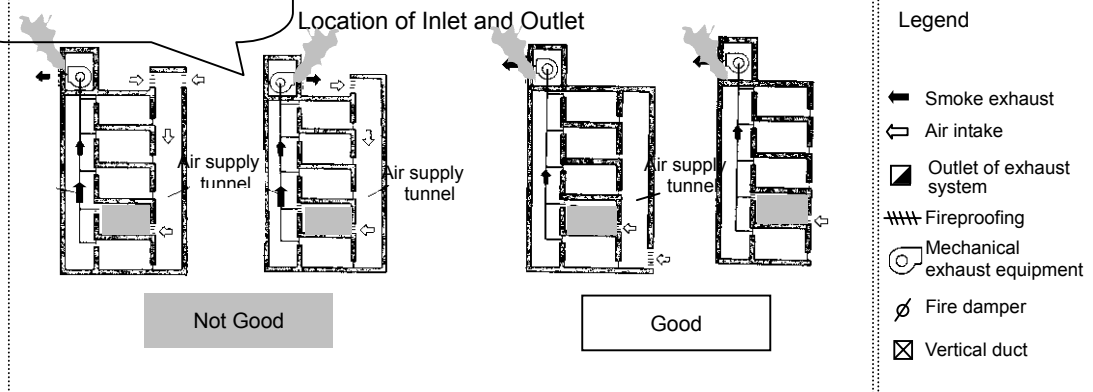
Mechanical Smoke Exhaust System (2/2)

Typical Points for Planning of Mechanical Smoke Exhaust System



Install outlet higher than and far from inlet to;
 Protect inlet from smoke intrusion,
 Take advantage of buoyancy.

Install smoke exhaust equipment at the highest part of a building, to take advantage of buoyancy.



Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	4.5.5
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Pressurized Smoke Control System (1/2)

Pressurized smoke control systems work by preventing smoke spread by difference of air pressure. The system has the advantages of comprehensive control of smoke behavior for a long period of operation, while it requires high air-tightness.

Advantages and Disadvantages of Pressurized Smoke Control System

Advantage

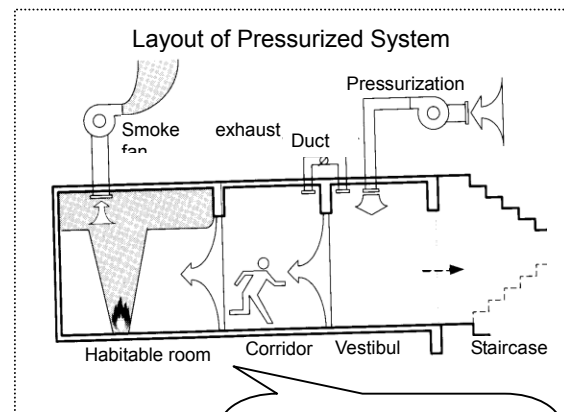
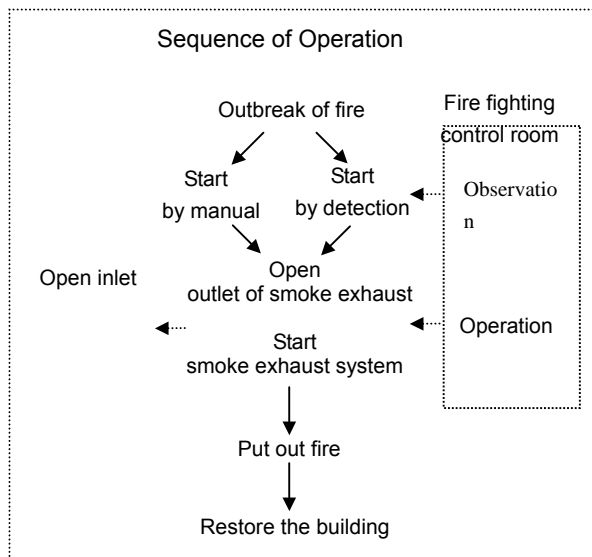
- Reliable smoke control if combined with a mechanical exhaust system,
- No need for horizontal duct,
- Capability of a long time operation in high temperature.

Preferable for fire fighting.

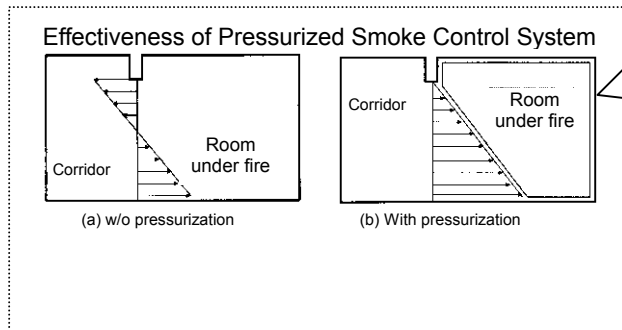
Disadvantage

- Space for ventilators needed in basement,
- Complicated control of ventilators, and doors, etc,
- Require very precise construction for air-tightness.

Typical Points for Planning of Pressurized Smoke Control System



Smoke exhaust system strengthens efficiency of the smoke control system.



Pressurized air forces back smoke from a room under fire.

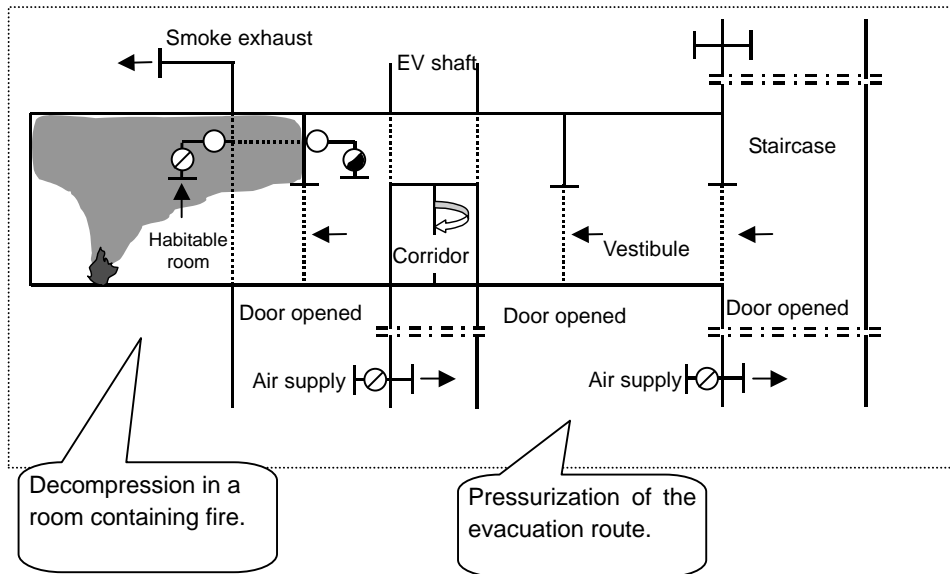
4.5.5	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Pressurized Smoke Control System (2/2)

The pressurized smoke control system is generally installed to pressurize air in corridors, staircases, and elevator shafts. It aims to protect evacuation routes from smoke spread.

