Explanation of Fire Prevention Standards for Underground Stations

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After the subway fire accident in Deagu, Korea in February 2003, a “Study Group for Fire Prevention of Underground Railways” was established to examine the current status of subway fire prevention equipment and the circumstances of the accident, in order to promote a comprehensive study on preventing fires in underground railways in Japan, and a report was issued in March 2004. Based upon this report, the Ministry of Land, Infrastructure, Transport and Tourism reviewed Approved specification for Ministerial Ordinance Article No. 29 (Facilities of Underground Stations), which is the so-called “Fire Prevention Standards”.

Overview of Explanation: The structure and main points are shown below.

1. Scope of Application
   - This standard applies to underground stations and tunnels connected to underground stations.
   - Underground stations include cases where the starting and terminal stations in urban areas are underground, stations built due to crossing with roads overhead, and cases where railway tracks are underground.
   - The standard does not apply to cut and fill sections and stations in tunnels in mountain regions. However, these shall be studied separately depending upon the structure and facility.

2. Main Points - Fireproofing of structures, etc.
   - Fireproofing of structural materials and interior dressing
   - Maximum fireproofing of floors of rooms of train dispatch stations to ensure habitability
   - Maximum fireproofing of fittings (desks, lockers, etc.)
   - Stores are classified into two types:
     → Convenience station store: Passengers can enter a store.
     → Simple concession stand: This is a simple, face-to-face, small store which passengers cannot enter.
   - Convenience station stores require compartmentalization to prevent fire and smoke, and the installation of automatic fire alarm equipment and sprinkler equipment.
   - As compartmentalization is difficult for simple concession stands due to their structure, the structural materials, interior and fittings such as bookshelves must be non-flammable.
   - Compartmentalization of underground substations for fire prevention.

Table of Contents

- Remarks -

［Ministerial Ordinance］

・「Ministerial Ordinance to Provide the Technical Standard on Railway」
（Ministerial Ordinance No. 151 of December 25, 2001）

［Public Notice］

・ **「Public Notice to Stipulate Dangerous Items Under the Item 20 of Article 2 of the Ministerial Ordinance to Provide the Technical Standard on Railway」**
（Public Notice No.169 of 1987）

・ **「Public Notice Concerning the Regular Inspection of Facilities and Rolling Stocks」**
（Public Notice No.1786 of 2001）

［Approved specification］

・「Approved specification for Ministerial Ordinance to Provide the Technical Standard on Railway」

［Others］

・「Previous Ministerial Ordinances or related Acts and Ministerial Ordinances which were the sources of interpretive standards, etc. 」

・「Documents other than the above such as notifications on operation.」

[Ministerial Ordinance]

(Facilities of Underground Stations)

Article 29. Underground railway stations that are built mainly with underground structure and tunnels leading to stations or long tunnels (hereinafter referred to as “underground stations, etc.”) shall be equipped with ventilators of adequate ventilating capability. This does not apply, however, to those cases that are accessible to sufficient natural ventilation.

2. Underground stations, etc. shall be equipped with fire extinguishers, evacuation facilities and other necessary fire-prevention equipment, depending upon the structure and facility.

[Approved specification]

1 Scope of application

These standards are applicable to underground stations and the tunnels connected to them. The term “underground station” refers to a station having its platforms provided underground (excluding stations located in mountainous regions).

[Explanation]

This standard shall apply to underground railways as before, and shall apply to railways of sections where an underground station and a tunnel are connected as one. Namely, in addition to a railway generally called a “subway” which runs mainly underground in an urban area, the standard also applies to a section of a railway which runs above the ground in the suburbs but runs underground between starting and terminal stations in an urban area, as well as to a section of a railway where the railway track including a station is partially underground due to crossing with roads overhead.

Even if the platform position is lower than the nearby ground, this standard does not apply to a railway of cut and fill construction.

However, if improvements are made for the sake of utilization above the railway track, such as covering the cut and fill section with a roof, the section may have the same configuration as an underground station depending on its length. Therefore, the status of such a facility shall be studied separately.

“Underground stations” refer to stations where the platform is underground, but as the standard applies to mass-transportation railways in urban areas, stations in tunnels in mountain regions (for example, Doai Station of JR Joetsu Line) are excluded.

Stations in tunnels in mountain regions shall be studied separately depending upon the structure and facility.

[Approved specification]

2 Fireproofing of structures, etc

(1) Structures shall be made fireproof according to the following stipulations.

[1] Structural items and interior dressings (including substrata) shall use non-flammable materials as stipulated by Item 9 of Article 2 of the Building Standard Law (hereinafter called "non-flammable materials"). However, the interior finish of the floors and walls (limited to finished sections to a height of no more than 1.2 meters from the floor) of habitable rooms of the offices such as the operation command center, the electric power command center, the signal handling center, and the disaster prevention control center (hereinafter called "habitable rooms") shall be fireproof as far as possible.

[2] As far as possible, furnishings such as desks and lockers shall not be made of flammable materials.

[3] Substations, distribution stations and machine rooms shall be partitioned from other areas by floors and walls having a fire-resistant construction and also fire doors. Also, if cables and the like pass through these partitions, the penetrations of the partitions shall be filled with non-flammable material.

Fire doors shall be specialized fire prevention facilities as stipulated by Paragraph 1 of Article 112 of the enforcement ordinance of the Building Standard Law (hereinafter called "fire doors"), and shall be provided with automatic closing devices, such as door closers and similar equipment.

(2) Structural materials, interior dressings, bookshelves, and other parts of kiosks (limited to simple ones) shall be made of non-flammable.

[Explanation]

To stop fires from breaking out and spreading, structures such as station facilities in underground areas and tunnels (hereinafter referred to as "structure") must use non-flammable materials for both structural materials and interior dressing (including substrata) regardless of their importance.

2 (1) [1] Fireproofing of structural materials and interior dressings

The structural materials and interior dressings (including substrata) of the structure shall use non-flammable materials.

Structural materials refer to walls, pillars, floors, beams, stairs, partition walls and other similar parts of the structure. The interior dressing refers to a surface finishing part of structural materials facing the inside of the structure.

Non-flammable materials refer to building materials which conform to the technical standards concerning non-flammability stipulated in Item (9) of Article 2 of the Building Standard Law and materials stipulated or certified by the Minister of Land, Infrastructure, Transport and Tourism including concrete, steel, earthenware-porcelain tiles, aluminum, metal plate, glass and mortar. The technical standards require performance such that materials do not burn for 20 minutes after the start of heating when subjected to heat from a flame in a normal fire, do not suffer damage such as harmful deformation, melting and cracks in terms of fire prevention, and do not emit harmful smoke or gas in terms of evacuation.

Habitable rooms refer to underground rooms continuously used for the purpose of living, work, operation and other similar matters, and include train dispatch stations, electric power dispatch stations, signal dispatch stations, control offices for disaster prevention and other similar rooms (**Table 29.1**). The interior dressing of floors and walls in habitable rooms (limited to finishing areas up to 1.2 meters above the floor surface) shall use non-flammable materials or flame-retardant materials where possible in terms of habitability as before.

For the floors of vending machine rooms, low-power machine rooms, switch rooms, toilets for employees, etc., the commercialization of non-flammable materials for floor finishing materials has been slow partly because the Building Standard Law does not provide regulations on the interior dressing of floors. Floors finished with non-flammable materials are limited to inorganic hard materials such as stone, tiles, metal and mortar; these materials are suitable for outdoor use but not for indoor floor materials.

The floors of even non-habitable rooms need to be dustproof, resistant to dirt, etc. due to their use and function. If non-flammable materials are not suitable, efforts to achieve non-flammable shall be made and flame-retardant materials shall be used for floor finishing materials where possible.

Even in an aboveground habitable room, if it faces an evacuation route from underground, it is necessary to secure passenger safety by striving to achieve fireproofing equivalent to that of underground habitable rooms.

Signboards (service guidance displays, bulletin boards, advertising, etc.) (**Photo 29.1**), blocks for guiding the visually impaired (surface finished with synthetic rubber, etc.) and materials partially used for machinery and electric equipment of elevators, ticket machines, lighting, etc. are excluded from the scope of fireproofing. However, it is desirable to use flame-retardant or non-flammable materials where possible.

Photo 29.1　Example of signboard

Table 29.1　Example of habitable room

Example of habitable room	
Train station work related rooms	Stationmaster's office and station office
	Staff room, Nap room
	Ticket office
	Conference room
Control and management related rooms	Control room for disaster prevention
	Train dispatch station
	Electric power dispatch station
	Signal dispatch station
Ticketing and passenger service related rooms (**Photo 29.2**)	Railway ticket issuing office
	Information office
Maintenance and cleaning workers' room	Maintenance workers' room
	Cleaning workers' room
Others	Convenience station store

Photo 29.2　Example of railway ticket issuing office

2 (1) [2] Fittings such as desks and lockers

For fittings in a building such as desks and lockers (objects in a building which are not secured to the structural materials or interior dressing) (**Table 29.2**) (**Photos 29.3 - 29.4**), it is desirable to use fittings made of flame-retardant or non-flammable materials where possible to improve the fireproofing of the building.

The Fire Service Act stipulates flame-retardant products, and it is effective to use these to improve the fireproofing of the interior dressing.

Table 29.2　Examples of fittings

Examples of fittings
Desk, counter, chair, bed
Cabinet, bookshelf, locker
Partition, curtain
Bench, trash box, planter box
Ticket counter box, public phone, vending machine

Photo 29.3 Example of bench

Photo 29.4 Example of ticket counter box

2 (1) [3] Compartmentalization of substation, power distribution station and machine room
As a fire could occur in an underground substation, power distribution station or machine room (ventilation machine room, smoke exhaust machine room, etc.) due to a fault in electrical machinery, etc., they shall be enclosed by fire preventive blocks using the following methods to prevent a fire from spreading (**Photos 29.5 - 29.6**).

a) Floors and walls shall be of fireproof construction.
b) A fire door shall be installed in the opening.
c) Gaps in the blocks for routing cables, etc. shall be filled with mortar or other non-flammable materials.

The fireproof construction used for floors and walls which form a fire preventive block shall be of reinforced concrete construction, concrete block construction, brick construction or other construction which conforms to Item (1) and Item (2) of Article 107 of the Order for Enforcement of the Building Standard Law, and shall be constructed only of non-flammable materials from among the construction methods stipulated by the Minister of Land, Infrastructure, Transport and Tourism. If this method is not used, the situation shall be studied each time.

Photo 29.5 Example of automatic closing appliance (door closer)

Photo 29.6 Example of treatment of block penetration area

2 (2) Station store
Some underground station stores face the platform, concourse or passageway, and there is a recent trend toward diverse categories including restaurants such as spacious tearooms and stores offering services including travel agencies, barber shops and massage stores. At some stations, the construction of stores is encouraged to attract users and make effective use of space. However, such stores contain various flammabilities and a fire could occur, so careful attention is needed. In addition, the passenger flow of places where these stores are built must be taken into consideration as shown in 4 (6) [3].

To suppress a fire as much as possible, it is necessary to make not only the structure of stores but also the interior dressing and fittings such as bookshelves non-flammable.
Stores typically contain large amounts of flammabilities and are becoming larger to meet user needs. These stores are rarely moved, and convenience stores, for example, contain many flammabilities.
The Study Group for Fire Prevention of Underground Railways that was set up following the subway fire accident in Deagu, Korea in February 2003, classified stores into the following: a store that passengers other than clerks can enter such as convenience stores (hereinafter "convenience station store") (**Photo 29.7**) (**Fig. 29.1**) and a simple, small, face-to-face store often found on station premises that passengers other than clerks cannot enter (hereinafter "simple concession stand") (**Photos 29.8 - 29.9**) (**Fig. 29.2**).
Convenience station stores, which contain many flammabilities, are required to use flame-retardant or non-flammable materials for the interior dressing of floors and walls as well as fittings such as bookshelves, and to install automatic fire alarm equipment of 4 (1) [2], fire and smoke preventive compartments of 4 (6) [4] and sprinkler equipment of 5 (1) [3] to help prevent the spread and promptly extinguish a fire.

Photo 29.7 Example of convenience station store

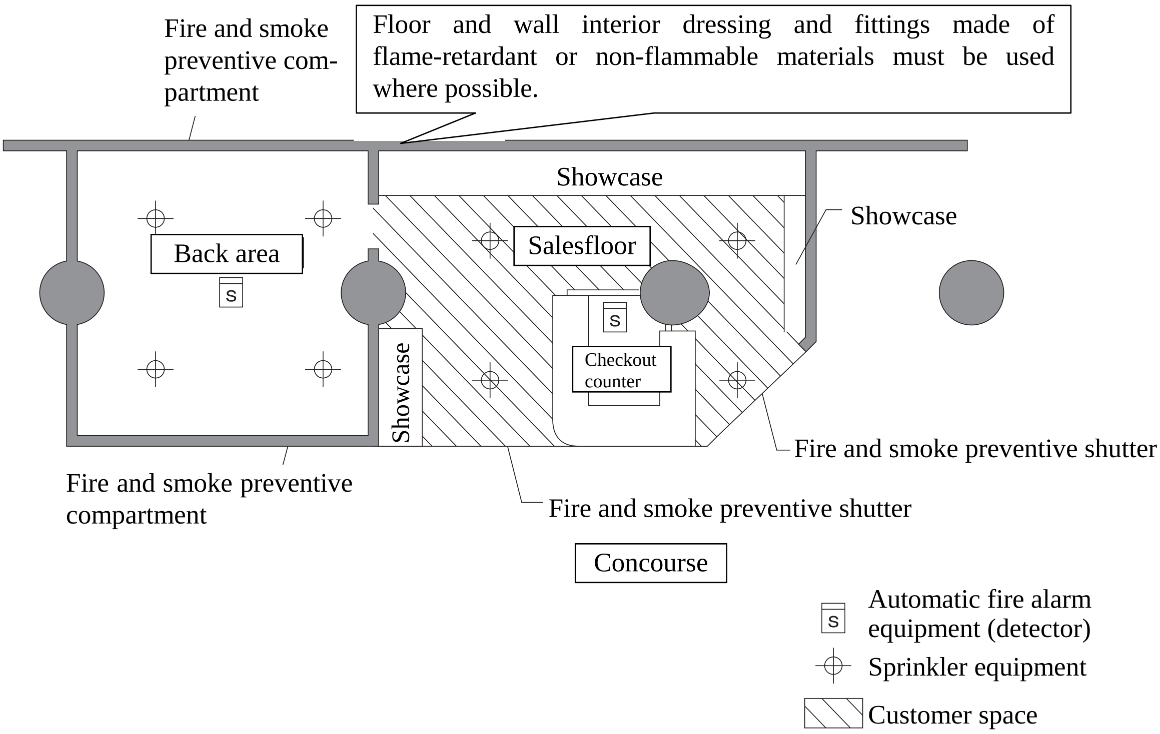


Fig. 29.1 Example of convenience station store

As it is difficult to compartmentalize simple concession stands due to their size and structure, it was decided to make not only structural materials but also the interior dressing (excluding the floor [Note 1]) and fittings such as bookshelves of simple concession stands non-flammable. The reason why even bookshelves are made non-flammable is that a fire experiment on a simple concession stand revealed that wooden shelves emit large amounts of smoke during a fire. However, if automatic fire alarm equipment is installed and fire and smoke preventive compartmentalization is employed, the interior dressing of walls and fittings such as bookshelves should use flame-retardant or non-flammable materials where possible.

Note 1: The floor is excluded because it is difficult to make non-flammable materials compulsory, since the floor of a simple concession stand must be dirt-resistant, easy to use, and comfortable. Therefore, if non-flammable materials cannot be used, flame-retardant materials should be used for the floor finish materials where possible.

Photo 29.8 Example of simple concession stand [1]

Photo 29.9 Example of simple concession stand [2]

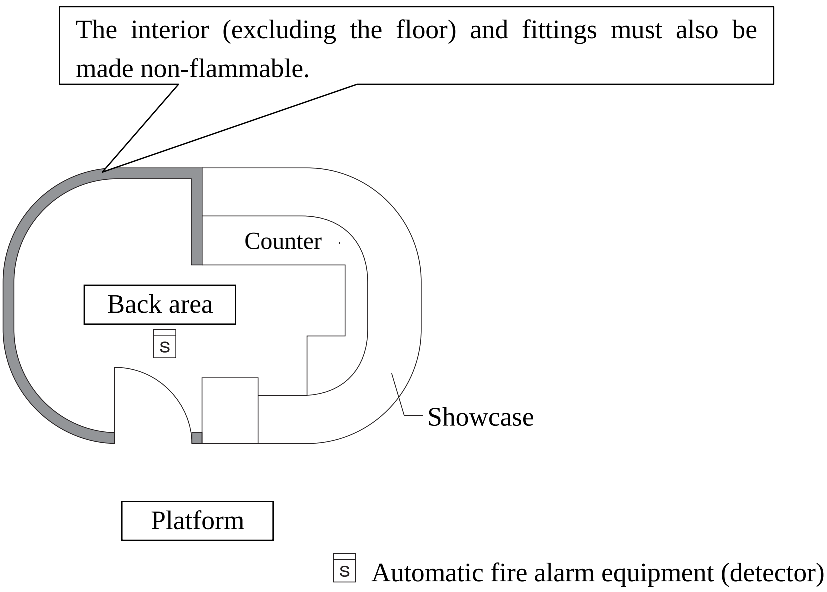


Fig. 29.2 Example of convenience station store

[Approved specification]

3 Provision of a disaster prevention control center (1) A railway station shall have a permanently manned disaster prevention control center that collects information, conveys notifications and commands, makes announcements for passengers, and also monitors and controls fire shutters and other facilities. In this case, it is desirable that the disaster prevention control center be a shared facility with the station office. (2) The disaster prevention control center shall be provided with lighting facilities that are powered by emergency power in the event of a power outage. (3) The emergency power source shall be either storage batteries or a dedicated power generator. This shall also apply to the following emergency power sources as well.