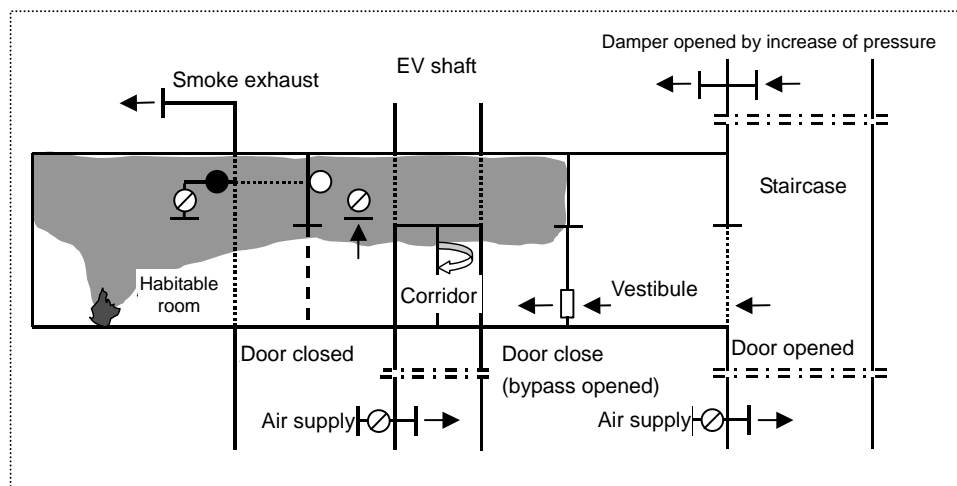
i) Smoke control for the evacuation from a floor under fire

Pressurized air in a staircase and an elevator shaft forces back smoke coming from a room under fire.



ii) Smoke control after smoke is discharged into a corridor

The pressurized air in a staircase and elevator shaft prevents smoke being discharged into the elevator hall or vestibule of the staircase.



Legend	
○	Fire damper opened
●	Fire damper closed
⊗	Smoke exhaust & air supply damper opened
⊙	Smoke exhaust & air supply damper closed

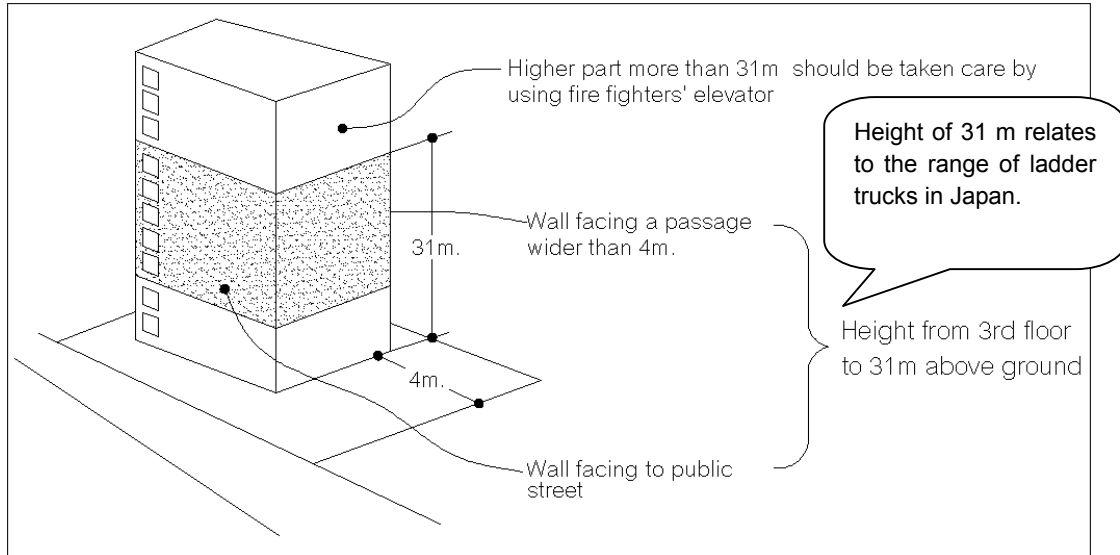
5 FIRE FIGHTING AND RESCUE

Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.1.1
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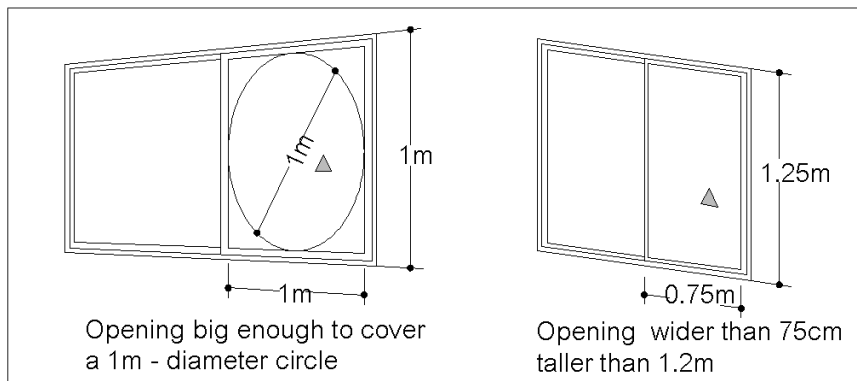
Window for Firefighters

Windows for firefighters provide a direct access for firefighters into a building. They should be located within the range of a ladder truck.

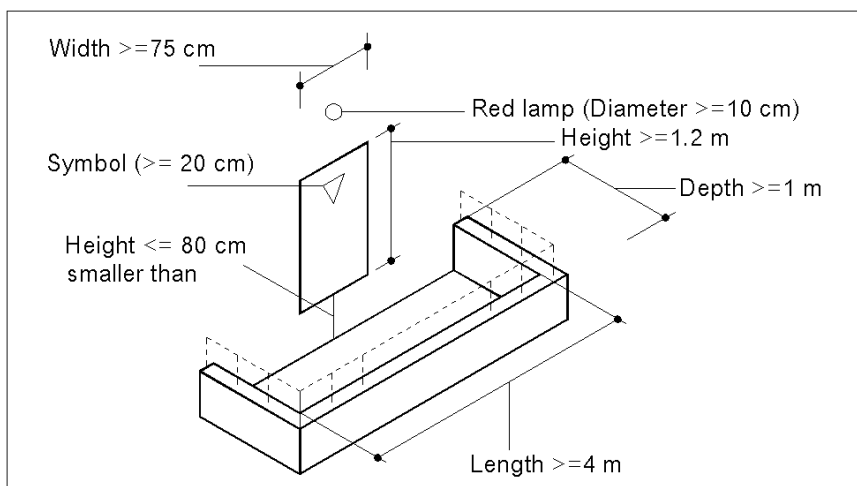
Location of Window for Firefighters in Japan



Dimension of Window for Firefighter in Japan



Alternative Entry for Firefighter in Japan

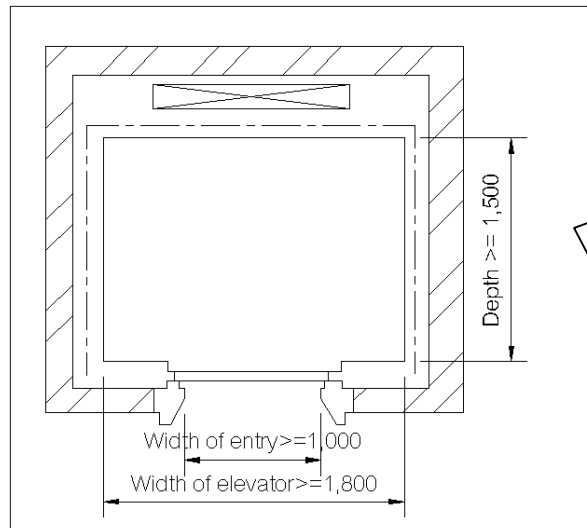


5.1.2	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Elevator and Life Lobby for Firefighters

The elevator for firefighters provides access to floors higher than the range of a ladder truck. It is useful for high-rise buildings to secure fast access for the firefighters.

Dimension of Elevator for Firefighter in Japan

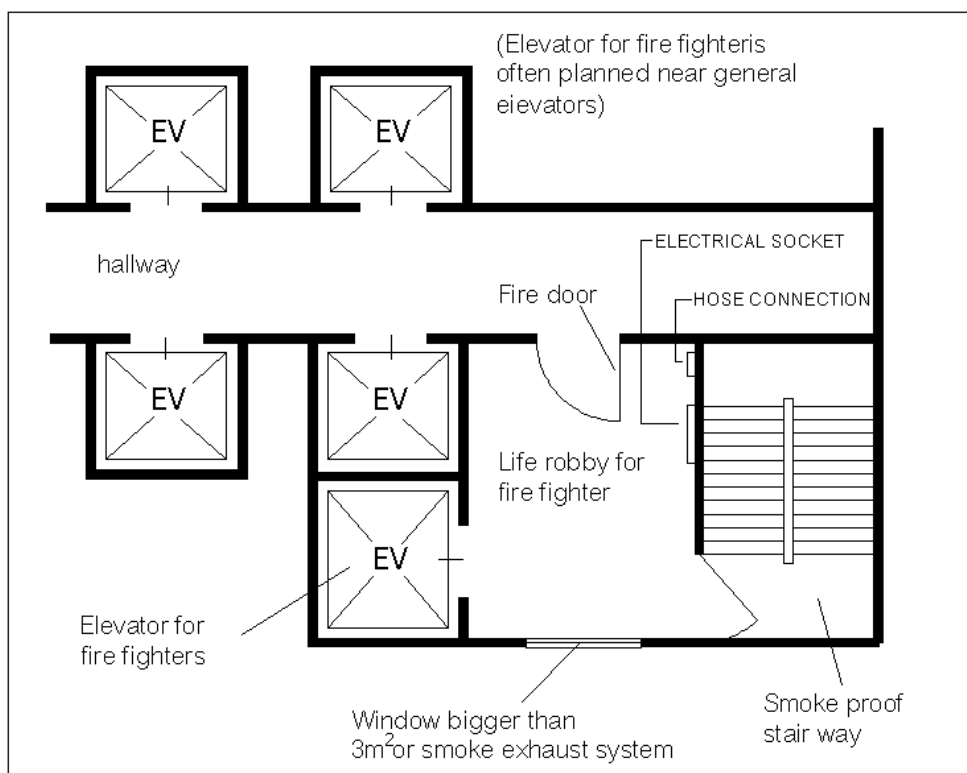


The number of elevators for firefighters depends on the floor area in Japan;

- One elevator for 1,500 m² or less,
- Two elevators for less than 4,500 m²,
- Additional elevator for every 3,000 m² after exceeding 4,500 m².

The life lobby for firefighter provides a base of fire fighting activities. The life lobby requires a sufficient floor area and supporting equipment, such as an emergency electric outlet, hose connection, and communication system. It also requires easy access from a fire fighting control room and fire resistance.

Layout of Life Lobby for Firefighter

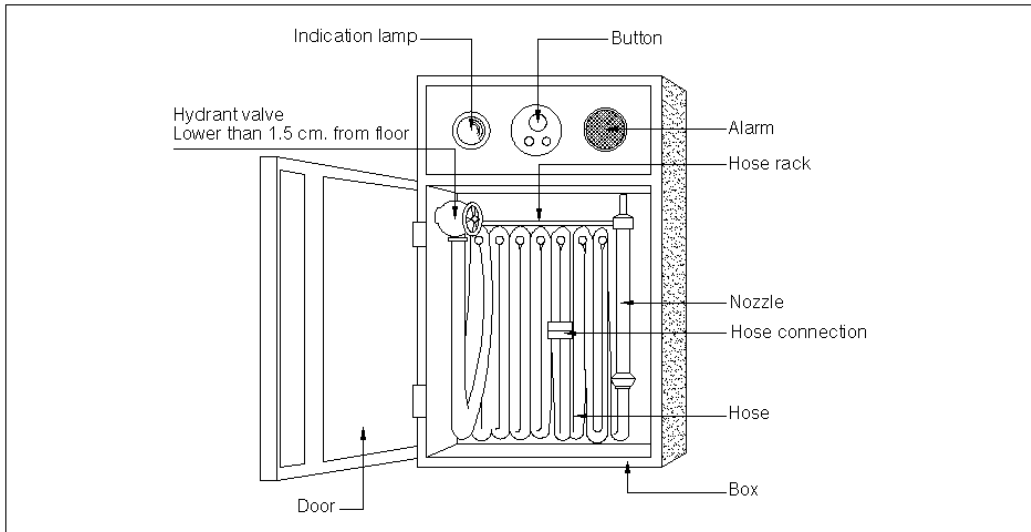


Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.2.1
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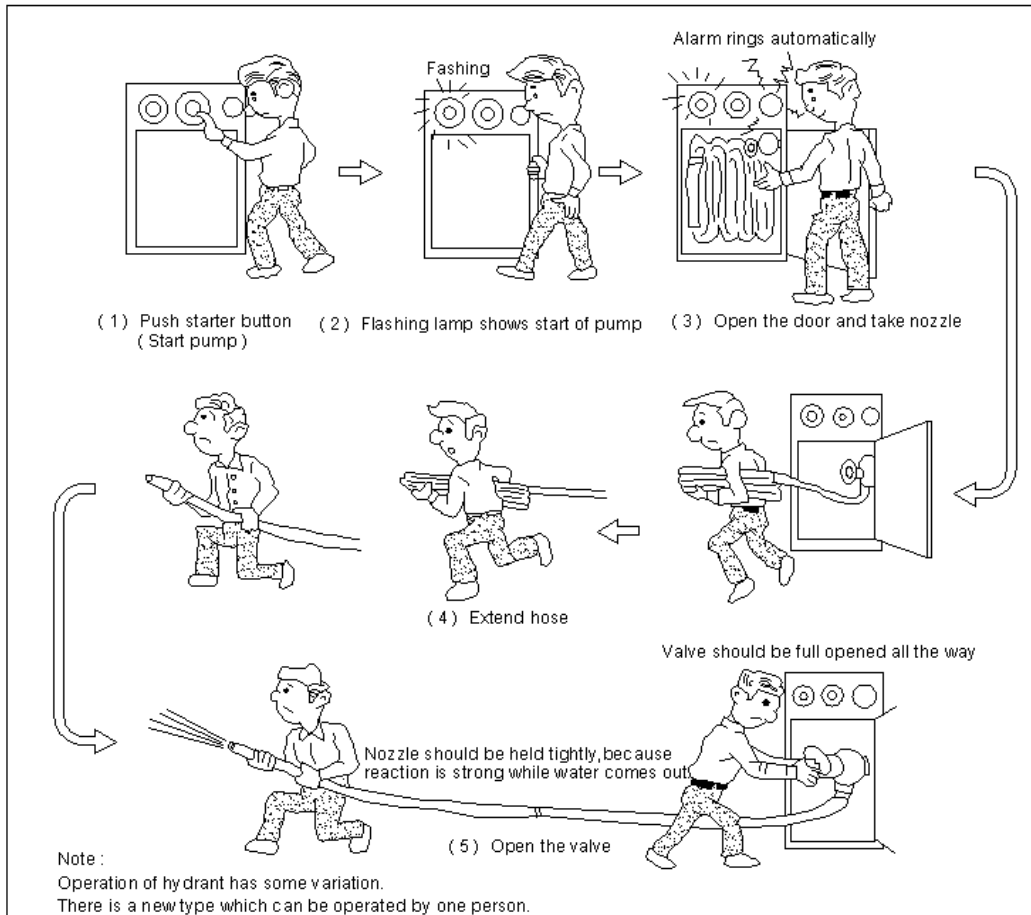
Indoor Fire Hydrant (1/2)

The indoor fire hydrant may be operated by trained occupant(s) in the initial development stage of a fire and by firefighters in the fire fighting stage. Depending on the operators' skill, the diameter and performance of the indoor hydrant is determined. Water supply to the hydrant is pressurized by the elevated tank, pressure tank, and fire pump.