[Explanation]

3 (1) Disaster prevention control center

As an unspecified large number of passengers get on and off trains at stations and stations are located in special areas underground, if a disaster such as a fire occurs, station staff must [1] notify the fire-fighting authorities, train dispatch stations, etc., provide passengers with information on the fire, operate the fire-fighting equipment such as smoke exhaust facility, monitor the operation status, [2] extinguish the fire quickly, [3] guide the evacuation of passengers, perform rescue operations, and so forth. To cope with a disaster such as a fire properly, a disaster prevention control center must be provided and station staff must always be on duty because information gathering, communication and transmission of instructions, public announcements to passengers, operation of fire-fighting equipment, monitoring of the status, etc. need to be centrally controlled at one location. The equipment that can be controlled and monitored in the disaster prevention control center includes an automatic fire alarm receiver, communication and public address system, operation monitoring panel of fire-fighting equipment, operation monitoring panel of smoke exhaust facility, operation monitoring panel of fire preventive doors and fire shutters, etc. (**Photos 29.10 - 29.15**) (**Fig. 29.3**).

It is desirable to set up the disaster prevention control center as an annex to the station office where station staffs are always on duty, because various responses must be made immediately when a fire occurs. If the disaster prevention control center is independent, dedicated station staff must always be on duty during business hours.

“Fire preventive shutters, etc.” refer to fire preventive shutters which can be remotely controlled, ITV, etc. which are set up at necessary locations for fire prevention.

In the case of an underground station, the provision of manuals concerning the response of staff in the event of a fire, education and training, and cooperation with the fire-fighting authorities are stipulated. At a station where multiple railways converge underground, administrators of stations and underground shopping center and fire prevention administrators jointly establish a joint fire prevention management council, prepare a joint fire-fighting plan, and submit it to the fire-fighting authorities in some cases.

Photo 29.10 Example of using station office as disaster prevention control center

Photo 29.11 Railway telephone (left)
Dispatcher telephone (right)

A subscriber telephone, railway telephone, dispatcher telephone, etc. are provided for communication with the fire-fighting authorities, train dispatch station, etc.

Photo 29.12 Example of public address system

The public address system is used to provide passengers with information on the fire.

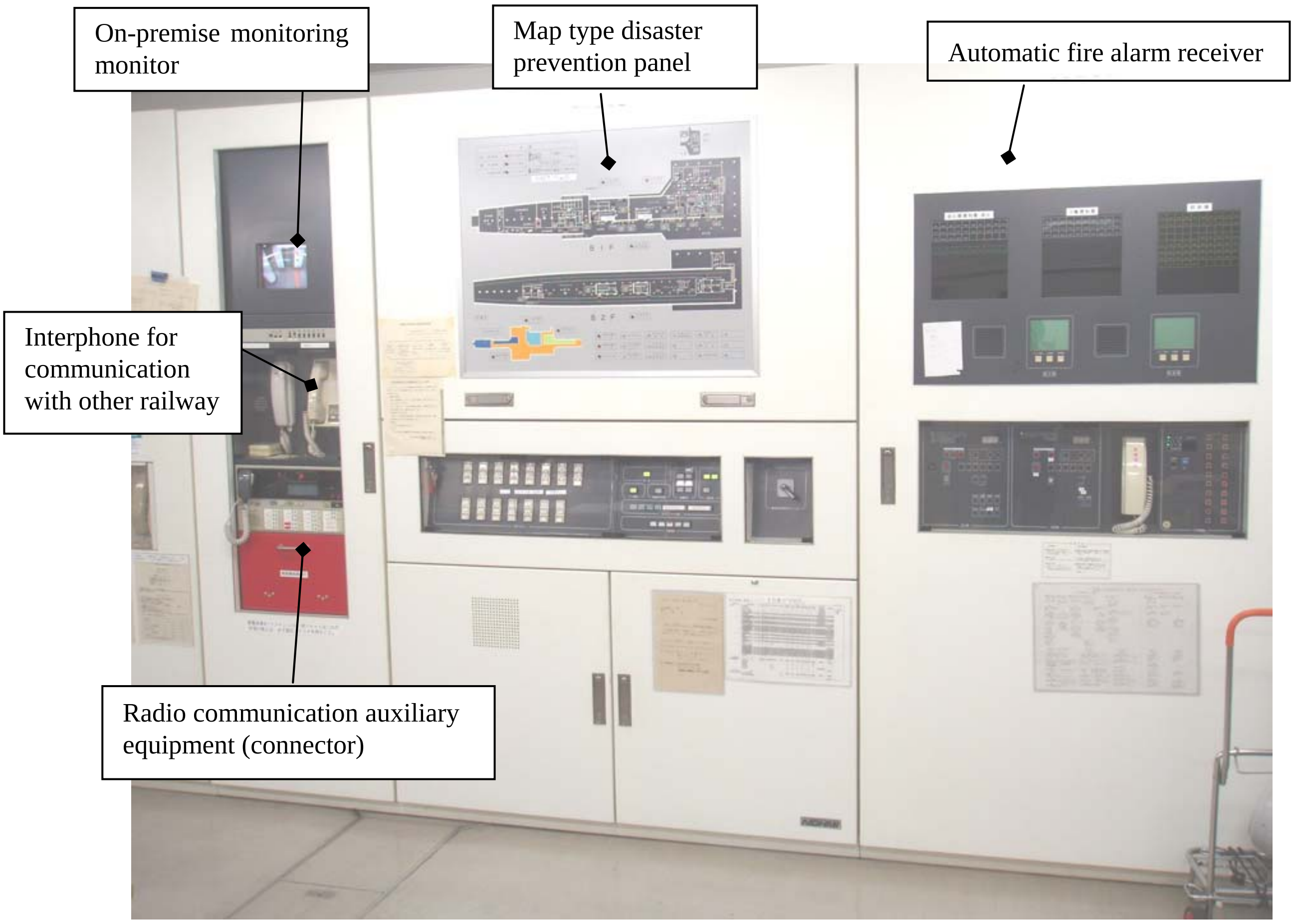


Photo 29.13　Disaster prevention monitor panel

Photo 29.14　Example of furnishings shelf

Photo 29.15　Example of fire extinguisher

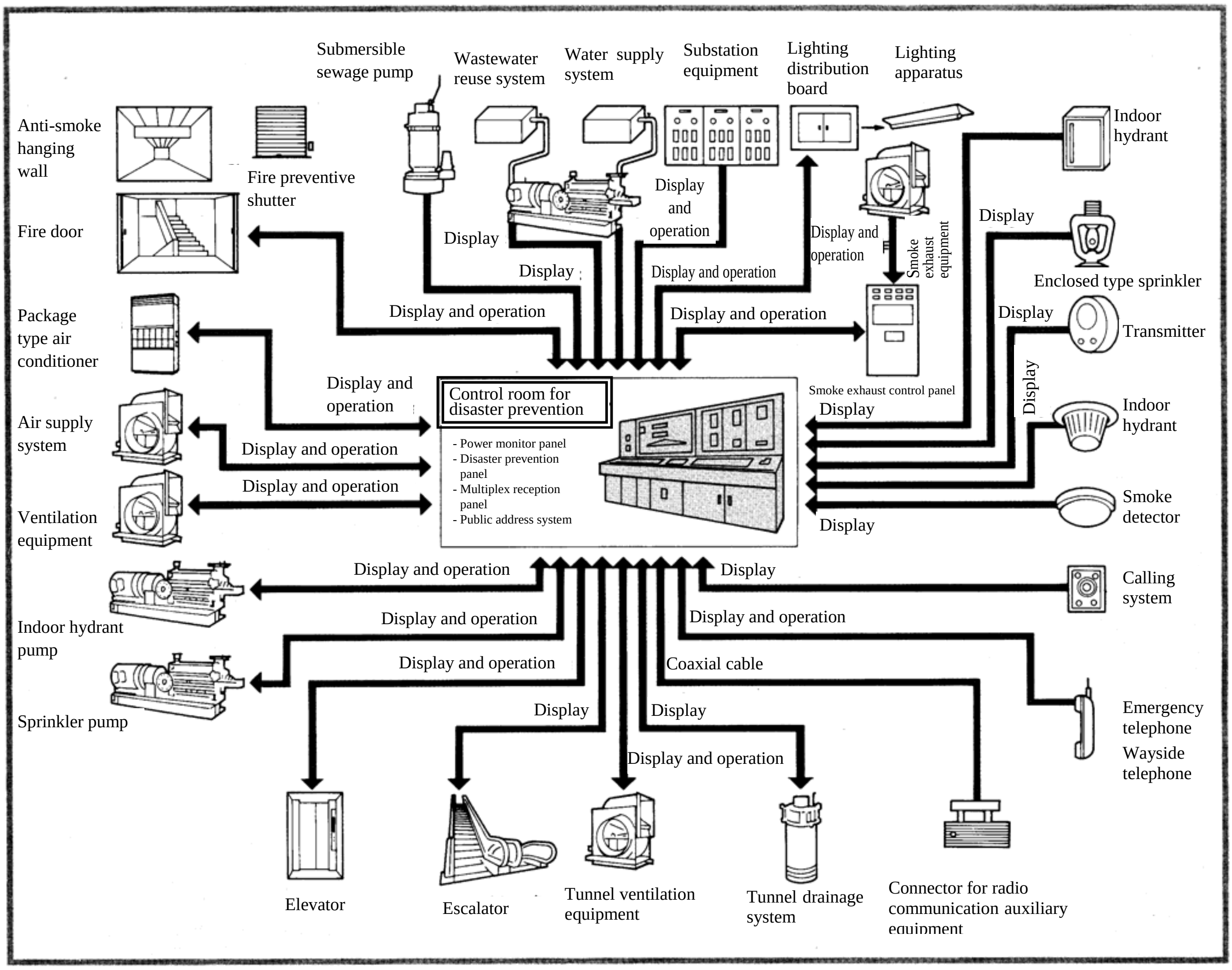


Fig. 29.3 Example of disaster prevention system

3 (2) Lighting equipment for disaster prevention control center

The brightness of lighting equipment in the disaster prevention control center shall not interfere with work and last for at least one hour as a guide even if the power source is switched to an emergency electric power source (**Photo 29.16**).

Although it is natural to comply with the illuminance stipulated by the Building Standard Law (the floor surface illuminance must be at least 1 lux for an incandescent lamp and at least 2 lux for a fluorescent lamp, and the illumination must last for 30 minutes or longer), higher illuminance is desirable since the disaster prevention control center will be used as a center of evacuation and fire-fighting activities in a disaster.

In this case, a guideline for the desirable illuminance is at least 10 lux and the illumination shall last for at least one hour. The illumination time shall be sufficient to allow evacuation from the platform level to above the ground.

Photo 29.16 Emergency lighting

3 (3) Emergency electric power source

It is important to acquire a power source in order to make fire-fighting equipment that uses electricity, such as smoke exhaust equipment and automatic fire alarms, function reliably when a fire occurs. An in-house power generating station or storage battery system must therefore be installed as an emergency electric power source for fire-fighting equipment. In the previous fire-fighting standards (Tetsu-Do No. 9 of February 14, 1975), interim measures were taken in which dual line power receiving equipment, which was regarded as equivalent to an emergency electrical power source, was approved as an emergency electrical power source for the time being in existing underground railways in addition to an in-house power generating station and storage battery system. However, since the Interpretive Standards were revised in December 2004, it has become mandatory to install an in-house power generating station or storage battery system even in existing underground railways built before the enactment of the previous fire-fighting standards when reconstruction or rebuilding work is performed in the future.

As the configuration for installing an in-house power generating station, there is the case in which a power generating station in each station supplies electricity to the fire-fighting equipment of the station, and the case in which a power generating station which provides power to multiple stations is installed in a transformer station which supplies electricity to necessary stations.

Although it is preferable that an in-house power generating station be installed in conformity with the Fire Service Act, the structure may differ from that stipulated in the Fire Service Act in some cases because in the case of a railway, the power source supply is considered to be highly reliable compared to other objects subjected to fire prevention due to multiplexing and networking of the distribution lines. For example, although the Fire Service Act stipulates that voltage be automatically established if the normal power source is cut off, in a railway where the power distribution equipment is networked, a monitoring station can supply a power source depending on the status of a power failure. Therefore, if fire-fighting equipment can be made to function without delay, it is considered permissible not to rely on a system in which voltage is automatically established in the case of power failure of the normal power source.

For an emergency generator, a diesel generator (**Photo 29.17**) or gas turbine generator is used. In the case of a water-cooled diesel generator, consideration is required to ensure that coolant is not interrupted at the time of a disaster.

If this is difficult, an air-cooled generator which needs no coolant can be installed.

Photo 29.17 Installation example of diesel generator

[Approved specification]

4 Provision of alarm facilities, notification facilities, evacuation guidance facilities, and the like

(1) Alarm facilities

[1] A railway station shall be provided with automatic fire alarm facilities, and the disaster prevention control center shall be provided with a receiver for the alarm facilities.

[2] Detectors for the automatic fire alarm facilities shall be provided in habitable rooms, kiosks, substations, distribution stations, machine rooms, and other such locations. Automatic fire alarm facilities shall be provided with emergency power sources.

[Explanation]

4 (1) [1] Automatic fire alarm facilities [1]

Automatic fire alarm facilities are alarm equipment intended to enable early detection of a fire, early notification, initial fire-extinguishing and early evacuation by detecting heat and smoke, etc. with a detector (**Photos 29.18 - 29.19**) at the time of a fire and to automatically issue an alarm. The equipment consists of a detector, receiver, repeater, transmitter, indicator lamp, acoustic apparatus, wiring, etc.

The automatic fire alarm facilities transmits fire signals to the receiver when the detector detects a fire or when a person who finds the fire operates the transmitter, and then a local sound is produced automatically, alerting attention to a fire inside the building. At the same time, the acoustic apparatus of the receiver sounds and the fire indicator lamp comes up, and the local indicator lamp which shows the location (warning district) of the fire comes on.

There are several types of detector of automatic fire alarm facilities, such as the smoke detector type and heat detector type, while for the transmitter there is the push button type and the telephone type. The receiver of the automatic fire alarm facilities shall be provided in the disaster prevention control center where station staffs are always on duty.

Photo 29.18 Example of smoke detector

Photo 29.19 Example of heat detector

The Study Meeting on Fire Prevention at Underground Railways stated that advanced automatic fire alarm facilities could improve fire prevention safety. The study meeting found that installing advanced automatic fire alarm facilities, which detect the ambient temperature or smoke density of individual detectors and display warnings at an early stage of a fire and can identify the triggered detector, is effective at deep underground stations or large stations where evacuation and fire-fighting are difficult.

The study meeting also suggested that it is effective to display the fire situation automatically (interlocked with automatic fire alarm facilities) in the disaster prevention control center using ITV in order to detect fires early on.

4 (1) [2] Automatic fire alarm facilities [2]

Locations where automatic fire alarm detectors are installed include habitable rooms, station stores, substation, machinery room and warehouse where there are flammabilities and a fire can occur.

Automatic fire alarm detectors shall be installed at locations such as the ceiling where a fire can be effectively detected according to the structure of the installed location and the type of combustibles based on the characteristics of the detector.

The provisions in Paragraph 2 and Paragraph 3 of Article 21 of the Order for Enforcement of the Fire Service Act and provisions in Article 23 to Article 24.2 of the Ordinance for Enforcement of the Fire Service Act shall be complied with as technical standards concerning the installation and maintenance of automatic fire alarm facilities.

The previous standards required automatic fire alarm facilities to be installed at locations other than the platform, concourse, passages (including stairs and ramps) and station stores (limited to movable ones). However, automatic fire alarm facilities were sometimes installed at locations where they were not necessarily needed, and therefore, requirements in the standards have been changed to read that automatic fire alarm detectors are installed at locations where a fire is likely to occur.

The previous standards stipulated that automatic fire alarm facilities should be installed at fixed station stores, but were not necessary for movable stores on platforms, concourses and passages, etc. because their position was not fixed. However, movable stores contain a large amount of combustibles and have become quite large to meet user needs, so they are actually moved very rarely. As it is important to detect a fire early to prevent it spreading and for evacuation guidance, it was stipulated that automatic fire alarm facilities should be installed at simplified concession stands.

If a fire occurs in a store, the local office that received the automatic fire alarm must be able to display that the store is where the fire has occurred. However, this shall not apply if the location of the fire can be identified by existing blocks.

Automatic fire alarm facilities do not need to be installed in tunnels as before because a fire in such a location cannot be effectively detected due to air currents caused by train movement depending on the detectors used.

Automatic fire alarm facilities must be equipped with an emergency electric power source to cope with a power failure.

[Approved specification]

(2) Notification facilities

[1] The following facilities shall be installed at a railway station.

(A) Communication facilities such that the disaster prevention control center shall be capable of communicating with the fire brigade, the police, the operation command center, the electric power command center, and various parts of the station (habitable rooms, both ends of the platform, and places that are important from the viewpoint of communication within the area that is controlled by the station), and also with related adjacent buildings.

(B) Broadcasting facilities that can be controlled from the disaster prevention control center. (The range over which announcements can be made from the disaster prevention control center shall include the platforms, concourse, passageways and other areas controlled by the station.)

(C) Auxiliary wireless communication facilities

[2] Communication facilities to enable communication from a train or the inside of a tunnel to the operation command center shall be provided between stations. In this case, the communication facilities that permit communication from the inside of a tunnel to the operation command center shall be provided at intervals of no more than 250 meters inside the tunnel.