What is in a Hose Cabinet



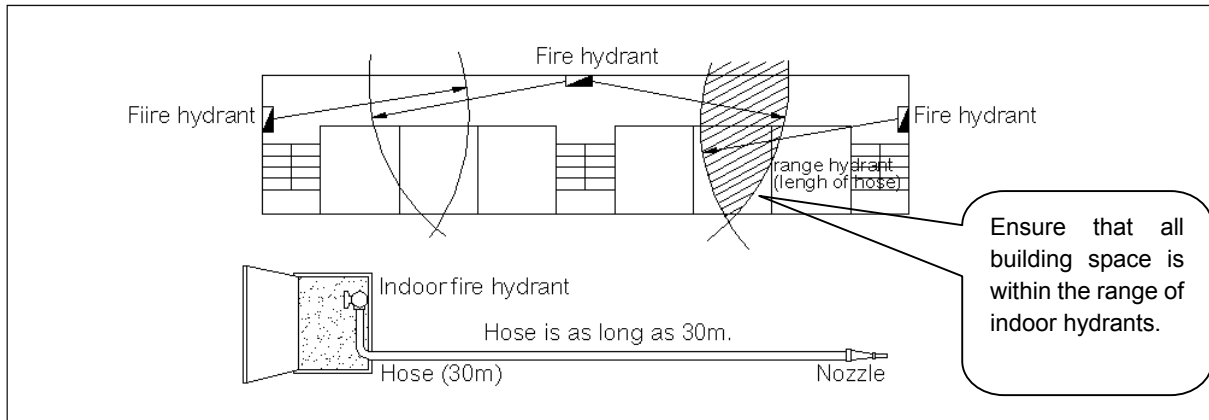
How to use Indoor Fire Hydrant



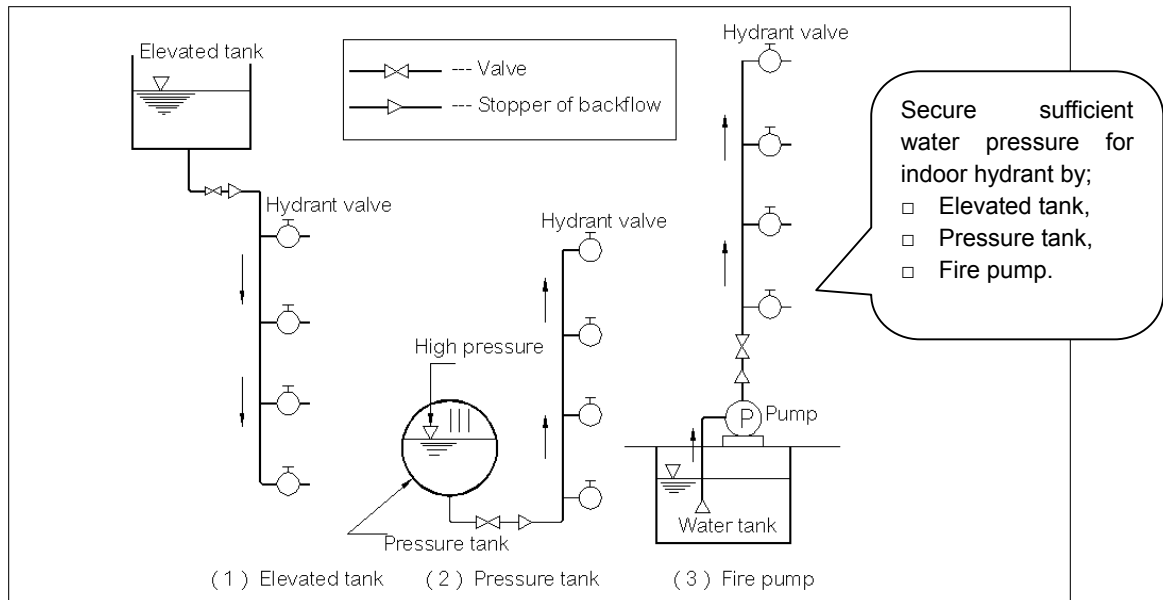
5.2.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Indoor Fire Hydrant (2/2)

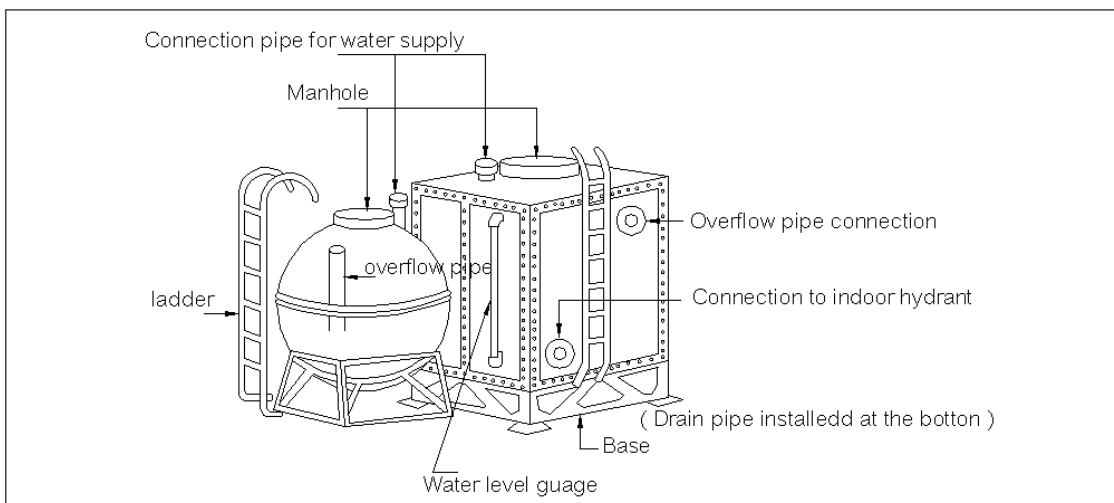
Location of Indoor Fire Hydrant



Pressurizing System of Indoor Fire Hydrant



Elevated Tank (sample)