[3] Communication facilities and broadcasting facilities shall be provided with emergency power sources.

[Explanation]

4 (2) [1] [A] Communication facilities

It is essential to notify the fire-fighting authorities when a fire occurs. Therefore, it must be possible to notify the fire-fighting authorities, police, train dispatch station, electric power dispatch station and various locations around the station, from the disaster prevention control center because this is where central monitoring and control is performed when a fire occurs.

“Related adjacent structure” refers to a structure such as an underground shopping center as part of, or connected to, a station underground, a department store the basement of which is connected to a station underground, and a station at which transfers are made underground. Equipment which can directly communicate with the disaster prevention control center shall be provided in the disaster prevention center in the underground shopping center.

However, for communicating with the fire-fighting authorities, police and related adjacent structures, a subscriber telephone may be used.

An emergency electric power source shall be provided in the communication facilities to cope with power failures.

4 (2) [1] [B] Broadcasting facilities

When a fire occurs, it is necessary to issue an alarm facilities sound, to guide passengers by public address, to inform passengers throughout the station of the situation quickly, and to evacuate an unspecified large number of passengers without causing panic and confusion. Therefore, the disaster prevention control center where information is gathered must grasp the situation, announce the appropriate information and evacuate passengers effectively.

The broadcasting range from the disaster prevention control center is the range where passengers or station staff are located such as the platforms, concourse, passages, and the area that the station controls.
An emergency electric power source shall be provided in the broadcasting facilities to cope with power failures.

4 (2) [1] [C] Auxiliary wireless communication facilities
Radio waves do not penetrate underground stations, hindering smooth fire-fighting activity. Therefore, to secure radio communication in an underground station, auxiliary radio communication facilities is installed and used to give commands for fire-fighting activities at the fire site. The auxiliary wireless communication facilities consists of connection terminals, coaxial cable, distributor, leaky coaxial cable, antenna and other similar apparatuses. The system may include a leaky coaxial cable system, antenna system and leaky coaxial cable and antenna system (combination system) depending on the difference of apparatus used to transmit radio waves.
As auxiliary wireless communication facilities is intended to be used by fire fighters, the frequency band width and the position of radio connection terminals are decided based on the Fire Service Act.
Connection terminals (ground terminals) provided on the ground are stored in a protection box, which is set up at a location where a fire company can conduct activities effectively on the ground.

4 (2) [2] Communication facilities between stations
The communication facilities provided in a tunnel is also called a wayside telephone, and shall be provided at intervals of 250 meters or less as before. If telephones are not fixed in a tunnel, in some cases a train crew member walks with a telephone and inserts a jack at intervals of 250 meters or less to enable communication, while in other cases a telephone using private PHS or wireless LAN is set up as a wayside telephone. It is necessary to determine the handling in the implementation standards for operation.
Wayside telephones are very effective not only at the time of an accident but also at the time of routine maintenance operation.

[Reference]
Even if a radio communication system such as private PHS (**Photos 29.20 - 29.21**) and wireless LAN is adopted, an antenna may be placed to ensure that no dead band exceeding 250 meters is created. However, it is preferable, utilizing the merit of radio, to investigate set-up locations to minimize dead bands.
Portable handsets are installed on rolling stock for use or a train crew member always carries one, and they need to be placed in a station and related offices such as track maintenance bases. Furthermore, the portable handsets must be controlled so that they can be used at any time.
If private PHS or wireless LAN is adopted and connection is made to the telephone line via a switchboard or transmission set placed in a station, an emergency electric power source such as UPS needs to be added to a switchboard or transmission set.

Photo 29.20 Example of PHS Antenna

Photo 29.21 Example of PHS portable handset

[Approved specification]

(3) Evacuation guidance facilities

[1] A railway station shall be provided with the following facilities.

(A) At least two different evacuation passageways from the platform to the ground level

A different evacuation passageway here shall mean an evacuation passageway that does not coincide with that of another evacuation passageway.

In this case, the evacuation passageway (stairways shall be limited to those of a non-spiral structure) shall enable passengers to be safely evacuated to the ground level, and the distance to the ground level shall be as short as possible. Also, as a general rule, it shall be possible to reach the ground level only by ascending from the platform.. However, this shall not apply when passengers evacuate to an adjacent building by descending from the platform, or in the case of opposite platforms, when there is a connecting passageway going down from one platform to another provided that a partition between tracks is installed to prevent smoke from flowing. The distance between the end of the platform to the entrance or exit of the nearest evacuation passageway shall be as short as possible.

(B) Lighting facilities that can instantaneously and automatically turn on the lights under emergency power in the event of a power outage, and ensure an illumination intensity of at least 1 lux at the main parts of the floor surface

(C) Evacuation exit guide lights and passageway guide lights

Technical standards concerning evacuation exit guide lights and passageway guide lights shall conform to the provisions of Paragraph 2 of Article 26 of the enforcement ordinance of the Fire Defense Law.

However, if the distance from the end of the platform to the entrance or exit of the nearest evacuation passageway is long, passageway guide lights shall be installed on the floor, along the lower part of the walls, and at other necessary locations.

[2] The following facilities shall be provided between railway stations.

(A) Lighting facilities that can promptly power the lights by emergency power in the event of a power outage, and maintain an illumination intensity of at least 1 lux at the main parts of the floor surface of the passageway used for evacuation

(B) Indicators installed near lighting facilities powered by an emergency power source, which indicate the distance to and the direction of the railway station exit or tunnel exit

Indicators shall be installed at a height of no more than 1.5 meters above the floor of the passageway used for evacuation, at intervals of within 100 meters, in such a way that they are adequately recognizable.

[Explanation]

4 (3) [1] [A] Evacuation passageway

In an emergency such as a fire, passengers need to evacuate safely and quickly, and so multiple evacuation passageways must be provided to ensure that there always is an escape route, and to prevent straying into a dead end during evacuation. During evacuation, passengers tend to evacuate using a passage they usually use. Therefore, such a passage should be used not only in an emergency, but also constantly at other times.

A different evacuation passageway refers to a passage where all of the walking routes of one evacuation passageway do not overlap other evacuation passageways. In a station, at least two independent passages through which passengers can evacuate to the ground from each platform shall be provided including an emergency passage which is normally partitioned by a fire door, etc. but which can be used in an emergency, and a fence which is normally closed but can be opened and closed quickly in an emergency, in addition to normal passages for passengers, so that if one passage is obstructed, passengers can evacuate to the ground safely via the other passage.

An evacuation passageway shall be such that passengers can evacuate to the ground safely without straying into a dead end during evacuation or being delayed during evacuation, and its length shall be as short as possible (**Photo 29.4**).

Except in a structurally unavoidable case due to the underground area crossing with an underground railway, the evacuation passageway shall be such that passengers can reach the ground from the platform only by ascending stairs, not descending them.

However, even if passengers have to descend stairs from the platform, the relevant passage is permitted as an evacuation passageway provided passengers can evacuate to the ground safely such as the distance to the ground is short and an effective evacuation passageway exists ahead. For example, passengers may reach a passage of an existing line or underground shopping center, etc. Furthermore, a connection passage under the track of opposed type platforms was not permitted in the previous standards, but is now permitted as an evacuation passageway if passengers can evacuate safely and an object is provided which hinders the flow of smoke between railway tracks.

Smoke during a fire cannot easily flow in a connection passage that descends from the platform, and in addition, by providing an object which hinders the flow of smoke between railway tracks to ensure safety on the opposite platform, a connection passage under railway tracks is permitted as an evacuation passageway.

This object which hinders smoke flow refers to a wall or hanging wall placed between railway tracks. A hanging wall in this case needs to be provided up to 2 meters from the platform floor surface in consideration of a disastrous conflagration. In this case, the fire-point block capacity of the platform is the capacity up to the hanging wall.

On the other hand, in the case of a connection passage on railway tracks in opposed type platforms, smoke tends to flow in the connection passage and remain there. For this reason, it is necessary to provide an object which hinders the flow of smoke between railway tracks and to take measures to prevent smoke from flowing in the connection passage.

For a connection passage with a station of another line or an underground shopping center, etc., fire doors are closed in an emergency. Therefore, a passage to the ground must be provided near the fire door so that there is no long dead end, or a shutter must be provided in the entrance area of a dead end so that unfamiliar passengers do not stray in there. However, this shall not apply to a case in which no dead end is created by providing a hatchway in the fire door on the connection passage.

If a fire occurs, to enable passengers to evacuate to the ground safely, the arrangement of stairs for entering an evacuation passageway and the width of the passage or stairs must be carefully considered.

It is preferable to provide an entrance to an evacuation passageway on both ends of the platform so that passengers do not stray during evacuation. However, even if entrances cannot be provided at both ends due to the arrangement of equipment or underground buried structure, the distance from the platform end (both ends) to the entrance to the nearest evacuation passageway shall be no more than 50 meters as the standard. However, this shall not apply if passage exit lighting is provided on the floor or lower part of the wall (1 meter or less from the floor surface). The platform end in this case shall be the end where passengers can move, not the platform end in terms of structure.

As explained in 4 (6) [3], if a simplified concession stand is provided between the platform end and the stairs, a fire on the relevant stand could seriously threaten the evacuation. Therefore, a simplified concession stand shall not be allowed between these areas.
The effective width of an evacuation passageway shall be 1.5 meters or more as the standard.
If the effective width of 1.5 meters for an emergency staircase cannot be acquired due to the situation of private land on the ground or the width of a sidewalk, then the width including handrail shall be such that the evacuation is not hindered.
For stairs, spiral staircases have a short inside tread and are dangerous and hard to evacuate, and so shall not be provided on an evacuation passageway for passengers. Measures for an emergency staircase such as handrails must be provided to prevent passengers falling off.
As an escalator must be often used as an evacuation passageway in an emergency, it is deemed to be an evacuation passageway only if the escalator structure ensures that passengers will not descend even if the legal live load is exceeded.
In an emergency such as a fire, it is assumed that a regularly-used escalator will be used for evacuation in addition to stairs. However, escalators have problems. The rise height of a footstep is higher than that of stairs, and unlike stairs the rise height differs between the area for getting on and off and the intermediate area. Furthermore, in an emergency, evacuating passengers congregate on escalators and exceed the legal live load, and the escalator could actually descend. Therefore, escalators that are provided with a device to prevent descending, which moves in the evacuation direction (generally ascent) or stops, are deemed to be an evacuation passageway, and the width of the escalator can be added to the width of stairs when calculating the evacuation time as per 4 (4) [1] [A].
To guarantee that the escalator will not descend, it is effective to use a device rated by the designated organization of performance evaluation based on the Building Standard Law.
An elevator is not deemed to be part of an evacuation passageway because passengers may become trapped on it if the power fails during a fire.

4 (3) [1] [B] Lighting facilities of evacuation passageway

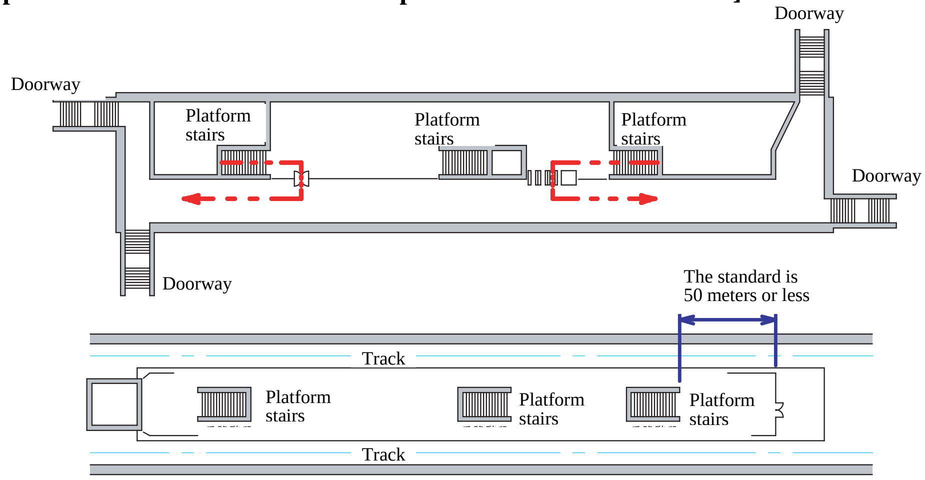
In an underground station, certain lighting is necessary to evacuate passengers to the ground safely and quickly. As it is assumed that the power will fail in a fire, emergency lighting which automatically comes on and provides lighting by an emergency electric power source must be provided to prevent passengers from panicking.
Emergency lighting shall be provided at evacuation passageways such as platforms, stairs, passages (including an emergency passage) and concourse. Emergency lighting must be maintained as before so that illuminance of 1 lux or more is secured at the main area of the floor surface or road surface of an area which serves as a passage during an evacuation.

4 (3) [1] [C] Evacuation exit guide lights and passage guide lights

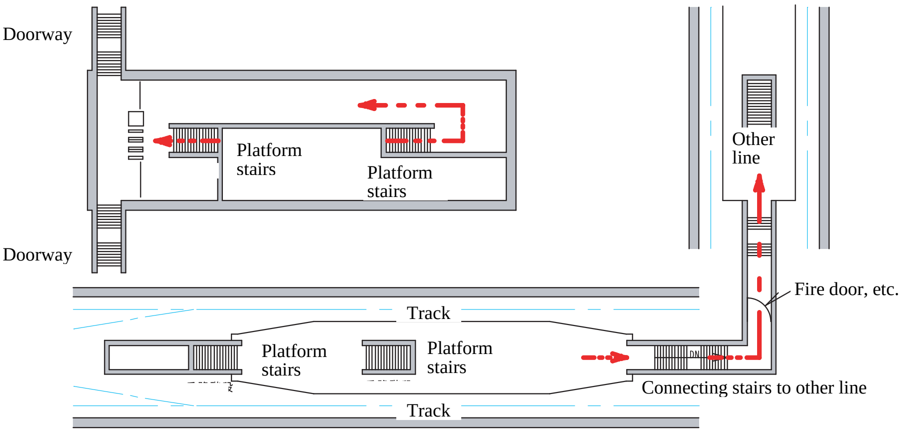
Technical standards concerning evacuation exit guide lights and passage guide lights shall be as per Paragraph 2 of Article 26 of the Order for Enforcement of the Fire Service Act.
As stated in 4 (3) [1] [A], the distance from the platform end to the doorway to the nearest evacuation passageway must be as short as possible, but if the distance is long (more than 50 meters) in existing stations, it is important to clearly indicate the direction for evacuation. Therefore, passage exit lighting shall be provided on the floor surface or lower part of the wall (1 meter or less from the floor surface). However, the installation of luminous guiding signs instead of passage exit lighting shall not be included. If exit lighting is buried in the floor surface, the surface shall be the non-slip type.
The Study Meeting on Fire Prevention at Underground Railways stated that, as main equipment to improve fire prevention safety, it was effective to install a flashing device actuated in linkage with automatic fire alarm facilities and advanced exit lighting with speech guidance, to ensure visibility

of the passage exit lighting and evacuation exit lighting. It was also considered effective to install luminous guiding signs and buried exit lighting in the floor surface as auxiliary functions. Furthermore, for deep stations, the combined use of an instantaneous power source supply from an in-house power generating station in addition to the storage battery system is effective as an emergency electric power source for exit lighting.

[Example of case where evacuation route passes on the same concourse]



[Example of evacuation to other line by descending stairs from platform]



[Example of evacuation to other platform by descending connecting stairs between platforms]

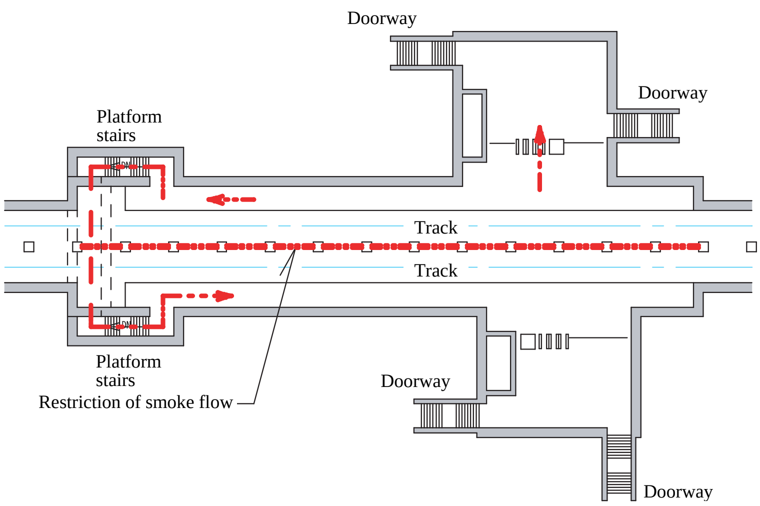


Fig. 29.4 Example of evacuation route diagram

4 (3) [2] [A] Lighting facilities between stations

If a fire occurs in a train or a cable fire occurs between stations while a train is moving, the train shall travel to the next station in principle, but in some cases the train cannot travel and must stop in a tunnel. In this case, as passengers must get off the train and walk in the tunnel along the evacuation route, emergency lighting, which is illuminated by an emergency electric power source, is necessary as in an underground station. The power supply circuit used for lighting facilities in a tunnel needs to be on a different system line from the electric traction so that there is no risk of interrupting the electric traction current which could cause a fire.