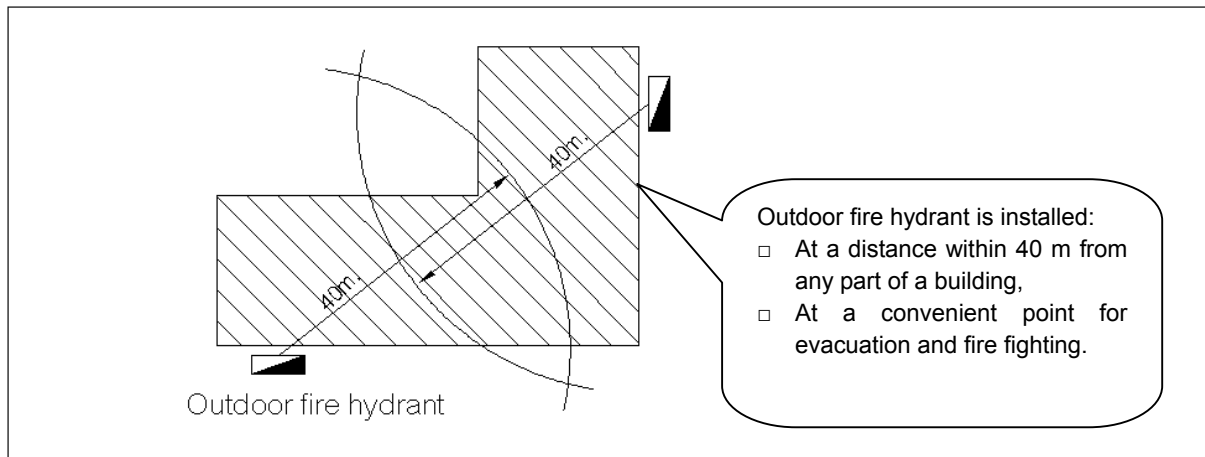


Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.2.2
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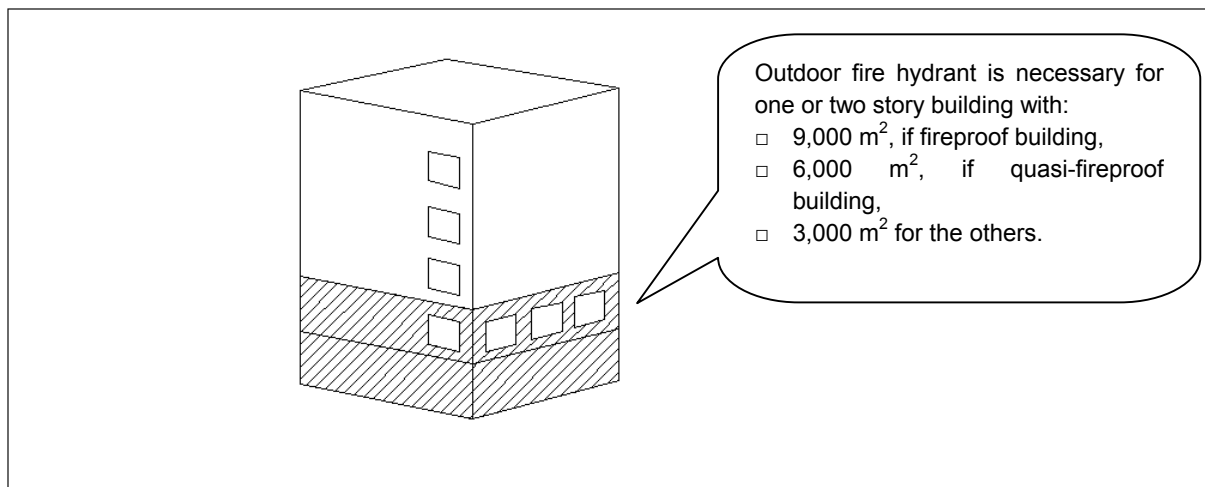
Outdoor Fire Hydrant

The outdoor fire hydrant is for extinguishing fire from outside a building, while the indoor fire hydrant is to directly extinguish fire inside the building. Therefore the outside hydrant can be used for one or two-stories buildings.

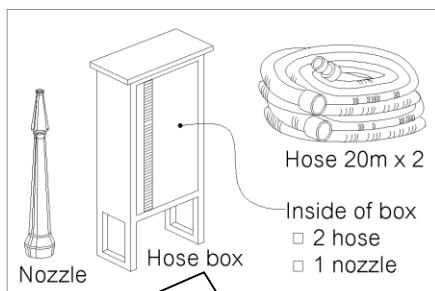
Installment of Outdoor Fire Hydrant



Necessity of Outdoor Fire Hydrant in Japan

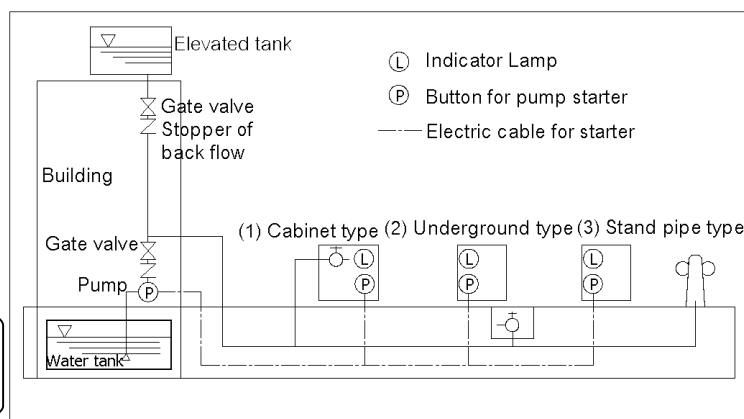


Hose Box and Incidental Equipment



Locate the hose box at a distance within 5 m from the outdoor fire hydrant.

Diagram of Outdoor Fire Hydrant

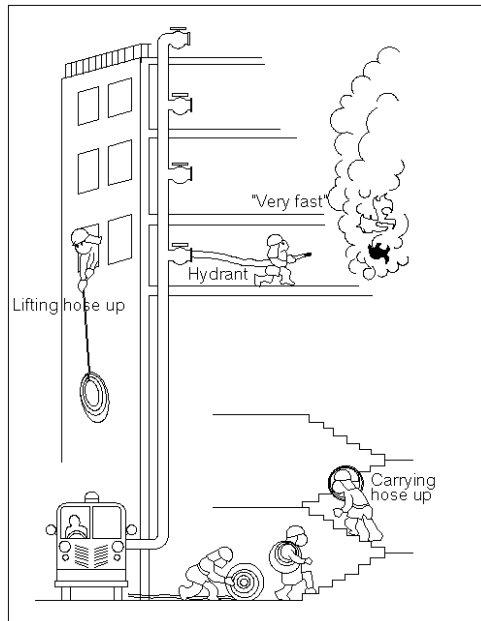


5.2.3	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Fire Department Hydrant

In high-rise buildings, it takes time to convey and prepare fire hoses for use on a higher floor. The fire department hydrant has the advantage of enabling fire hoses to be set up quickly by installing pipes for fire fighting in the building. In the case of a fire, water is immediately pumped by fire engine.

Advantage of Fire Department Hydrant



Necessity of Fire Department Hydrant in Japan

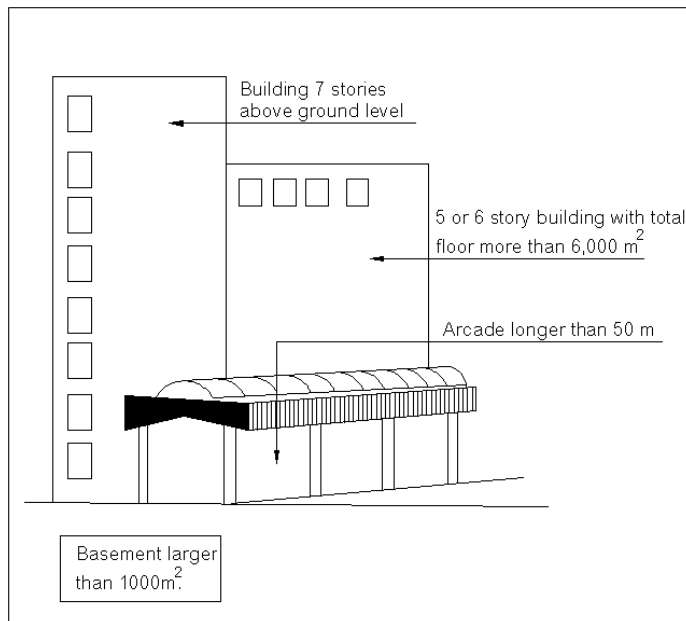
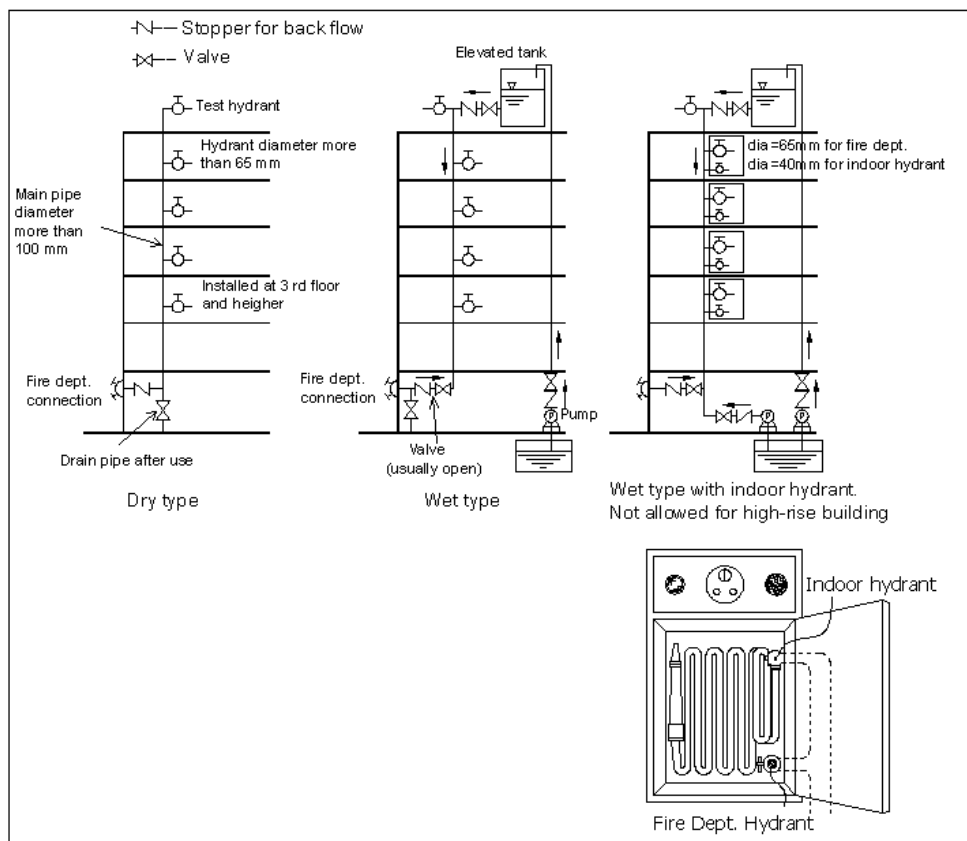


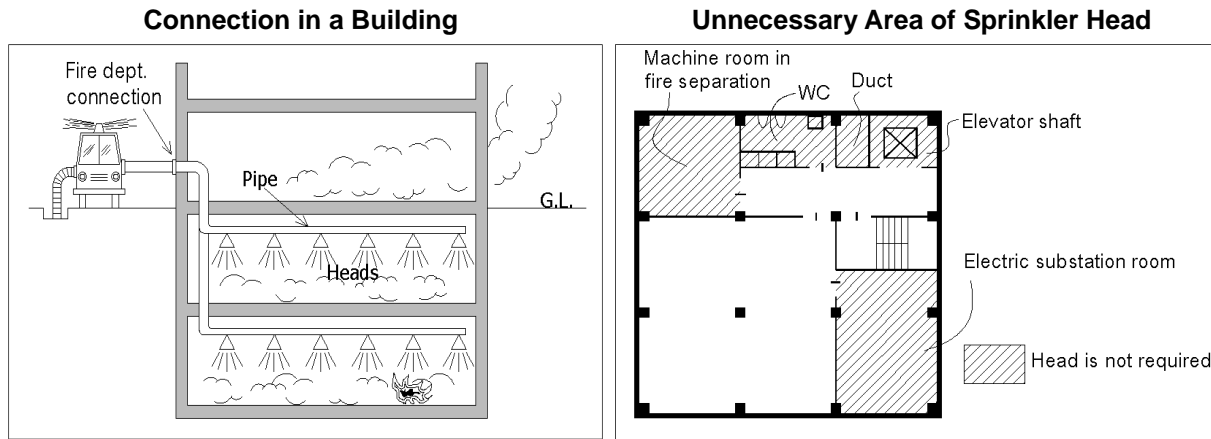
Diagram of Fire Department Hydrant in Japan



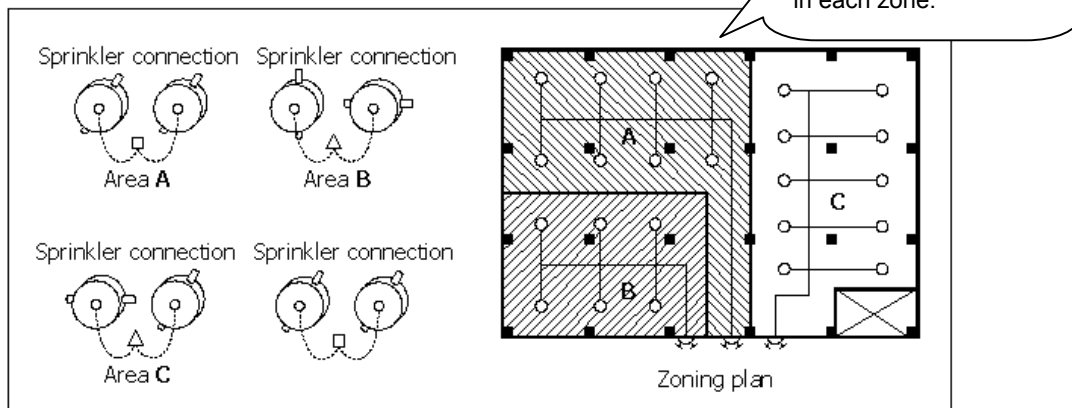
Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.2.4
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Sprinkler System with Hose Connection

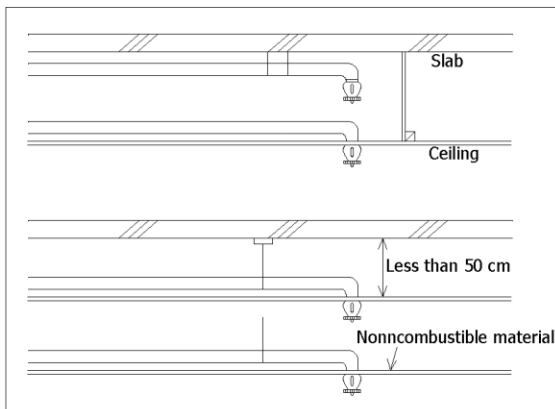
Evacuation and rescue is critical for if fire breaks out on basement floor. The sprinkler system by hose connection is effective for fire fighting on basement floors. A fire engine does not need high pressure to supply water, as sprinkler heads are located at a lower level than the fire engine.



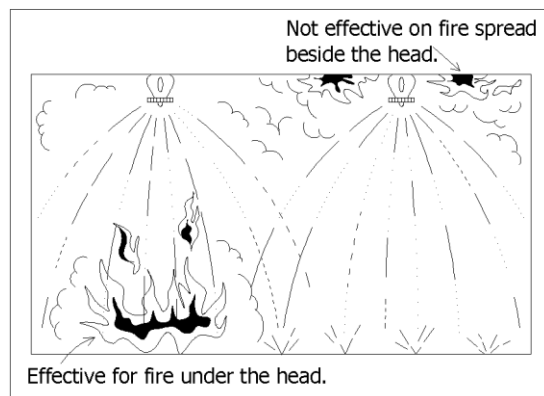
Fire Department Connection by Zoning



Installment of Sprinkler Head at Ceiling and Slab



Effectiveness of Sprinkler Head

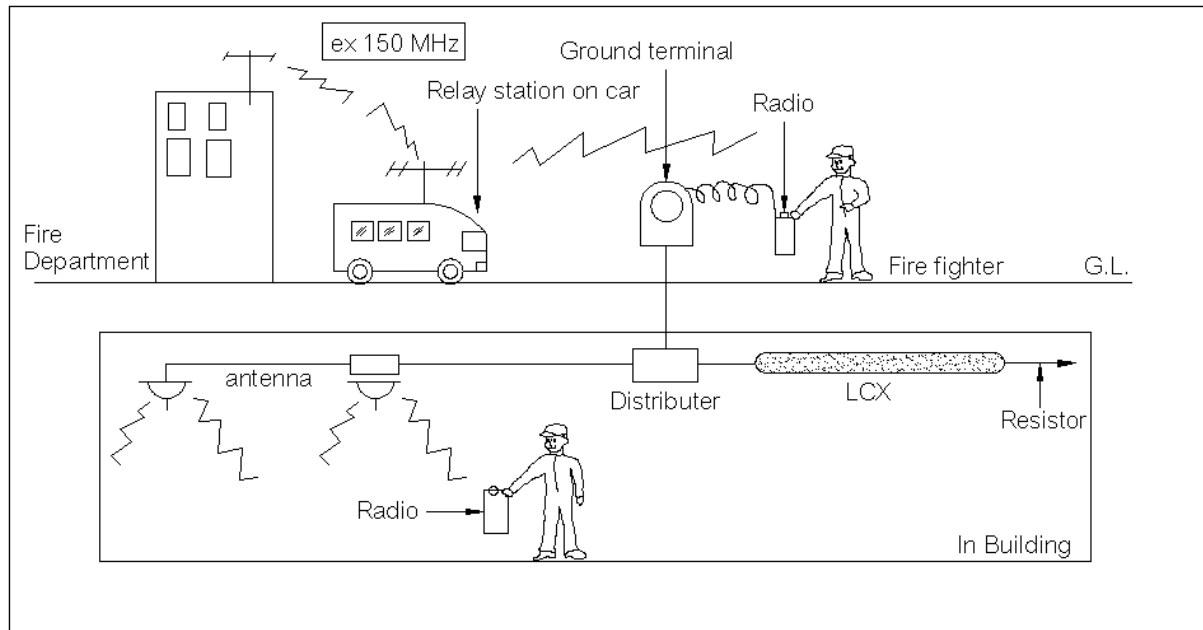


5.3.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Radio Communication System Support Equipment