If the electric traction is cut off and the train stops, the lighting in the tunnel is unlikely to go off because the electricity is supplied from the different system line. However, if the lighting in the tunnel should go off, the emergency lighting in the train must illuminate the instant the electric traction goes off, and illuminance necessary for evacuation must be secured. As the lighting in a tunnel is illuminated by an emergency generator in some cases, the lighting must come on quickly instead of instantaneously. The emergency lighting, as in a station, must be maintained so that illuminance of at least 1 lux is attained in the main areas of road surfaces of areas serving as passages during evacuation.

4 (3) [2] [B] Signs showing distance and direction between stations

When passengers walk in a tunnel for evacuation, they need information on the direction for evacuation and the distance to the nearest station or tunnel entrance so that train staff or passengers can make an appropriate decision at the time of evacuation (**Photo 29.22**).

The signs shall be set up where they are easy to see during evacuation and close to the lighting facilities with an emergency electric power source so that they can be distinguished easily. The signs shall be provided at 1.5 meters or less above the road surface of the evacuation passageway and at intervals of 100 meters or less.

Fig. 29.22 Example of sign

[Approved specification]

(4) Smoke exhaust facilities

[1] Facilities that can effectively remove smoke as necessary to ensure that passengers can evacuate safely shall be provided at railway stations and also between railway stations.

(A) The required capacity etc., of smoke exhaust facilities shall be determined according to the Attachment 7.

(B) It is permissible to combine the use mechanical ventilating facilities as smoke exhaust facilities.

(C) If, based upon the vertical alignment of the tunnel, it can be expected that the smoke in a tunnel can be adequately exhausted by the natural ventilation openings, it is permissible not to install smoke exhaust facilities.

(D) Smoke exhaust facilities that require an electric power supply shall be provided with an emergency power source.

[2] At a railway station, hanging barriers or the like shall be installed as necessary between the platform and the track, at stairways, escalators, and other locations, in order to block off the flow of smoke.

In this case, facilities that block off the flow of smoke shall mean hanging barriers protruding downward from the ceiling, or other barriers that have at least the equivalent effectiveness in blocking of the flow of smoke (including barriers that descend when activated by a detector, and can also be operated by remote control from the disaster prevention control center), and shall be made of, or covered with, non-flammable material.

[Explanation]

4 (4) [1] [A] Required smoke exhaust amount, etc. of smoke exhaust facilities

If high-temperature smoke caused by a fire obstructs visibility and contains poisonous gases, it could greatly hinder evacuation, and many people have been killed or injured by such smoke in past fire accidents. Therefore, how to exhaust smoke is important.

In the previous standards, a train fire due to ignition from underfloor equipment or a store fire due to arson using a lighter, etc. was assumed. The Study Meeting on Fire Prevention at Underground Railways added a “disastrous conflagration” as an assumed fire in addition to a “ordinary fire” in the previous standards because there is always the possibility of a disastrous conflagration due to gasoline, etc. in Japan.

Explanations are summarized in Attachment No. 7 and described from page 46.

4 (4) [1] [B] Combined use of facilities

From the standpoint of space which houses an exhaust exclusive duct, saving of pieces of machinery, convenience of equipment maintenance, etc., equipment that can effectively exhaust smoke may be used also as machine ventilation equipment.

In an underground station where there is little space for providing an exclusive exhaust duct on the ceiling, in some equipment a blowoff port of air supply serves also as an exhaust port and an air supply duct serves also as a smoke exhaust duct, and the duct connecting to the front and rear of the air supply machine is switched by a damper. An exhaust port and a smoke exhaust port shall be provided on the upper part.

4 (4) [1] [C] Case in which there is no need to provide a smoke exhaust machine

If smoke in a tunnel is fully exhausted by natural ventilation ports or a tunnel entrance depending on the vertical alignment of the tunnel, such as when a short tunnel connects to an underground station and the tunnel entrance is an effective port for eliminating smoke, and if the tunnel is not deep and natural ventilation ports are properly placed, then a smoke exhaust machine need not be provided for either new or existing tunnels.

If an exhaust port and smoke exhaust port are not provided on the ceiling of a tunnel, their effect is substantially reduced.

A tunnel on a grade section acts as a kind of chimney, and the upward flow of air along the grade is stronger. Therefore, exhaust equipment resisting this flow has little effect and a convex-shaped area in the vertical section is suitable for installing natural ventilation ports and smoke exhaust ports.

4 (4) [1] [D] Emergency electric power source of smoke exhaust facilities

For passengers to evacuate safely during a fire, smoke must be exhausted properly. Smoke exhaust facilities which needs a power source instead of natural ventilation must be equipped with an emergency electric power source so that smoke can be exhausted even during a power failure.

4 (4) [2] Hanging barriers, etc.

Depending on the smoke exhaust system, it is necessary to provide an object which hinders the flow of smoke such as a hanging wall in order to prevent smoke from flowing before passengers evacuate to evacuation passages and a linked concourse. Especially if a fire door, etc. is provided on the upper part of stairs because it is difficult to provide it on the lower part of stairs which connect the platform to the concourse due to structural reasons, it is necessary to provide a hanging wall, etc. on the lower part of stairs.

A hanging wall protruding downward between the platform and railway track effectively prevents smoke from spreading over the platform in the case of a train fire.

An object which hinders the flow of smoke shall be a hanging wall protruding downward from the ceiling by 50 cm or more (if a hanging wall protruding downward by 50 cm or more cannot be provided in existing stations, up to the height of 2 meters from the floor surface in consideration of a disastrous conflagration) and other objects which are equal to or better than the hanging wall at preventing the flow of smoke (including those which descend in linkage with detectors and can be remotely controlled from the disaster prevention control center) which are fabricated of or covered by noncombustible materials.

A ceiling, when the height difference between the platform ceiling and the ceiling above the railway track is 50 cm or more, is deemed to be an object which hinders the flow of smoke.

An object which can be remotely operated from the disaster prevention control center is included because not only hanging barriers at locations in linkage with detectors but also lowering hanging barriers over a wide range by operation from the disaster prevention control center and preventing the flow of smoke is more effective.

[Approved specification]

(5) Fire doors and the like

[1] Connecting underground passages between one railway station and other station of another line (excluding cases where the same platform is used) and between the railway station and underground shopping malls etc. shall be provided with fire doors and the like ([fire doors provided with hinged or sliding doors and the fire shutter (limited to those that move up and down),and this shall also apply to the following fire doors and the like]).

[2] Fire doors and the like shall be provided at evacuation stairways and the like of the platform and also at other necessary locations to enable passengers to evacuate safely.

In this case, the fire shutters used shall mean specific fire prevention facilities stipulated by Paragraph 1 of Article 112 of the enforcement ordinance of the Building Standard Law., They shall lower when activated by a detector down to a height of 2 meters above the floor, and shall also be capable of being lowered by remote control from the disaster prevention control center. In addition, said fire shutters shall be of a 2-stage closing construction whereby they are closed completely by an attendant at the locations where they are installed. It shall be possible to verify the lowering and closure of the fire shutter from the disaster prevention control center.

[Explanation]

4 (5) [1] Fire doors, etc. [1]

At underground connection locations in a connecting station with other lines and at locations connecting an underground shopping center or department store underground, fire doors, fire preventive shutters, etc. must be closed to prevent effects on each other and to prevent the damage from spreading. In such a case, it is preferable for a fire preventive shutter, as in the fire preventive shutter of 4 (5) [2], to be a two-stage falling shutter to prevent an evacuating person from being trapped by the shutter. However, if a connection location is not an evacuation passage, a one-stage falling shutter may be used depending on the situation.

In this case, the shutter falling shall be capable of being operated by the manager of the relevant connection location on site to avoid evacuees being trapped due to one-stage falling. If a shutter is lowered in linkage with detectors, measures to prevent a person from being trapped shall be taken such as installing an obstacle detector in the shutter. In setting up the above fire doors, etc., as it is necessary to secure safety of both evacuating passengers of a subway and users of other facilities, the related fire-fighting authorities or administrators of the underground shopping center, etc. should be consulted

Even if the operator is the same, fire doors must be provided at connection locations with other lines.

However, if it is not preferable to provide fire doors, etc. on an evacuation route of passengers at a station which shares a ticket gate, this shall not apply provided the area is compartmentalized by a fire preventive shutter, etc. provided on the stairs area, etc.

4 (5) [2] Fire doors, etc [2]

As newly required fire prevention facilities based on the subway fire accident in Korea, safe evacuation of passengers must be secured, and also to assist fire-fighting activities, a fire door or fire preventive shutter which can block smoke and flames from the fire location shall be provided at the lower part of staircases, escalators, etc. which connect the platform to the concourse. However, if it is difficult to provide a fire door or fire preventive shutter on the lower part of the staircase or escalator due to the station structure, it shall be provided on the upper part of the staircase, escalator, etc. If there is a passage where passengers evacuate horizontally from the platform stage on an evacuation route, a fire door or a fire preventive shutter shall be similarly provided at the entrance of the evacuation passage.

A fire preventive shutter shall be designated fire preventive facilities stipulated in Paragraph 1 of Article 112 of the Order for Enforcement of the Building Standard Law. At locations where it is difficult to provide a conventional steel fire preventive shutter, a screen type made of fire-proof cloth or a water screen using water film which is certified as designated fire preventive facilities stipulated in Paragraph 1 of Article 112 of the Order for Enforcement of the Building Standard Law may be used, in which case it should be provided based on the installation location and characteristics of the relevant facilities (**Photo 29.23**).

The fire preventive shutter shall be of the two-stage falling type, and the first stage shall be lowered to 2 meters from the floor surface of the platform by a smoke detector or remote control from the disaster prevention control center to secure an evacuation passage for passengers and to prevent the flow of smoke. In addition, if station staff have confirmed that passengers have evacuated, the shutter shall be lowered to the floor surface to close the fire preventive shutter. In principle, the closing shall be performed by station staff close by the fire preventive shutter, but it should also be possible to perform the closing from the disaster prevention control center.

In lowering or closing a fire preventive shutter from the disaster prevention control center, station staff shall be sent to the relevant shutter to confirm that no person is trapped.

Photo 29.23　Installation example of fire-proof screen

[Approved specification]

(6) Others

[1] Self-contained-compressed air breathing apparatus shall be provided at railway stations. In this case, the breathing apparatus shall conform to JIS T 8155, JIS T 8156 or JIS M 7601, and the number of units permanently provided shall be at the least the number of staff engaged in work such as helping passengers, guiding officers engaged in fire extinguishing and fire prevention activities, and other such work.

[2] In principle, dedicated ventilating facilities shall be installed at a substation. However, in the case of an existing substation where it is difficult to install dedicated ventilating facilities, a fireproof damper shall be installed at the ventilation port.

[3] A kiosk shall not be located at the places where it impedes the evacuation of passengers, or between the end of the platform and the nearest entrance or exit of an evacuation passageway.

[4] A convenience store type kiosk shall be compartmented to protect it from fire and smoke.

[5] If the fourth and lower underground levels of a railway station have a total floor area of at least 1000 square meters, emergency power outlet(s) shall be provided for each of the fourth and lower underground levels.

[6] Emergency power outlets shall be provided with an emergency power source.

[7] The distance from each part of a habitable room to the evacuation exit at a railway station shall be no more than 100 meters.

[8] A passageway between railway stations that is used to evacuate passengers shall be of a construction that does not impede evacuation.

[Explanation]

4 (6) [1] Self-contained-compressed air breathing apparatus, etc.

Self-contained-compressed air breathing apparatus or oxygen breathing apparatuses must be kept on hand because station staff must conduct work such as rescuing passengers and guiding fire-fighting teams and staff. When keeping such apparatuses, it is preferable to keep apparatuses of the same specifications to avoid mishandling (**Photos 29.24 - 29.25**).

Photo 29.24 Example of Self-contained-compressed air breathing apparatus

Photo 29.25 Example of oxygen generating type circulating breathing apparatus

4 (6) [2] Ventilation facilities of substation

Dedicated ventilation facilities must be provided at a substation underground to prevent smoke from flowing in the underground railway track and station when a fire occurs there.

However, if it is difficult to provide dedicated ventilation facilities instead of ventilation in a tunnel due to the rebuilding of the tunnel in an existing substation, fire preventive dampers shall be provided at exhaust ports toward inside the tunnel and these dampers shall be fully closed when a fire occurs.

4 (6) [3] Installation position of simplified concession stand

A simplified concession stand shall not be set up near stairs or escalators, etc. or at dead ends in consideration of safe evacuation of passengers. Such stands shall not be located on the platform either, because the area between the platform end and nearest stairs, etc. is similar to a dead end. However, this shall not apply if measures to avoid interfering with the evacuation of passengers such as compartmentalization for fire prevention are taken in full consideration of the facility situation such as the flow of passengers and width of the platform.

4 (6) [4] Convenience station store

For a convenience station store, measures for compartmentalization for fire and smoke prevention must be taken because passengers can enter the store.

4 (6) [5] Emergency power outlet

If a fire occurs at an underground location with a large number of floors, in order to provide a power source for floodlights to secure lighting when smoke fills the area as well as for demolition tools to break down doors, etc. for fire-fighting activities, emergency power outlet must be provided.

When fire-fighting facilities requiring electricity is used, much labor may be needed to acquire a power source such as carrying generators, etc. at a station deep underground. Emergency power outlet is designed to enable fire-fighting activities to be performed smoothly and effectively using a power source provided in advance.

It is stipulated that such equipment shall be installed in an underground station with four floors underground or deeper, with a total floor area of 1,000 m^2 or more. To facilitate fire-fighting, however, such equipment should also be installed at deep underground stations and structurally complicated stations even if the equipment is not mandatory. Similarly, although existing stations may follow the conventional regulations until the first rebuilding or reconstruction work is completed after the Notification of Approved specification is issued, the equipment should be installed as soon as possible.

4 (6) [6] Emergency electric power source for emergency power outlet

The emergency power outlet must not only be equipped with an emergency electric power source stipulated in Article 29 of the Approved specification 3 (3) but also conform to the Fire Service Act for the following [1] because it is designed to enable fire-fighting activities to be performed smoothly and effectively. However, for existing underground stations, the following [2] need not conform to the Fire Service Act in some cases judging from their structure and equipment status. Therefore, it is necessary to consult the fire-fighting authorities.

[1] Matters that must conform to the Fire Service Act:

- Installation position (horizontal distance): Item (1) of Paragraph 2 of Article 29.2 of the Order for Enforcement of the Fire Service Act
- Capacity (single-phase AC 100V-15A or more): Item (2) of Paragraph 2 of Article 29.2 of the Order for Enforcement of the Fire Service Act
- Specification of plug socket: Item (3) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
- Installation method of power source: Item (5) of Article 31.2 of the Ordinance for Enforcement

of the Fire Service Act
- Circuit from power source: Item (6) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
- Arrangement of emergency electric power source: Item (3) of Paragraph 2 of Article 29.2 of the Order for Enforcement of the Fire Service Act
- Sign of installation (“Sign of emergency plug socket”): Item (9) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act

[2] Although conformity to the Fire Service Act is preferable, the following need not conform to the Fire Service Act under certain circumstances (consultation with the fire-fighting authorities is required)
- Installation position (height): Item (1) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
  When it is not rational to judge conformity to the Fire Service Act such as the provision of existing plug socket equipment in place of the emergency power outlet (equipment which satisfies the items described above as conforming to the Fire Service Act)
- Installation position (inside a buried protection box): Item (2) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
  When involved in large-scale rebuilding such as reinforcement of the wall to bury the protection box
- Installation method of emergency electric power source: Item (8) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
  As power supply sources are more reliable for a railway utilizing multiplexing and networking of distribution lines compared to other facilities subject to fire prevention, when the intensive type is adopted which supplies electricity to necessary stations by providing a generator at a substation, etc.
- Sign of installation (red light): Item (9) of Article 31.2 of the Ordinance for Enforcement of the Fire Service Act
  When the position of the emergency power outlet can be identified even when a fire occurs by installing a sign by an indoor hydrant
- Others (installation of MCCB, installation of hook, size of box, etc.): Fire prevention ordinance of municipalities
  When a box containing plug sockets protrudes from a wall and interferes with the passage of passengers, etc.

4 (6) [7] Distance from habitable room to evacuation exit

In an emergency such as a fire, it is necessary not only for passengers to evacuate but also for station staff on duty in an habitable room to guide passengers to evacuate quickly. Therefore, the distance from each part of an underground habitable room to a doorway to the evacuation passage on the same floor or the distance to a doorway to the passage leading to the ground provided for station staff on duty in an habitable room to evacuate in an emergency shall be as short as possible. This distance shall be 100 meters or less as the standard, as in the previous standards, because it is assumed that station staff know the structure of the station well.

4 (6) [8] Evacuation between stations

If a train fire occurs while a train is moving, the train shall travel to the next station in principle, but in some cases the train cannot travel and must stop in a tunnel. In this case, passengers get off the train and walk in the tunnel along the evacuation route, and so it is necessary to keep the inside of the tunnel in an easy-to-walk condition to prevent passengers from being injured. If there is allowance outside the construction gage in a tunnel, a passage can be set up for evacuation. There

shall be no protrusions in the passage area during evacuation, namely on the top face of crossties and the track bed, etc., and the structure must be made as easy to walk as possible by placing covers over drainage channels.
When passengers arrive at a station after evacuating through a tunnel and climb to the platform, stairs used for maintenance are used in some cases, but if such stairs are narrow, emergency stairs should be provided under the platform so that passengers can easily climb to the platform.