Communication between firefighters is necessary for effective fire fighting activities and their safety. Fire fighters communicate by radio; however, the quality of radio waves often decreases in underground malls. The radio communication system support equipment is designed to strengthen radio communication. It has connection with the fire fighting control room.

Diagram of Radio Communication System Support Equipment in Japan

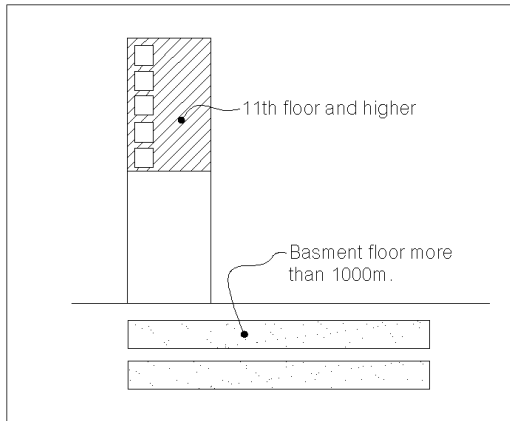


Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.3.2
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Emergency Electric Outlet

When fire fighter uses electrical equipment, such as chainsaws to gain access, the electric supply must be secured. The emergency electrical outlet is protected in terms of system and physical specification.

Necessity of Emergency Outlet in Japan



Installment of Emergency Outlet in Japan

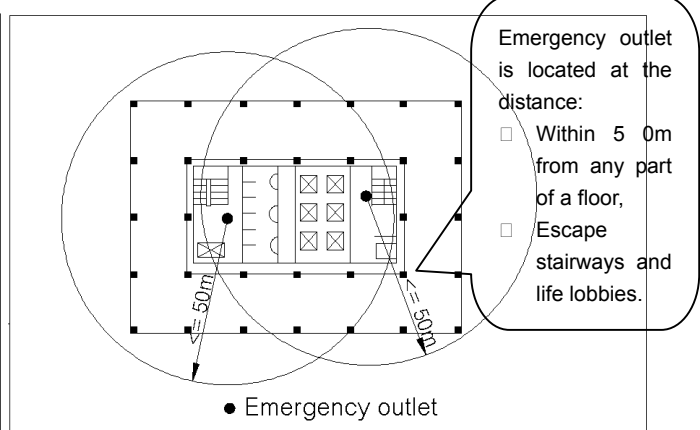
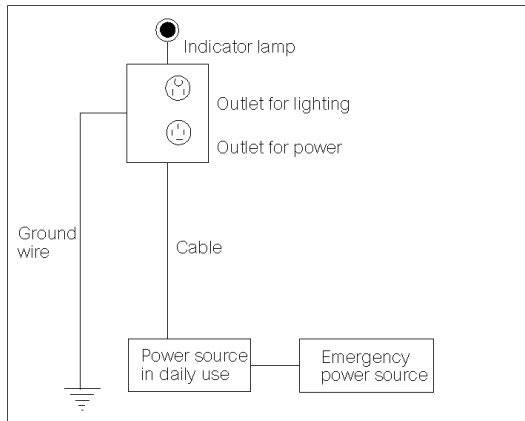
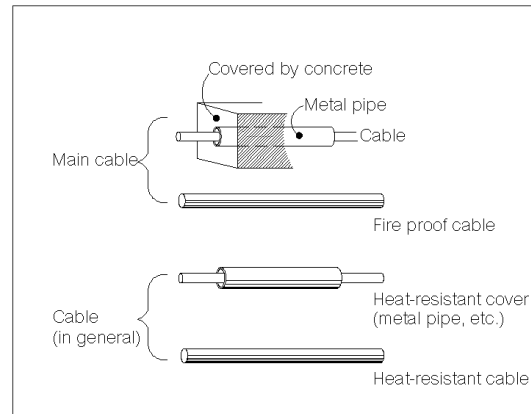


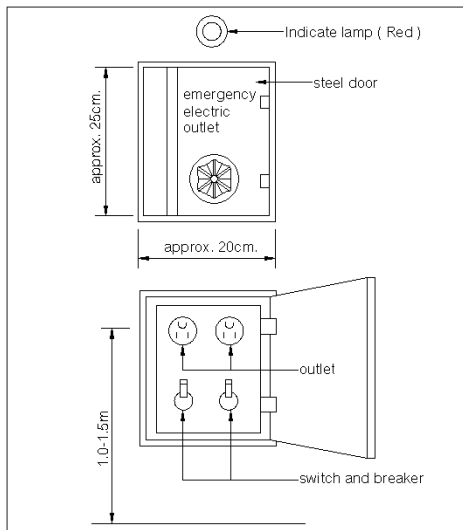
Diagram of Emergency Outlet



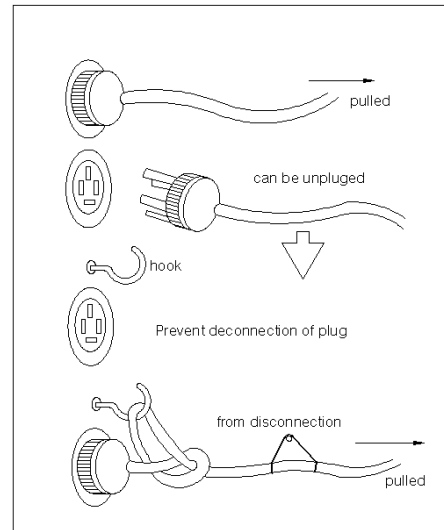
Fireproof Electric Cable



Layout of Emergency Outlet in Japan



Hook to protect Connection



5.4.1	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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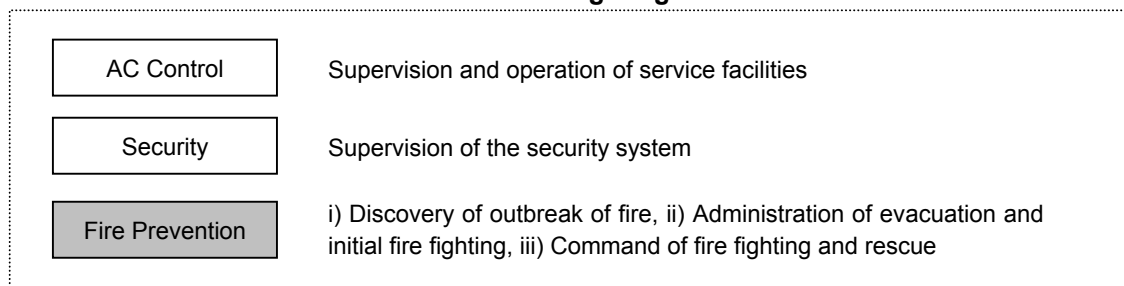
Principles of Fire Fighting Control Room

The fire fighting control room takes a different role at each stage of a fire.

- Supervising fire protection equipment of a building before the outbreak of fire,
- Administrating evacuation and initial fire fighting in the initial development stage of a fire,
- Having command of fire fighting and rescue in all stages of the fire.

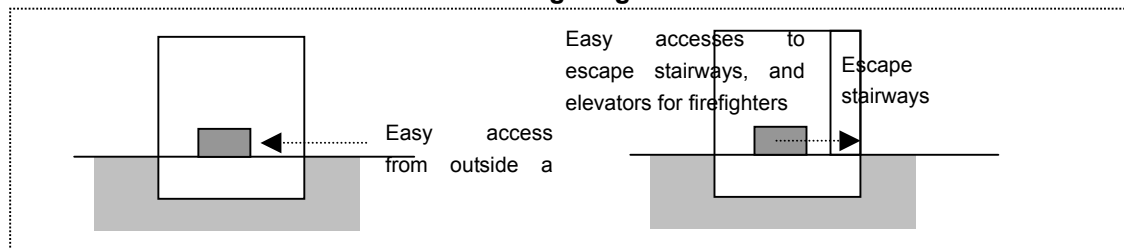
The fire fighting control room is usually annexed to a central administration room which supervises the security system and service facilities of a building.

Different Roles of Fire Fighting Control Room



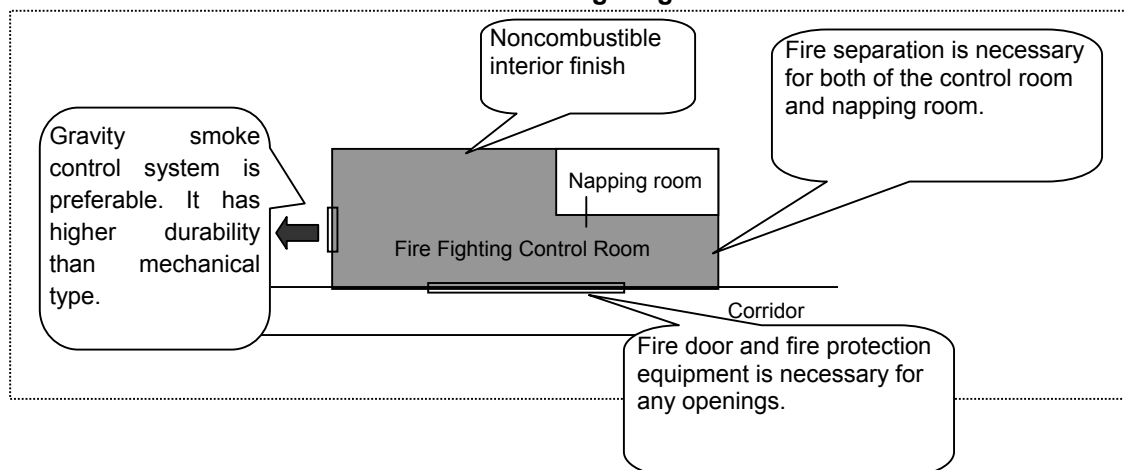
The fire fighting control room has to be placed with easy access from outside a building and to escape stairways.

Location of Fire Fighting Control Room



The fire fighting control room requires resistance to heat and smoke until suppression of fire.

Fire Resistance of Fire Fighting Control Room

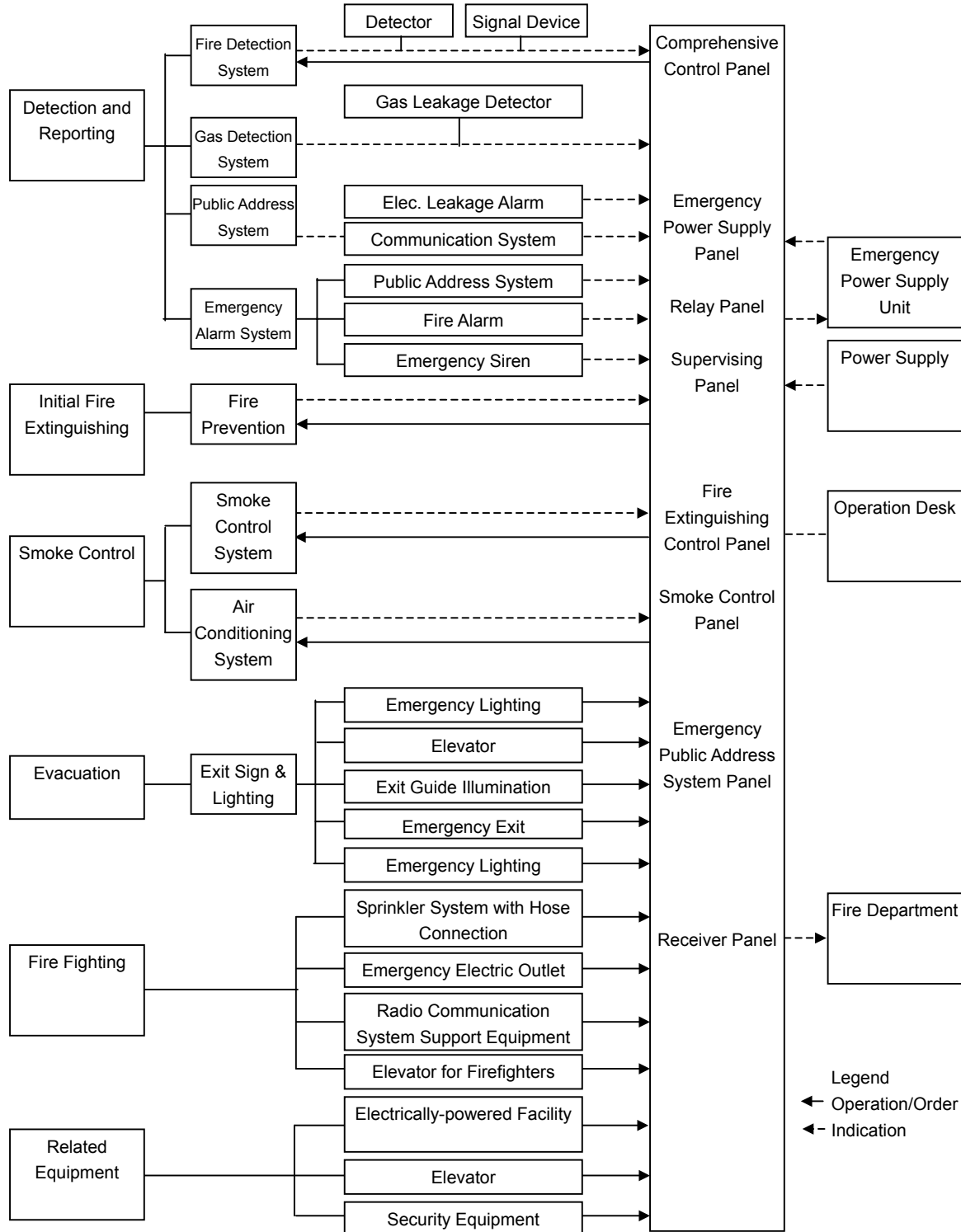


Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire	5.4.2
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Management System in Fire Fighting Control Room

The comprehensive control panel of a fire fighting control room supervised and operated fire protection equipment of a building.

Control Panel and Fire Protection Equipment by Stage of Fire



5.4.3	Outbreak	Initial Fire	Fire Spread	Evacuation	Fire Fighting	Collapse	Exposure Fire
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Fire Fighting Control Room of Complex Building

Complex buildings have different characteristics of occupants and fire hazards by the classification of building. Administration systems and fire fighting activities also differ with building classification.

It is preferable to subdivide a building into blocks which are demarcated by the administration system and the classification of the building. Each block is separated by the spatial layout, service facilities, and fire protection system. The fire fighting control room is subdivided into sub control rooms—one for each block. They are comprehensively integrated by the communication system.

Fire Fighting Control Room of Complex Building