[Reference]
The Study Meeting on Fire Prevention at Underground Railways stated that equipment which could improve fire prevention safety includes equipment to assist evacuation and transportation, secure access routes, and serve as a base for the activities of the fire company.
As support equipment for evacuation and transportation, trucks for transporting mechanical equipment and materials, etc. are also effective for transporting passengers who fail to get out in time, as well as for transporting mechanical equipment and materials (**Photo 29.26**).
As a means of securing an access route and activity base for a fire company, shafts and so forth for long distances between stations and special evacuation stairs with pressurized smoke exhaustion system for deep underground stations and large stations are effective for securing safety and ease of fire-fighting activities. In addition, a passage for operations for evacuation and access of a fire company is effective. Furthermore, the disaster prevention control center should be designed to keep out smoke by a pressurized smoke exhaust and outside air supply.

Photo 29.26 Example of truck for transporting mechanical equipment and materials

[Approved specification]

5 Provision of fire extinguishing facilities

(1) The following fire extinguishing facilities shall be provided at a railway station.

[1] Fire extinguishers

Fire extinguishers shall be provided according to the provisions of Paragraphs 2 and 3 of Article 10 of the enforcement ordinance of the Fire Defense Law, at the locations in a railway station deemed necessary for fire extinguishing activities.

[2] Indoor fire hydrants

Indoor fire hydrants shall be provided according to the provisions of Paragraphs 3 and 4 of Article 11 of the of the enforcement ordinance of the Fire Defense Law, at the locations in a railway station deemed necessary for fire extinguishing activities, and shall be provided with an emergency power source.

[3] Internal piping for distributing water for spraying equipment or sprinkler equipment that have water supply ports

Habitable rooms (excluding rooms relating to train operation safety), and the like, shall be provided with internal piping for distributing water for spraying equipment or sprinkler equipment that have water supply ports, according to the provisions of Paragraph 2 of Article 12 and also Paragraph 2 of 2 of Article 28, of the enforcement ordinance of the Fire Defense Law.

A convenience store type kiosk shall be provided with sprinkler equipment that has a water supply port, according to the provisions of Paragraph 2 of Article 12 of the enforcement ordinance of the Fire Defense Law.

[4] Internal piping for distributing water for fire fighting

Outlets for internal piping for distributing water for firefighting at a railway station shall be provided at the locations deemed necessary for fire extinguishing activities on platforms, concourses and in passageways. Internal piping for distributing water for firefighting shall be provided according to the provisions of Paragraph 2 of Article 29 of the enforcement ordinance of the Fire Defense Law. However, this shall not apply in the case where indoor fire hydrants equipped with water supply ports are installed, and in addition it is deemed that they are effective for performing fire extinguishing activities.

(2) If the distance between the outlets of internal piping for distributing water for fire fighting on the platforms of adjacent railway stations exceeds 500 meters, internal piping for distributing water for firefighting shall be installed between adjacent railway stations as well.

The distance between the outlets of internal piping for distributing water for firefighting shall be so determined as to be necessary for performing fire extinguishing activities, and according to the provisions of Paragraph 2 of Article 29 of the enforcement ordinance of the Fire Defense Law.

[Explanation]

If a fire occurs in an underground station or tunnel connecting to an underground station, the fire-fighting authorities are notified and a request is issued for fire-fighting by a fire company. It is also important to perform initial fire-fighting activities properly before the fire company arrives to prevent the spread of damage.

Fire-fighting equipment to perform initial fire-fighting activities includes fire extinguishers and Indoor fire hydrants equipment, and fire-fighting equipment suitable for fire-fighting activities depending on the scale and location of the fire, to extinguish the fire and prevent it from spreading in the early stage

Fire-fighting equipment to be used by the fire company includes Internal piping for distributing water for fire fighting, water spray system or sprinkler equipment to a water supply inlet. The equipment must be placed so that the fire company can perform fire-fighting activities smoothly at the station or tunnel by connecting the water supply inlet on the ground near the station, etc. to a fire engine.

These pieces of equipment must therefore conform to the stipulations on fire-fighting equipment based on the Order for Enforcement of the Fire Service Act, and must be installed in coordination with the fire-fighting authorities.

5 (1) [1] Fire extinguisher

When a fire occurs, it is important to extinguish it quickly to prevent the damage from spreading. To perform initial fire-fighting effectively, fire extinguishers shall be installed so that station staff and anybody else can use them easily (**Photos 29.27 - 29.28**).

Fire extinguishers shall be installed where they do not interfere with passages or evacuation and where they can be taken out easily for use, at locations where necessary for fire-fighting at a station such as where combustibles exist, and shall be subject to the stipulations in Paragraph 2 and Paragraph 3 of Article 10 of the Order for Enforcement of the Fire Service Act. When installed on a platform or concourse, they may be installed side by side with an Indoor fire hydrants box or near the Indoor fire hydrants box.

Photo 29.27 Example of fire extinguisher installed side by side with Indoor fire hydrants box

Photo 29.28 Example of fire extinguisher installed independently in a machine room

5 (1) [2] Indoor fire hydrants equipment

It is possible to extinguish a fire with a fire extinguisher of [1] at an early stage, but when the flames reach the ceiling and it is difficult to extinguish the fire with a fire extinguisher, Indoor fire hydrants equipment shall be provided to handle large amounts of water

Indoor fire hydrants equipment is designed to perform initial fire-fighting activities before a fire company arrives at the fire site, and shall be subject to the stipulations in Paragraph 3 and Paragraph 4 of Article 11 of the Order for Enforcement of the Fire Service Act. An Indoor fire hydrants box must be provided so that for each floor, the horizontal distance from each part of the floor to the connection port of the hose of "–" is 25 meters or less in the case of a No. 1 hydrant and 15 meters or less in the case of a No. 2 hydrant (**Photo 29.5**).

When an Indoor fire hydrants box is provided on opposed type platforms, it is preferable to provide one on each platform.

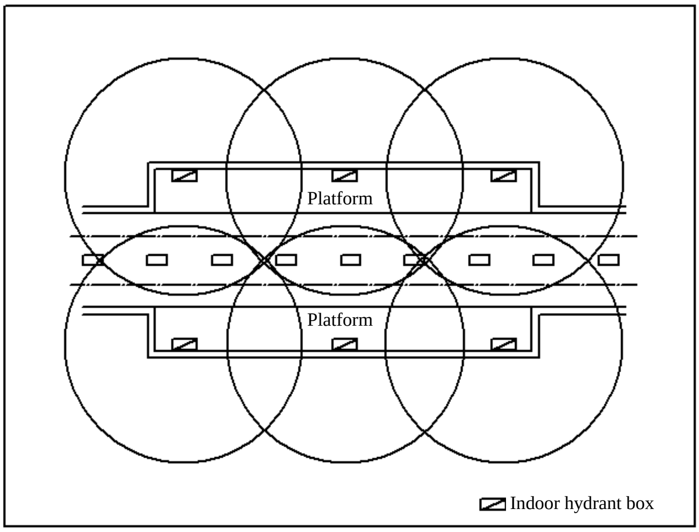


Fig. 29.5 Installation example of indoor hydrant box on platform

The water source shall be exclusively for the fire-fighting equipment, and the water tank capacity must be 5.2 m^3 (130 liters/minute x 2 locations x 20 minutes) or more for a No. 1 hydrant, and 2.4 m^3 (60 liters/minute x 2 locations x 20 minutes) or more for a No. 2 hydrant. Pressurized water supply equipment must be provided at a location compartmentalized by noncombustible materials to allow easy inspection and prevent damage by a disaster such as a fire.
The hose must conform to the regulations of the ministerial ordinance which specifies technical standards, and for a No. 1 hydrant, two hoses with a bore of 40 mm and length of 15 meters or longer must be installed. In addition, a hose with a bore of 30 mm and length of 30 meters for an easy-to-operate No. 1 hydrant, and a hose with a bore of 25 mm and length of 20 meters for a No. 2 hydrant must be installed (**Photos 29.3-29 - 29.31**).
An emergency electric power source must be attached to Indoor fire hydrants equipment.

Photo 29.29 Example of No. 1 hydrant

Photo 29.30 Example of easy-to-operate No. 1 hydrant

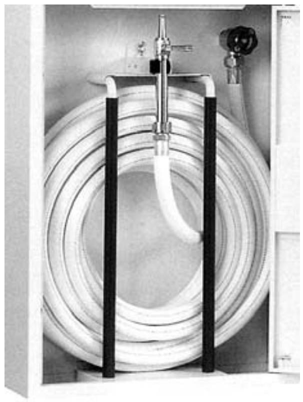


Photo 29.31 Example of No. 2 hydrant

With conventional Indoor fire hydrants equipment, one person extinguishes the fire by directing the nozzle toward the flames and another person opens the valve or holds down the hose, but the modern easy-to-use No. 1 hydrant and No. 2 hydrant which can be used by one person for fire-fighting have increased.
In these hydrants, the hose shape does not change due to the water pressure and the device to stop the flow is attached to the end of the hose, and the hydrants can be operated by one person unlike in the past.

5 (1) [3] Sprinkler equipment
In the case of a fire in an occupied room of an underground station, smoke generated from the fire source is assumed to fill the occupied room, etc. This smoke may hinder prompt entry by a fire company and make it difficult to spray water on the fire source effectively. Sprinklers may be more effective for spraying water than pouring water with a fire hose (**Photo 29.32**).
The connected water spray system or sprinkler equipment with a water supply inlet attached is installed at locations other than the platform, concourse, passages (including staircases and ramps), various rooms related to the operation safety, transformer station, electric room and machine room as per the stipulations in Paragraph 2 and Paragraph 3 of Article 12 and Paragraph 2 and Paragraph 3 of Article 28.2 of the Order for Enforcement of the Fire Service Act.

Photo 29.32 Example of sprinkler head

In transformer stations and electric rooms, fire-extinguishing systems such as an inert gas fire-extinguishing system or a dry powder fire-extinguishing system may be installed because of the effects that water would have.
In principle, sprinkler equipment shall not be installed on the platform and concourse where there are few combustibles. Among occupied rooms, sprinklers shall not be installed in the train dispatch station, electric power dispatch station, signal dispatch station and control room for disaster prevention where spraying water could cause equipment to malfunction. However, if the control room for disaster prevention is alongside the stationmaster's office or station office (including combined use), it is necessary to coordinate with the related fire-fighting authorities when installing sprinkler equipment; supplementary measures may be taken such as placing a fire extinguisher in these locations.
The water source shall be exclusively for fire-fighting equipment, in the quantity of 1.6 m^3 (80 liters/minute x 20 minutes) x number of units, depending on the category of objects to be protected against fire and the type of head. In occupied rooms of a station, the spray quantity of 10 units for a normal closed-type head and 8 units for a high-sensitivity type must be secured. Pressurized water supply equipment must be provided at a location compartmentalized by noncombustible materials so that it is convenient to inspect and less likely to be damaged by a disaster such as a fire. The sprinkler equipment must be equipped with an emergency electric power source.

Photo 29.33 Example of sprinkler installed at convenience station store

As a convenience station store has blind spots that store staff cannot see, it may be difficult to notice a fire immediately, and such stores also contain many combustibles compared to a simplified concession stand. Therefore, a sprinkler connected to a water inlet shall be installed to prevent a fire spreading (**Photo 29.33**).
Even in a simplified concession stand, sprinklers are effective initial fire-extinguishing equipment when a fire occurs, and should be installed as in a convenience station store.
The Study Meeting on Fire Prevention at Underground Railways stated that package type fire-extinguishing equipment could improve fire prevention safety. For a simplified concession stand, package type fire-extinguishing equipment is effective for extinguishing a fire quickly and preventing damage from spreading, and can be retrofitted comparatively easily. It is an automatic fire-extinguishing device which releases downward upon detecting heat, and there are a wet agent type and dry powder type. However, when installed in a simplified concession stand, the position of the detector and display positions of merchandise must be considered. When the dry powder type of fire-extinguishing agent is released, the powder is likely to be mistaken for smoke

5 (1) [4] Internal piping for distributing water for fire fighting
The Internal piping for distributing water for fire fighting is used by a fire company when it arrives at the fire site, and water outlets in a station shall be provided at the platform, concourse and passages where fire-fighting is necessary for each floor, and the maximum horizontal distance from anywhere on the floor to the hose connection port of "-" shall be 50 meters.
Its structure shall comply with the stipulations in Paragraph 2 of Article 29 of the Order for Enforcement of the Fire Service Act. However, if the water outlet is installed in a hydrant box, water can be effectively fed from the water inlet on the ground, etc., and if effective for fire-fighting, it may be treated as having the same function as the case where a Internal piping for distributing water for fire fighting is installed on the relevant part.

The water outlet must be placed where it can be easily seen from the road near the doorway and where a fire engine can easily access the water. Although the water outlet shall be installed in a water outlet storage box, an Indoor fire hydrants box can also be used instead. The hose connection port shall be an insertion type joint of nominal size 65. It is preferable to coordinate with the fire-fighting authorities when installing it (**Photos 29.34 - 29.36**).

Photo 29.34　Example of water outlet installed in hydrant box

Photo 29.35　Example of water inlet provided by doorway

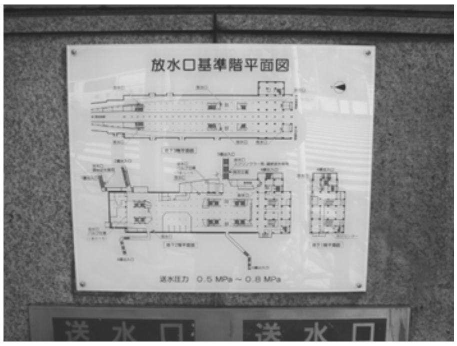


Photo 29.36　Example of guide map of water outlet provided near water inlet

5 (2) Internal piping for distributing water for fire fighting between stations

If a train fire occurs while a train is moving, in principle the train will travel to the next station without stopping, but the Internal piping for distributing water for fire fighting is installed between stations for fire-fighting in case a train stops in a tunnel.

If the distance between the water outlet of the Internal piping for distributing water for fire fighting on the platform of adjacent stations exceeds 500 meters, a Internal piping for distributing water for fire fighting shall be provided, with water outlets at intervals of 500 meters or less between stations, and its structure shall comply with the stipulations in Paragraph 2 of Article 29 of the Order for Enforcement of the Fire Service Act. It is preferable to coordinate installation with the fire-fighting authorities.

Photo 29.37　Example of water outlets between stations

Photo 29.38　Example of water delivery equipment stored in storage box

The Internal piping for distributing water for fire fighting may be installed between stations by being extended from one station and installing water outlets in the tunnel, or by providing a water inlet on the ground where a fire company can enter from a ventilation tower between stations and connecting it to a water outlet in a tunnel. Water delivery devices such as hoses should be kept by the water outlet (**Photos 29.37 - 29.39**).

Photo 29.39　Example of water outlet of Internal piping for distributing water for fire fighting between stations on ventilation tower between stations

[Approved specification]

6 Maintenance of fire fighting equipment

Fire fighting equipment shall be subject to an operation check at least once a year and kept in a maintained condition.

[Explanation]

1. Necessity of maintenance

It is assumed that the fire prevention equipment shown in Paragraph 1 - 5.7 of the Interpretive Standards will operate without fail in an emergency such as a fire which can occur at any time, and will function fully to allow safe evacuation guidance of passengers, initial fire-extinguishing, preventing the fire from spreading, fire-fighting by a fire company, etc. To ensure it can function properly at any time, periodic function checks, maintenance and necessary repairs must be performed.

With regard to periodic function checks, it is important to comply with related laws and regulations governing the inspection method, interval, etc. according to the usage conditions, structure, etc., and to always ensure proper maintenance.

To achieve these objectives, these Interpretive Standards stipulate that proper maintenance be performed to ensure that the equipment functions fully when a fire occurs by performing operation checks, etc. at least once a year. Equipment may be inspected more frequently, and this shall not apply to equipment such as continuous water supplying pipes which are to be inspected at intervals of longer than one year for special reasons (exceptional measures).

2. Regulation of inspection period and method in the Fire Service Act

The “Prescription of a report format on the inspection period, inspection method and inspection result according to the type and inspection contents of fire-fighting equipment or special fire-fighting equipment based on Ordinance for Enforcement of the Fire Service Act” (May 31, 2004), stipulates the following (excerpt).

No. 2 Inspection content and inspection method

The inspection content and inspection method shall be as follows. However, special fire-fighting equipment shall be subject to the Installation, Maintenance and Management Plan of Equipment, etc. stipulated in Paragraph 3 of Article 17 of the Fire Service Act.

1 Equipment inspection

Check the following items according to the standards stipulated separately by the notification according to the type, etc. of fire-fighting equipment, etc.

(1) Normal operation of emergency electric power source (limited to in-house power generating station) attached to the fire-fighting equipment, etc. or powered fire engine

(2) Appropriate arrangement and presence/absence of damage, etc. of fire-fighting equipment, etc. and other items distinguished mainly by appearance

(3) Functional items of fire-fighting equipment, etc. which can be distinguished by appearance or simple operation

2 General inspection

Check the overall function of fire-fighting equipment, etc. by operating all or part of it, or using the relevant parts depending on the type of equipment and according to the standards separately stipulated by the notification (Prescription of inspection standards for fire-fighting equipment, etc. and the inspection sheet to be attached to the inspection result report of the fire-fighting equipment, etc.) (Notification No. 14 of Fire and Disaster Management Agency of October 16, 1975).

No. 3 Inspection period
The inspection period shall be, according to the types of fire-fighting equipment, etc., as listed in the left column of the following table, the inspection content shall be as listed in the center column, and the method as listed in the right column. However, the inspection period for special fire-fighting equipment, etc. shall be as stipulated in the Installation, Maintenance and Management Plan of Equipment, etc. stipulated in Paragraph 3 of Article 17 of the Fire Service Act.

Types of equipment for fire-fighting, etc.	Inspection content and method	Inspection period
Fire-fighting equipment, Fire alarm to notify the fire-fighting authorities, Exit lighting, Guide sign, Fire cistern water, Emergency plug socket equipment and radio communication auxiliary equipment	Equipment inspection	6 months
Indoor hydrant equipment, Sprinkler equipment, Water spray fire-extinguishing system, Foam extinguishing system, Carbon dioxide extinguishing system, Halogenated fire-extinguishing system, Dry powder fire-extinguishing system, Outdoor hydrant equipment, Powered fire engine, Automatic fire alarm, Gas leak fire warning system, Leak fire alarm, Emergency alarm apparatus and equipment, Evacuation apparatus, Smoke exhaust equipment, Connected water spray system, Continuous water supplying pipe, Emergency electric power source (excluding wire part), General control panel, Package type fire-extinguishing equipment and package type automatic fire-extinguishing equipment	Equipment inspection	6 months
	General inspection	1 year
Cabling	General inspection	1 year

3. Considerations when installing equipment for inspection and maintenance
Equipment should be installed at locations where inspection and maintenance can be easily performed. When installed inside the ceiling, at high elevations, narrow locations, etc., consider inspection ports, inspection stands and the installed locations of equipment.

4. Others
When performing operation checks, etc., check the operation according to the function of various equipment based on related laws and regulations and inspection standards, etc. of each railway operator. If a failure is found, then a special inspection of the cause, etc. and quick maintenance and restoration must be performed. To perform various inspections quickly and accurately without affecting passengers and train operations, discuss the inspection procedures of interlock tests of various equipment, such as smoke exhaust equipment, fire preventive shutters and fire doors, with other parties in advance and keep the operation manuals for apparatuses and inspection procedures (flowcharts, etc.) in the control room for disaster prevention. These will help speed up inspections and responses to troubles.
Inspection and maintenance details should be recorded and kept for the next inspection and maintenance. In principle, the records should be kept until after the next inspection.
Regarding the scope of management, in addition to underground stations and tunnels connected to underground stations which are managed by the railway operator, it is necessary to manage the stations of other lines and underground shopping centers, fire doors and fire preventive shutters along underground connection passages with adjacent buildings, connection phones and fire alarms (mutual transfer) mutually provided in the disaster prevention center by clarifying where the management responsibility lies based on an agreement.

[Reference]

Reference examples of operation checks, etc. of fire prevention equipment

Underground stations and tunnels include various fire prevention equipment, and operation of the equipment must be checked accordingly. The operation check is designed to maintain and manage the equipment properly and to keep it in good condition.
Regarding the operation check of various equipment, if the fire-fighting equipment, etc. is inspected according to “Prescription of report format on the inspection period, inspection method and inspection result according to the type and inspection contents of fire-fighting equipment or special fire-fighting equipment based on Ordinance for Enforcement of the Fire Service Act” (May 31, 2004) based on “Article 17.3.3 of the Fire Service Act”, the results can be used.

The inspection of fire-fighting equipment, etc. based on Notification No. 9 of the Fire and Disaster Management Agency refers to a case where the apparatus is inspected once every six months and a general inspection is performed once a year.
The equipment for fire prevention blocks to prevent the spread of a fire and the equipment provided for evacuation guidance are placed in large numbers throughout the station building. For effective and efficient inspection, at least the following equipment must be inspected.

[1] A fire door on a two-way evacuation passage, access route for a fire company, etc. and one installed next to a fire preventive shutter, and one which is always open but is closed by interlock with a detector
[2] A fire preventive and anti-smoke damper which is automatically opened and closed by interlock with a detector, ventilation and air-conditioning equipment and smoke exhaust equipment
[3] A fire preventive shutter which is provided on a two-way evacuation passage, access route for a fire company, etc. and one which is always open but is closed by interlock with a detector
[4] An anti-smoke hanging wall which is automatically lowered by interlock with a detector
[5] Emergency lighting
[6] A section of an evacuation passage (staircase) made available as a two-way evacuation route and an access route for a fire company

For other fire prevention equipment which does not have inspection standards, voluntary standards, etc. should be provided and inspections performed where possible.

[Reference]

Examples of operation check of fire prevention equipment

Equipment category / Stipulation of Interpretive Standards	Equipment name	Operation check item	Inspection period (within)
Fire preventive block 2 (1) [3] 4 (5) [1]	Fire door	There must be no abnormality in manual opening/closing of doors, appearance and installed condition.	1 year
		There must be no object near a fire door which hinders closing and evacuation.	
		If a door is always open, it must be automatically closed from the open state by a door closer, etc.	
		If a door is always open, it must be automatically closed from the open state by interlock with a detector, etc.	
2 (1) [3] 4 (5) [1]	Fire preventive shutter	There must be no abnormality in appearance or installed condition. There must be no object which hinders opening/closing.	1 year
		If the shutter is manually operated and is always closed, it must be capable of being easily opened/closed manually.	
		If the shutter is electrically operated and is always closed or open, it must be capable of being easily opened/closed or stopped at an intermediate position with a push button, handle or chain.	
		If the shutter is automatically closed at the time of a fire, it must be automatically closed by interlock with a detector, etc.	
		If the shutter is automatically closed at the time of a fire and has a sound device when closing, it must make a sound while being closed.	
4 (5) [2]	Two-stage falling shutter	The shutter must lower to the specified height from the floor surface in linkage with a detector at the first stage, and must lower to the floor surface manually at the second stage.	1 year
		The opening/closing operation must be capable of being performed normally at the site or from the control room for disaster prevention. The operation status must be capable of being monitored from the control room for disaster prevention.	
2 (1) [3] 4 (6) [2]･[4]	Fire preventive and anti-smoke damper	There must be no abnormality such as deformation, dust, corrosion and damage on the installed condition, damper body, or automatic opening/closing device.	1 year
		If the damper is automatically closed by a thermal fuse, there must be no abnormality in appearance such as discoloration of the thermal fuse, sticking of oil and grease, deformation, or adhesion of dust. There must be no corrosion of a fuse device.	
		If the damper is automatically closed by a thermal fuse, there must be no abnormality in the manual closing and restoration operation.	
		If the damper is automatically closed in linkage with fire signals and air-conditioning equipment, etc., it must operate in linkage with the signals.	
	Fire-proof treatment of penetration area of cables	There must be no abnormality such as breakage or falling off of fire-resistant boards, heat-resistant seal materials and other installed conditions. There must be no gap in the penetration area.	Each time modification is performed
Equipment of control room for disaster prevention 3 (1)	Central fire prevention monitoring equipment	Various functions such as displaying a fire and the alarms of each station, activation and stoppage of smoke exhaust equipment on the platform and restoration control by the central fire prevention monitoring equipment such as the train dispatch station must be normal (Inspection period column with * mark: Inspection period for equipment based on Notification No. 9 of the Fire and Disaster Management Agency)	6 months* 1 year

3 (1) 4 (1) [1]	Map type disaster prevention monitoring panel	Setting of the fire display, operation, alarm and interlocking operation in the station building and various other functions by means of the disaster prevention monitoring panel in the station control room for disaster prevention must be normal.	Six months One year
3 (1)	Shutter control panel	The status monitor and remote control function, etc. of each shutter in the station building by means of the shutter control panel installed in the station control room for disaster prevention must be normal.	1 year
	Elevating machine control panel	The status monitor and remote control function, etc. of each elevating machine in the station building by means of the elevating machine control panel installed in the station control room for disaster prevention must be normal.	1 year
3 (1) 4 (2) [1] [B]	Public address system	It must be possible to broadcast to various locations in a station building from the station control room for disaster prevention.	1 year
	Emergency public address system	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
3 (1)	ITV monitoring equipment	The position, angle of view and monitor image of monitor cameras installed in various locations in a station building must be normal.	1 year
Alarm system 3 (1) 4 (1) [2]	Automatic fire alarm	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
Notification system 3 (1) 4 (2) [1] [A]	Adjacent communication building telephone	Apparatus inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months
	Instruction telephone	Normal mutual communication must be possible by instruction telephones at the control room for disaster prevention and train dispatch station.	1 year
	Railway telephone	Normal mutual communication must be possible by dedicated railway telephones at the train dispatch station, electric power dispatch station and various locations in a station.	1 year
4 (2) [1] [C]	Radio communication auxiliary equipment	Apparatus inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months
4 (2) [2]	Train radio	Normal mutual communication between each train and the train dispatch station by train radio must be possible.	1 year
	Sideway telephone	Normal mutual communication between the train dispatch station and sideway telephones at various locations in a tunnel must be possible.	1 year
Evacuation guidance equipment 4 (3) [1] [A] 4 (6) [7]・[8]	Two-way evacuation passage	There must be no obstacles when passengers evacuate.	1 year
3 (2) 4 (3) [1] [B]	Emergency lighting	There must be no emergency lights that do not come on.	1 year
		The illuminance on the reference floor surface must be equal to or better than the specified value.	
		In the case of a power failure, the lighting must automatically come on instantaneously.	
4 (3) [1] [A]	Automatic ticket gate	If the automatic ticket gate is used as an evacuation passage, there must be no hindrance to evacuation (when all gates are opened at once)	1 year
	Escalator (if used as an evacuation passage)	If the escalator is interlocked with a detector or a fire preventive shutter, it must stop normally.	1 year
		The status monitor and operation of each escalator must be normal from the escalator control panel installed in the station control room for disaster prevention. If equipped with a device to stop it descending, it must function normally even if the legal live load is exceeded.	

4 (3) [1] [C]	Exit lighting of evacuation exit and passage exit lighting	Apparatus inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months
4 (3) [2] [A]	Tunnel lighting	There must be no abnormality in appearance such as stain or damage and there must be no lights that do not come on. In the case of power failure, the lights must come on again quickly by the emergency electric power source.	1 year
4 (3) [2] [B]	Evacuation sign in tunnel	There must be no abnormality in appearance such as falling off, deformation, stain or damage. The writing must be easy to read. The signs must be installed at the proper positions.	1 year
7	Evacuation sign in station building	There must be no abnormality in appearance such as falling off, deformation, stain or damage. The writing must be easy to read. The signs must be installed at the proper positions.	1 year
Smoke exhaust equipment 4 (4) [1]	Tunnel smoke exhaust equipment	There must be no abnormality in appearance such as stain, damage or corrosion, no abnormal noise, and no abnormality in other functions. The starting and stopping operation and status monitor from the relevant station control room for disaster prevention or central disaster prevention monitoring equipment must be normal.	1 year
	Station smoke exhaust equipment	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
4 (3) [1] [A] 4 (4) [2]	Anti-smoke hanging wall	There must be no abnormality in appearance such as the installed condition or damage. If movable, there must be no object around the hanging wall which hinders operation. If movable, it must be easy to perform manual hoisting with a handle or chain. If movable, the hanging wall must be set in a normal condition. If the hanging wall is movable and lowers automatically by interlock with a smoke detector, it must lower normally. It must be possible to perform restoration normally. The status monitor and remote control function, etc. of each anti-smoke hanging wall by means of the disaster prevention monitoring panel installed in the station control room for disaster prevention must be normal.	1 year
Others 4 (6) [1]	Air-breathing apparatus	There must be the necessary number of apparatuses in the proper locations. There must be no air leak, and no abnormality in a pressure gauge or appearance. The cylinder pressure must be within the specified value. The air-breathing apparatus must operate normally.	1 year
4 (6) [5]･[6]	Emergency plug socket equipment	Apparatus inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months
Fire-extinguishing equipment 5 (1) [1]	Fire extinguisher	Apparatus inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months
5 (1) [2]	Indoor hydrant equipment	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
5 (1) [3]	Connected water spray system or sprinkler equipment with water inlet attached	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year

5 (1) [4]	Continuous water supplying pipe	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
Emergency electric power source 3 (3)	Intensive emergency generator	The specified quantity of fuel must be secured.	1 year
		The power supply to necessary stations or loads at the time of power failure must be normal.	
		Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
	Emergency in-house power generating station	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year
	Storage battery system	Apparatus and general inspection based on Notification No. 9 of the Fire and Disaster Management Agency	6 months 1 year

[Approved specification]

7 Indicators shall be provided at railway stations to inform passengers of the following items. (1) In principle, if a fire breaks out in a train that is traveling through a tunnel, the train will continue traveling to the next station and then evacuate the passengers. (2) That it is possible to evacuate from the front and the rear of the train. (3) Necessary information, including an evacuation route map, that will enable passengers to safely evacuate in an emergency.

[Explanation]

If a fire occurs in a train traveling in a tunnel, it is important to provide passengers with information on what to do to stop them panicking. Since the subway fire in February 2003, the Daegu Metropolitan City subway public corporation of Korea has provided passengers with information by public address to give guidance and respond to them when any abnormal situation occurs.

The provision of Approved specification 7 states that if a fire occurs in a train traveling in a tunnel, the train should travel to the next station for evacuation; if the train stops between stations, passengers should evacuate from the front and rear of the train; and that passengers should always be made aware of this. This provision encourages posters to be put up at locations where passengers can easily see them, such as platforms.

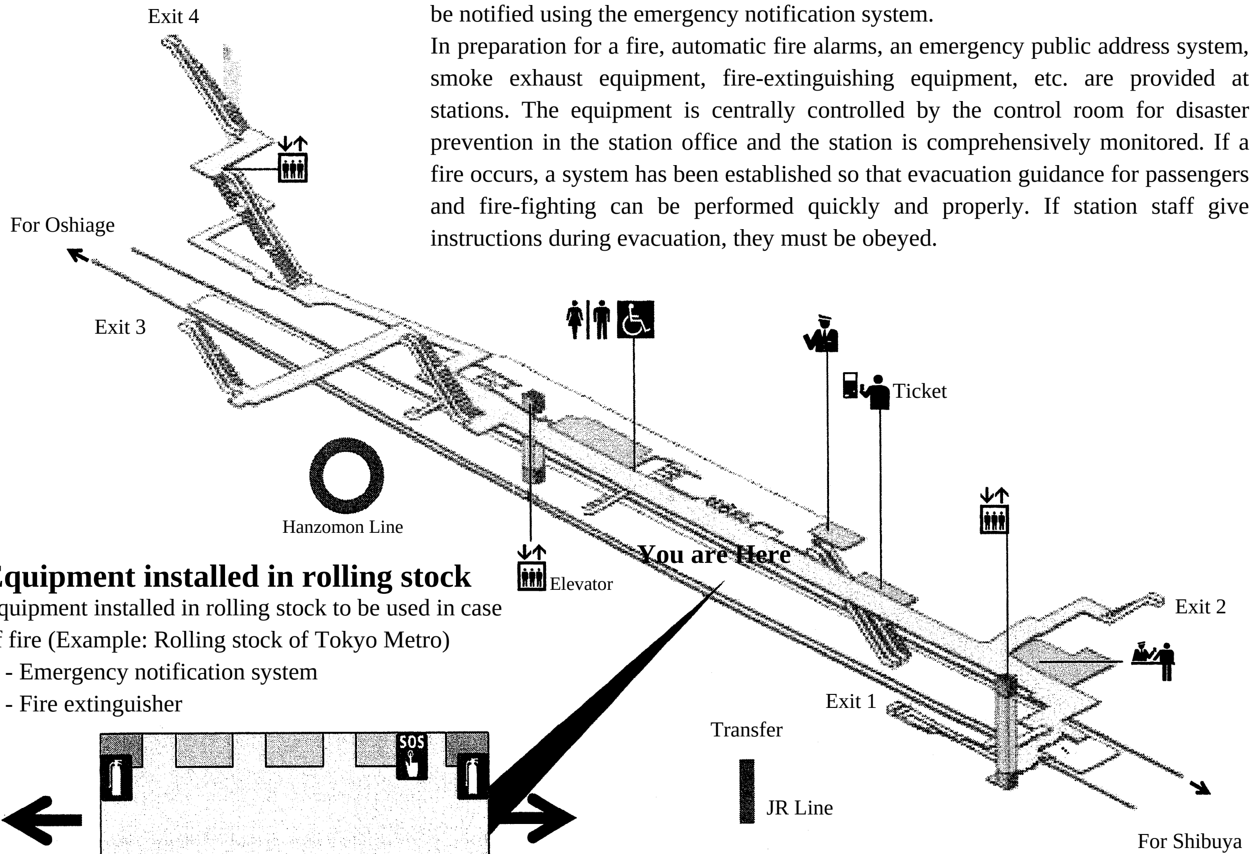
It is also important to actively inform passengers about evacuation such as obeying station staff's instructions in case of abnormal conditions, through fire prevention campaigns, putting up notices and publicizing the information with announcements in stations and on trains.

An example of "Display equipment" in the text of Approved specification 7 is shown in **Figure 29.6** for reference.

Responding to a fire

Tokyo Metro Co., Ltd. stipulates that if a train fire occurs while a train is traveling in a tunnel, it must travel to the next station for evacuation. If the train cannot avoid stopping in a tunnel, passengers can evacuate from the front and rear of the train safely under the instructions of staff. If a fire occurs in a train, the train staff should be notified using the emergency notification system.

In preparation for a fire, automatic fire alarms, an emergency public address system, smoke exhaust equipment, fire-extinguishing equipment, etc. are provided at stations. The equipment is centrally controlled by the control room for disaster prevention in the station office and the station is comprehensively monitored. If a fire occurs, a system has been established so that evacuation guidance for passengers and fire-fighting can be performed quickly and properly. If station staff give instructions during evacuation, they must be obeyed.



Equipment installed in rolling stock

Equipment installed in rolling stock to be used in case of fire (Example: Rolling stock of Tokyo Metro)

- Emergency notification system
- Fire extinguisher

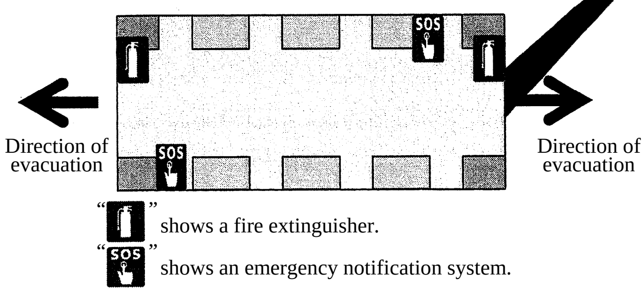


Fig. 29.6 Example of indicator

[Approved specification]

8 At each railway station, a manual stipulating the following items relating to the action to be taken by the staff in charge in the event that a fire breaks out, education and training, and also collaboration with a fire fighting organization shall be prepared. In this case, the contents of the manual shall be determined after adequate consultation with the fire fighting organization.

(1) Items relating to action to be taken by the staff in charge in the event of a fire

(2) Implementation method etc., of education and training for the staff in charge (this training mainly refers to training in initial fire extinguishing activities, evacuation guidance, etc.)

(3) Providing effective information concerning fire fighting activities to the fire fighting organization

[Explanation]

With regard to "Training of staff" in Approved specification 8, it is preferable for an arson situation (large fire) in a train, to give training such as evacuation guidance according to the method and procedure prepared based on the following Notification (Article 29 related (1)) for the train dispatch station, train crew, station staff and fire-fighting authorities as one group. If possible, the training will be more effective if the general public including passengers participate, so it is necessary to draw up a systematic plan accordingly. After training, it is important to identify and evaluate items that did not proceed smoothly during the training and to review the method of evacuation guidance. In principle, such training shall be given at least once a year at all stations. However, if the number of stations is too large, certain stations should be selected for holding the training, with the participation of staff from other stations, while coordinating with the fire-fighting authorities.

As the operation procedures, methods, etc. for responding to arson, etc. are not conventionalised, it is necessary to periodically practice these during disaster prevention training during normal conditions.

With regard to training of staff for responding to a fire, and cooperation with the fire-fighting authorities, the following Notification has been issued, and stations subject to Article 8 of the Fire Service Act should ensure their fire-fighting plan prepared as stipulated in Paragraph 3 of Article 4 of the Order for Enforcement of the Fire Service Act complies with this Notification.

Article 29 related (Equipment of underground station, etc.) (Notification on operation)

Training of staff for responding to a fire, and cooperation with the fire-fighting authorities in Approved specification 8

(1) "Response of staff to a fire" in Approved specification 8 (1) refers to a method, procedure, etc. of initial fire-fighting, evacuation guidance, etc. conducted by railway staff when a fire occurs in an underground station, etc.

For this reason, an underground station shall specify the method and procedure for the following items for each station and prepare for them based on the essential roles of railway staff, according to the situation of staff who are on duty in a train, personnel arrangement, and the structure, etc. of the station.

[1] Notifying the fire-fighting authorities

[2] Informing passengers about the fire

[3] Checking and operating fire prevention equipment such as smoke exhaust equipment

[4] Initial fire-fighting

[5] Giving evacuation guidance to passengers

(2) "Staff training" in Approved specification 8 (2) refers to giving disaster prevention training

during normal conditions and efforts to improve self fire-fighting capability so that railway staff can perform initial fire-fighting, evacuation guidance, etc. quickly and properly when a fire occurs.

With regard to “Training”, a plan shall be created and the training shall be conducted periodically, at least once a year, and a post-event evaluation shall be made after the training.

(3) “Effective information in fire-fighting” in Approved specification 8 (3) refers to, assuming that a railway company as an operator can cooperate with the fire-fighting authorities, the arrangement plan for various fire prevention equipment, disaster prevention system, etc. during normal conditions, and the evacuation status of passengers, and operation status of fire prevention equipment, etc. when a fire occurs.

With regard to this Notification (1), passengers must suffer no injuries even if a fire occurs in an underground station, etc. It is therefore important to determine in advance who should act and how for each possible situation. As items [1] - [5] are most important, it is necessary to specify the method, procedure, etc. at least for these items. Possible situations include a train on fire heading for the next station, a train on fire arriving at the next station, a train on fire stopping between stations, a fire on a platform, and a fire on a concourse. It is also necessary to consider situations in which a fire has occurred in other locations such as an electric room or machine room where a fire might occur.

In specifying the method and procedure for items [1] - [5] when a fire occurs, it is necessary to ensure the specifications are suitable for respective stations, since modern stations are complicated and located deep underground, and that fewer personnel are posted at each station as workforces have been reduced to rationalize business operations and some lines are one-man operation.

If a fire occurs in a traveling train, in principle the train travels to the next station and passengers are guided for evacuation. At a station where the train on fire is approaching, it is important to start the evacuation guidance for passengers on platforms and concourses before the train approaches, and to ensure as few passengers remain in the station as possible.

In the subway fire accident in Deagu City, Korea, major damage was caused when the fire spread to an oncoming train approaching on an adjacent line to the train on fire. This probably occurred because there was no appropriate evacuation guidance and many passengers could not evacuate because the boarding doors were closed. At stations where platform doors or platform fences are installed, if a train on fire stops offset from the normal position and cannot be moved, evacuation will take longer.

These matters must be considered when specifying the method and procedure for evacuation guidance, etc. for each station.

The required exhaust capacity, etc of a smoke exhaust system for an underground station shall be determined on the basis of the following confirmation procedures, etc.

I. Smoke control for platform floor and concourse floor

1. Fire assumptions and methods for checking evacuation safety

The fire assumptions for rolling stock and at station shall be classified into two categories: ordinary fire and major fire.

The checking of evacuation safety shall be based on passengers being able to safely escape to the evacuation area (ultimately to ground level), which is checked by the following procedure that corresponds to the characteristics of the fire and the nature of smoke flow

TABLE-1 Fire Assumptions

Fire	Type	Fire Source
Ordinary Fire	Train	From underfloor equipment on rolling stock
	Kiosk	Arson using lighter, etc.
Major Fire	Train	Arson using gasoline
	Kiosk	Arson using gasoline

(1) In case of an ordinary fire, checking shall be based on smoke density (fading coefficient) at the platform level: Cs, or smoke diffusion volume at the concourse level: V.

(2) In case of a major fire, checking shall be based on the time required for smoke to descend to the height where it will impede evacuation.

Then, the allowable values for checking shall be as follows;

(i) In case of an ordinary fire at platform level, smoke density Cs shall be less than 0.1 (1/m),

(ii) In case of an ordinary fire at platform level, smoke diffusion volume shall be greater than the value derived from the evacuation time, and

(iii) In case of a major fire, the bottom of the obstructive smoke layer shall be 2.0 (m) higher than the floor.

2. Calculation of evacuation time

Dwell time, for the purpose of calculating the evacuation time, shall be calculated by the following formula.

$$T=Q / (N \times B)$$

T: Dwell time (sec)

Q: Number of evacuees (person)

N: Crowd flow rate (person/m/sec)

B: Breadth of stairway, etc. (m)

The evacuees' walking speed and flow rate, for the purpose of calculating the elapsed walking time (t) and dwell time (T) on the evacuation route shall be as follows;

Walking speed: 1.0 (m/sec) for horizontal sections and 0.5 (m/sec) for stairways, and

Flow rate: 1.5 (person/m/sec) for horizontal sections and 1.3 (person/m/sec) for stairways

3. Calculation method of number of evacuees

The number of evacuees to check the evacuation safety shall be as follows corresponding to the fire assumption categories

When the assumed fire is in the concourse, the number of evacuees of the station without kiosks in the concourse shall be 0 (zero).

(1) Stations located in the three major metropolitan areas (of Japan)

(i) Stations having island platforms

Possible Fire		Passenger Load Factor (%)			Total Passenger Load Factor (%)	
		Train	Waiting Passenger		Without Starting Train	With Starting Train
			Without Starting Train	With Starting Train		
Rolling Stock	Ordinary	200	—	—	200	200
	Major	200	75 (150)	125 (200)	275 (350)	325 (400)
Platform Kiosk	Ordinary	200	75 (150)	125 (200)	275 (350)	325 (400)
	Major	200	75 (150)	125 (200)	275 (350)	325 (400)
Concourse	Ordinary	—	75 (150)	125 (200)	75 (150)	125 (200)
	Major	—	75 (150)	125 (200)	75 (150)	125 (200)

(ii) Station having opposing platforms and single platforms

Possible Fire		Passenger Load Factor (%)			Total Passenger Load Factor (%)	
		Train	Waiting Passenger		Without Starting Train	With Starting Train
			Without Starting Train	With Starting Train		
Rolling	Ordinary	200	—	—	200	200

Stock	Major	200	50（100）	100（150）	250（300）	300（350）
Platform Kiosk	Ordinary	200	50（100）	100（150）	250（300）	300（350）
	Major	200	50（100）	100（150）	250（300）	300（350）
Concourse	Ordinary	—	50（100）	100（150）	50（100）	100（150）
	Major	—	50（100）	100（150）	50（100）	100（150）

(2) The stations located outside of the three major metropolitan areas (in Japan)

(i) Stations having island platforms

Possible Fire		Passenger Load Factor (%)			Total Passenger Load Factor (%)	
		Train	Waiting Passenger		Without Starting Train	With Starting Train
			Without Starting Train	With Starting Train		
Rolling Stock	Ordinary	150	—	—	150	150
	Major	150	60（115）	95（150）	210（265）	245（300）
Platform Kiosk	Ordinary	150	60（115）	95（150）	210（265）	245（300）
	Major	150	60（115）	95（150）	210（265）	245（300）
Concourse	Ordinary	—	60（115）	95（150）	60（115）	95（150）
	Major	—	60（115）	95（150）	60（115）	95（150）

(ii) Station having opposing platforms and single platform

Possible Fire		Passenger Load Factor (%)			Total Passenger Load Factor (%)	
		Train	Waiting Passenger		Without Starting Train	With Starting Train
			Without Starting Train	With Starting Train		
Rolling Stock	Ordinary	150	—	—	150	150
	Major	150	40（75）	75（115）	190（225）	225（265）
Platform Kiosk	Ordinary	150	40（75）	75（115）	190（225）	225（265）
	Major	150	40（75）	75（115）	190（225）	225（265）
Concourse	Ordinary	—	40（75）	75（115）	40（75）	75（115）
	Major	—	40（75）	75（115）	40（75）	75（115）

(NOTE)

1. The figures in (　) of the tables are the set values for the terminal stations.
2. Terminal station means a station in which number of passengers per day is more than 100, 000 in average.
3. Three major metropolitan areas include;

The existing urban area (the special wards, Musashino-city and Mitaka-city in Tokyo;

Yokohama-city and Kawasaki-city in Kanagawa Prefecture; and Kawaguchi-city in Saitama Prefecture) according to Article 2 of Metropolitan Area Readjustment Act (Act No. 83 of 1956),

The existing urban area (Kyoto-city in Kyoto Prefecture; Osaka-city, Moriguchi-city, Fuse-city, Higashiosaka-city and Sakai-city in Osaka Prefecture; and Kobe-city, Amagasaki-city, Nishinomiya-city and Ashiya-city in Hyogo Prefecture) according to Article 2 of Kinki Area Adjustment Act (Act No. 129 of 1963), and

The area (Nagoya-city in Aichi Prefecture) defined in the annex table of the Enforcement Ordinance to Act on State's Special Financial Measures on Arrangement of Suburban Development and Redevelopment Areas, etc. in Tokyo Metropolitan Area, Kinki Area and Chubu Area, and the urban area according to Article 2 of Chubu Area Development and Improvement Act (Act No. 102 of 1966).

4. Checking procedure for ordinary fire

4.1. Checking of smoke density of the platform level

Smoke density (Cs) at the evacuation time (t) shall be calculated using the following formulas that correspond to the fire assumptions and the evacuation time, with calculating the fire block volume at the platform level, which is then rounded off to two decimal places. It shall be confirmed that the calculated smoke density (Cs) does not exceed the allowable value of 0.1 (1/m),

(1) Rolling stock fire

(i) Where the evacuation time is less than 7 minutes,

$$Cs=21 \cdot (1-e^{-Ve \cdot t / V}) / Ve$$

(ii) Where the evacuation time is more than 7 minutes,

$$Cs=(66 \cdot V \cdot e^{-Ve \cdot (t-7)/V} - 21 \cdot Ve \cdot e^{-Ve \cdot t/V} + 66 \cdot Ve \cdot t - 441 \cdot Ve - 66V) / Ve^2$$

(2) Kiosk fire

(i) Where the evacuation time is less than 10 minutes,

$$Cs=2.1 \cdot (Ve \cdot t - V + V \cdot e^{-Ve \cdot t/V}) / Ve^2$$

(ii) Where the evacuation time is more than 10 minutes and less than 11 minutes,

$$Cs=\{(24 \cdot V - 21 \cdot Ve) \cdot e^{-Ve \cdot (t-10)/V} + 24 \cdot Ve \cdot t - 198 \cdot Ve - 26.1 \cdot V + 2.1 \cdot V \cdot e^{-10 \cdot Ve/V}\} / Ve^2$$

(iii) Where the evacuation time is more than 11 minutes,

$$Cs=\{(1.8 \cdot V - 45 \cdot Ve) \cdot e^{-Ve \cdot (t-11)/V} + 1.8 \cdot Ve \cdot t + 91.2 \cdot Ve - 27.9 \cdot V + 2.1 \cdot V \cdot e^{-10 \cdot Ve/V} + (24 \cdot V - 21 \cdot Ve) \cdot e^{-Ve/V}\} / Ve^2$$

Cs: Smoke density (1/m)

V: Fire block volume (m^3)

t: Evacuation time (min.)

Ve: Exhaust rate of the smoke exhaust system per fire block volume (m^3/min.)

Where there is no kiosk on the platform floor, t = 0 (Cs = 0).

(3) Fire block volume

The fire block volume means a certain space where smoke density is estimated to be the highest level within the platform space filled with smoke at the time of train fire. The fire block volume shall be determined taking the following conditions into account.

a. The section right angled to the railway shall be per the figures below and that of different type stations shall be determined in similar way.

b. The sectional area filled with smoke shall be of hatched part as shown in the figures with reduction of the sectional area of train.

c. The longitudinal length shall be 20 m.

d. The fire block volume shall be calculated by the following formulas;

$V = (A_0 - A_V) \times 20$

$A_0 = (V_a - V_m) / L$

V: Fire block volume (m^3)

A_0: Sectional area right angled to the railway (m^2)

A_V: Sectional area of the train (including under floor) (m^2)

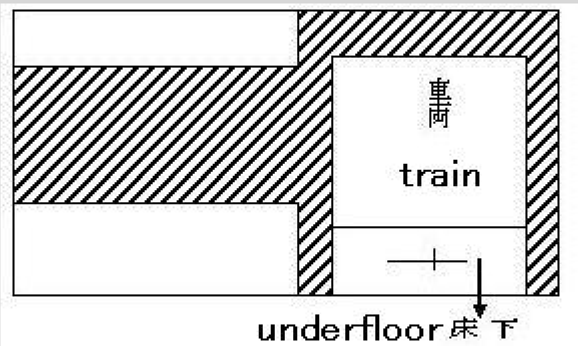
V_a: Total volume calculated by the setting fire block section and the effective length of platform (m^3)

V_m: Volume of the parts not filled with smoke within V_a, such as pillars, stairways, etc. (m^3)

L: Effective length of the platform

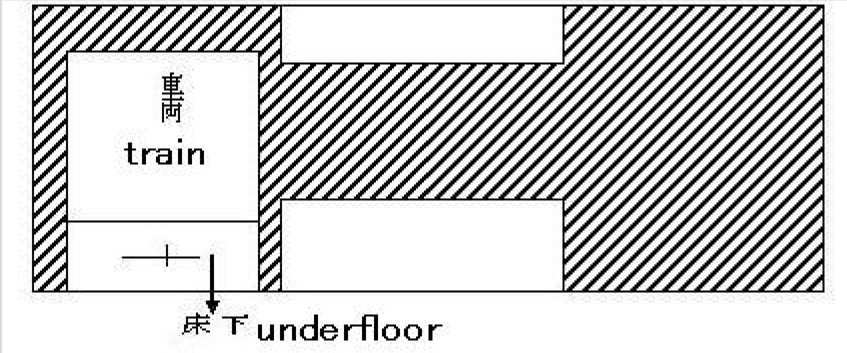
Figures: Sectional area right angled to the railway for setting up the fire block

(A) Platform with single track



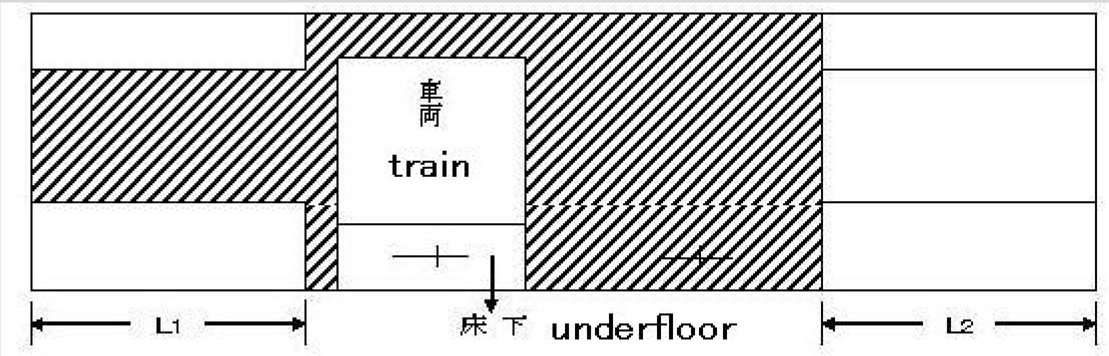
(CONCEPT) Smoke is assumed to spread all over the sectional area.

(B) Island platform with double track



(CONCEPT) Smoke is assumed to spread over the adjacent platform and the opposite track due to the up-draft caused by heating.

(C) Opposing platforms with double track



(CONCEPT) Smoke does not spread over the platform on the opposite side of the burning train, because the platform ceiling is lower than that in way of the track, but smoke spreads over the adjacent platform. The two sectional areas shall be calculated with the burning train on either track, and whichever is smaller shall be adopted, (e.g. on the above figure (C), the hatched part shall be adopted when the breadth of platform L1 is equal to or smaller than L2.)

(NOTE) Smoke is assumed to spread within the hatched part.

(4) Minimum smoke exhaust rate

The platform story shall be equipped with the smoke exhaust system of not less than 5,000 m^3/h for the fire block volume.

4.2 Checking of the smoke diffusion volume required for the concourse (excluding the case of the concourse level being independently separated into two or more areas)

The required smoke diffusion volume (V_0) corresponding to evacuation time (t) shall be calculated by the following formulas and rounded off to one decimal place. Smoke diffusion volume (V) calculated separately shall not be less than the required smoke diffusion volume (V_0).

(i) Where evacuation time is less than 10 minutes:

$V_0 = 10.5t^2$

(ii) Where evacuation time is more than 10 minutes and less than 11 minutes:

$V_0 = 120t^2 - 2190t + 10950$

(iii) Where evacuation time exceeds 11 minutes:

$V_0 = 9t^2 + 252t – 2481$

V_0: Required smoke diffusion volume (m^3)

t: Evacuation time (min.)

In addition, the smoke diffusion volume (V) shall be calculated by the following formula;

$V = V' + t \times V_e'$

$V' = (Af - At) \times (H - 2)$

$V_e' = V_e \times (H - 2) / H$

V': Smoke diffusion volume without considering the exhaust rate of the smoke exhaust system (m^3)

Ve': Effective exhaust rate (m^3/min.)

Af: Floor area of the concourse story (m^2)

At: Floor area of the concourse story where smoke does not spread, such as pillars (m^2)

H: Ceiling height of the concourse story (m)

Ve: Exhaust rate of the smoke exhaust system of the concourse story (m^3/min.)

5. Checking procedure for major fires

The elapsed time (t_0) for smoke, etc. to descend to the obstructive level of 2 m above the floor shall be calculated by the following formula, and shall be confirmed that the calculated elapsed time (t_0) is greater than the evacuation time (t) separately calculated.

(1) In case of train fire or kiosk fire on the platform story

$t_0 = V_E / (V_S - V_e')$

$V_E = (A_E - A_V') \times L$

$V_e' = V_e \times (A_E - A_V') / (A_0 - A_V)$

Where $(V_s - V_e')$ is 0 or negative, $t_0 = \infty$

V_E: Effective volume of whole platform story, 2.0 m above the platform top (m^3)

V_S: Smoke flow rate and generation rate, both are 300 (m^3/min.)

V_e': Effective smoke exhaust rate against the effective volume (V_E) of whole platform story (m^3/min.)

A_E: Sectional area of the platform story right angled to the railway, 2.0 m above the platform top excluding pillars, stairways, etc. where smoke does not spread (m^2)

A_V': Sectional area of train 2.0 m above the platform top (m^2)

V_e: Exhaust rate of smoke exhaust system of whole platform story (m^3/min.)

A_0: Sectional area right angled to the railway in calculation of fire block volume (m^2)

Av: Sectional area of train (including under-floor area) (m^2)

(2) In case of concourse story fire (excluding the case of the concourse story being independently separated into two or more)

$t_0 = V' / (V_s - V_s')$

$V' = (Af - At) \times (H - 2)$

$V_e' = V_e \times (H - 2) / H$

where (V_S - V_e') is 0 or negative, $t_0 = \infty$, and in case of the concourse story without kiosk, if t_0 is equal to or greater than 3, $t_0 = \infty$

V': Smoke diffusion volume without considering the exhaust rate of the smoke exhaust system (m^3)

V_S: Generation rate of smoke, etc. = 300.0 (m^3/min.)

V_e': Effective exhaust rate (m^3/min.)

Af: Floor area of the concourse story (m^2)

At: Area of pillars, etc. of the concourse story, where smoke does not spread (m^2)

H: Ceiling height of the concourse story (m)

V_e: Exhaust rate of the smoke exhaust system for the concourse story (m^3/min.)

In the subway station having the ceiling of the platform story provided with blow-by and the same ceiling height as the concourse story, or similar conditions, where complicated smoke flow is foreseeable, “Two layer zone smoke transport prediction” may be applied for calculating t_0.

6. Countermeasures

The following countermeasures shall be applied if the capacity of the smoke exhaust system is not enough as a result of checking for Big Fire;

(1) To provide new evacuation route or to widen the route in order to shorten the evacuation time,

(2) To enlarge the smoke diffusion volume,

(3) To make kiosk, where fire may start, fire- and smoke-proofed and to install sprinkler type fire-extinguishing system,

(4) Not to install kiosk from which fire may start, and/or

(5) To install other arrangements to secure passengers’ evacuation safety.

If (1), (2), and/or (5) are applied, rechecking shall be carried out, and if (3) or (4) are applied, rechecking shall be carried out excluding kiosk.

II. Smoke control for living quarters

The living quarters shall be installed with smoke exhaust system.

The smoke exhaust system shall be automatically actuated when a smoke exhaust outlet is opened, and shall be capable of exhausting at the rate of more than 120 m^3/min. and more than 1 m^3/min. for 1 m^2 of smoke-proof compartment floor area (the system working for more than two (2) smoke-proof compartments, shall have the exhaust rate of more than 2 m^3/min. for 1 m^2 of the largest floor area among the relevant compartments).

As for other structures, Paragraph 3 of Article 126 of the enforcement ordinance to the Building Standard Law shall be conformed.

[Explanation]

The explanation in Attachment No. 7 describes the concept and method, etc. for verifying evacuation safety and how to calculate the necessary amount of smoke exhaust, based on the Study Meeting on Fire Prevention at Underground Railways.

1. Basis of fire prevention

1.1 Concept of fire prevention

The basis of fire prevention in an underground railway is to make it noncombustible and take comprehensive measures to enable passengers to evacuate to the ground safely if a fire occurs.

1.2 Assumed fire

In the fire prevention standards of underground railways formulated in 1975, a train fire due to ignition from underfloor equipment or a store fire due to arson using a lighter, etc. was assumed. In view of the subway fire accident in Deagu City, Korea, a large fire due to arson, etc. using gasoline could occur in Japan.

Therefore, “a large fire” must also be considered in addition to “an ordinary fire” in the fire prevention standards formulated in 1975 as shown in **Table 29.3**.

The characteristics of fire and smoke flow properties are different between an ordinary fire and a large fire. In an ordinary fire, the temperature of smoke is low and so the smoke spreads evenly while in a large fire, the temperature of the smoke is high and so the smoke forms a layer on the ceiling, flows, and descends while accumulating.

Table 29.3 Assumed fire

Fire	Type	Fire source
Ordinary fire	Rolling stock	Fire from underfloor equipment of rolling stock (standards formulated in 1975)
	Store	Arson with a lighter, etc. (standards formulated in 1975)
Large fire	Rolling stock	Arson with 4 liters of gasoline*
	Store	Arson with 4 liters of gasoline*

* The amount of gasoline scattered in the subway fire in Deagu was initially estimated to be about 2 liters, but later this was revised to 4 liters, so the assumed fire source has been determined to be 4 liters of gasoline.

2. Verification of evacuation safety

2.1 Stations subject to verification of evacuation safety

The fire prevention standards formulated in 1975 set the evacuation time in a typical underground station and designed capabilities, etc. that the smoke exhaust equipment should have in order to secure sufficient evacuation time. In recent years, however, there are many deep underground stations and stations where the evacuation route is complicated, and the station layout and evacuation routes differ from station to station. It is therefore necessary to verify evacuation safety for all underground stations*.

The verification result is also useful for the initial response system of fire-fighting.

* An underground station refers to a station where the platform is underground (except those in mountain regions).

2.2 Subject of verification by location of assumed fire

With regard to measures to ensure the evacuation safety of passengers, in addition to the structure of individual stations, the location where a fire breaks out is also important. Therefore, a study was conducted on the evacuation safety of passengers (subject of verification) for each location of a fire; the results are shown in **Table 29.4**. The necessity of verifying evacuation safety for each fire location was also studied; the results are shown in **Table 29.5.**

An evacuation location in the table refers to a location where smoke and flames from the fire can be shut off with a fire preventive shutter, etc. (fire preventive block).

Table 29.4 Fire location and subject of verification of evacuation safety

Fire location			Subject of verification of evacuation safety		
			Train passengers	Station passengers	
		Train operation		Platform	Concourse
Rolling stock	Between stations	Stop	○	×1	×1
		Travel to the next station	○	×2	×2
	Station	Stop	○	○	×3
Station	Store on platform		○	○	×3
	Store on concourse		×4	○	×3
	Occupied room		×5	×5	×5
Tunnel (cable)		Stop	○	×1	×1
		Travel to the next station	×6	×6	×6

Notes:

○: Evacuation safety is to be verified

×: Evacuation safety is not to be verified

×1: Evacuation safety of passengers on the platform floor and concourse floor can be secured by smoke exhaust of a tunnel, etc.

×2: Passengers on the platform floor and concourse floor have already evacuated before the train arrives at the station

×3: As stairs from the concourse floor to the ground are usually wider than the platform stairs and ticket gates, and in view of the time for passengers to evacuate from the platform floor to the concourse floor, passengers on the concourse floor hardly affect the evacuation time of passengers on the platform floor. Therefore, when calculating the evacuation time in a fire of stores on the concourse, passengers on the concourse shall not be included in the verification.

×4: Evacuation safety of train passengers can be secured by a train passing a station on fire and releasing passengers at the next station.

×5: Since measures to prevent fires from spreading are taken for occupied rooms by fire preventive blocks, etc. and an unspecified large number of passengers do not get in and out, the evacuation safety of train passengers and passengers on the platform floor and concourse floor can be secured.

×6: Evacuation safety of train passengers and passengers on the platform floor and concourse floor can be secured by smoke exhaust of a tunnel.

Table 29.5 Assumed fire and subject of verification of evacuation safety

Fire location			Assumed fire	Subject of verification	Evacuation route	Subject of verification
Rolling stock	Between stations	Stop	Ordinary fire Large fire	Train passengers	Rolling stock →Tunnel →Platform floor →Concourse floor (evacuation location) →Ground	×
		Travel to the next station	Ordinary fire*1 Large fire*2	Train passengers	Rolling stock →Platform floor →Concourse floor (evacuation location) →Ground	○
	Station	Stop	Large fire*3	Train passengers Passengers on platform floor	Rolling stock →Platform floor →Concourse floor (evacuation location) →Ground	○
Station	Store on platform		Ordinary fire Large fire	Train passengers Passengers on platform floor	Platform floor →Concourse floor (evacuation location) →Ground	○
	Store on concourse		Ordinary fire Large fire	Passengers on platform floor	Platform floor →Concourse floor →Ground (evacuation location)	○
Tunnel	Between stations	Stop	Cable fire	Train passengers	Rolling stock →Tunnel →Platform floor →Concourse floor (evacuation location) →Ground	×

Notes:

○: Perform verification of evacuation safety.

×: The smoke layer will remain high in a tunnel and not interfere with the evacuation of train passengers due to tunnel smoke exhaust. For the tunnel smoke exhaust, it is generally considered that smoke does not accumulate sufficiently to affect passengers in a tunnel by forced or natural ventilation.

*1: In an ordinary fire, it is considered that station staff have finished giving evacuation guidance to passengers on the platform after being notified of a fire before the train on fire arrives at the station.

*2: Because only train passengers require evacuation, a large fire can be covered by the verification when a train stops at a station (subject of verification = train passengers + passengers on a platform floor).

*3: The verification of an ordinary fire when a train stops at a station can be covered by the verification of an ordinary fire when a train travels to the next station in consideration of fire properties when a train fire is found on a platform, the evacuation time of passengers on a platform floor, etc. Therefore, only a large fire is considered.

2.3 Method of verifying evacuation safety

(1) Verification of evacuation safety

The fire prevention standards formulated in 1975 assumed a typical underground station and designed smoke exhaust capabilities, etc., assuming that the time to evacuate from a platform floor to a concourse floor was uniformly 7 minutes for a train fire, and the evacuation time from a platform floor to the ground was uniformly 10 minutes for a concourse fire. In recent years, however, there are many deep underground stations and stations with complicated evacuation routes, and so designers should choose a verification method that can take these station configurations and evacuation routes into consideration.

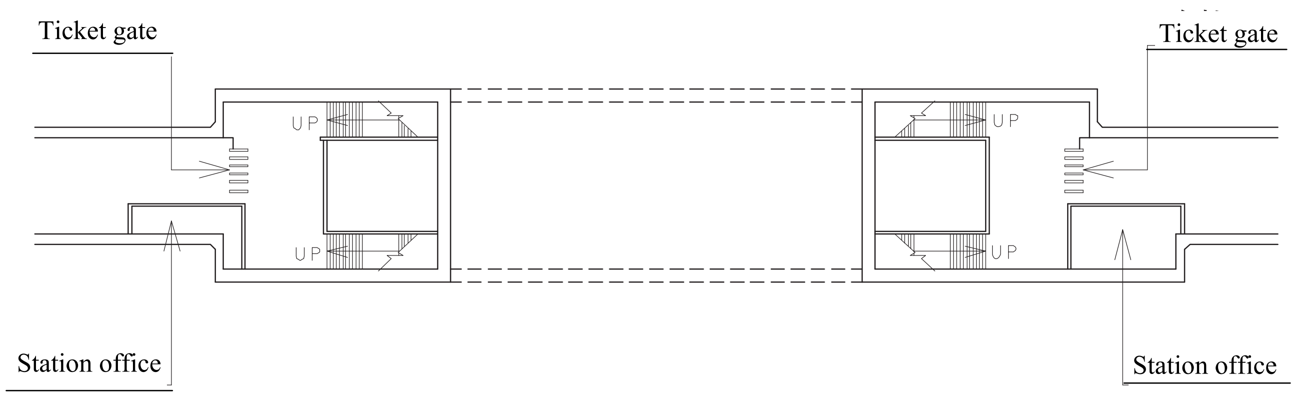
In addition, following the subway fire accident of Deagu City, Korea, it is necessary to consider also the method of verifying evacuation safety for a large fire.

In view of these issues, a method was proposed which can verify the evacuation safety corresponding to the structure of individual stations and which can consider the fire properties and smoke flow properties. The flow of the verification is shown in **Figure 29.8** and **Figure 29.9**.

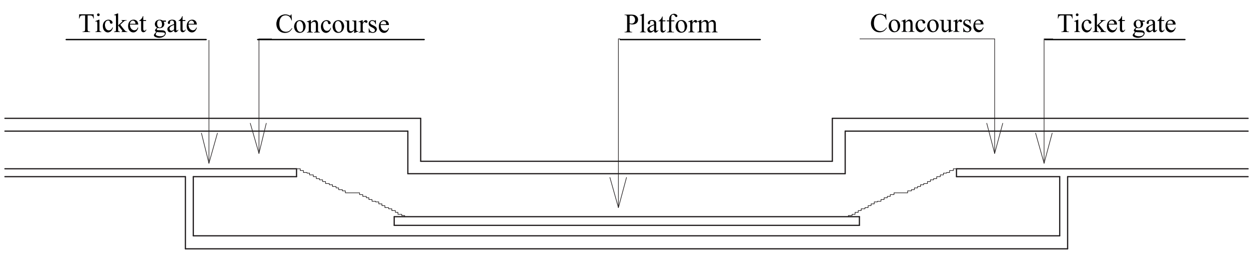
Assuming that there are no stores on a platform floor or concourse floor, or that stores are compartmentalized to prevent fire and smoke (with a sprinkler), a store fire on a platform or concourse need not be verified because there are no combustibles as fire sources, and a store fire does not affect evacuation passages, etc. and therefore passengers can evacuate on the concourse floor safely. Although a fire could occur in a trash box on a concourse floor, the amount of combustibles is small and the fire would not last long, so passengers can evacuate the concourse floor safely.

If there are opposed type platforms and a concourse on the same floor, the concourse area is small, and the distance to the ground is short, the platforms and concourse can be deemed to be the same space. As a platform fire is verified and smoke exhaust equipment is installed, a concourse fire need not be verified. For a concourse on the ground also, a concourse fire need not be verified.

If a concourse fire occurs, passengers on the concourse floor can promptly evacuate to the ground, etc. if the station staff find the fire quickly and give evacuation guidance. Therefore, the evacuation safety of passengers on a platform floor must be verified.
When a concourse floor is divided into at least two independent locations, even if a store fire occurs on one concourse, passengers on a platform floor can evacuate to the ground, etc. through a concourse where there is no store fire by following the evacuation guidance of station staff. Therefore, a concourse fire need not be verified. If there is an emergency staircase which does not pass through the concourse, passengers on a platform floor can safely evacuate to the ground, etc., and so a concourse fire need not be verified.
The division of a concourse into at least two independent locations means that respective concourses are independent in structure and space as shown in **Fig. 29.7**.



Plan view (concourse floor)



Longitudinal section

Fig. 29.7 Example in which concourse floor is divided into at least two independent locations

For reference, stipulations for the fire prevention equipment which must be considered are shown in **Table 29.6**.

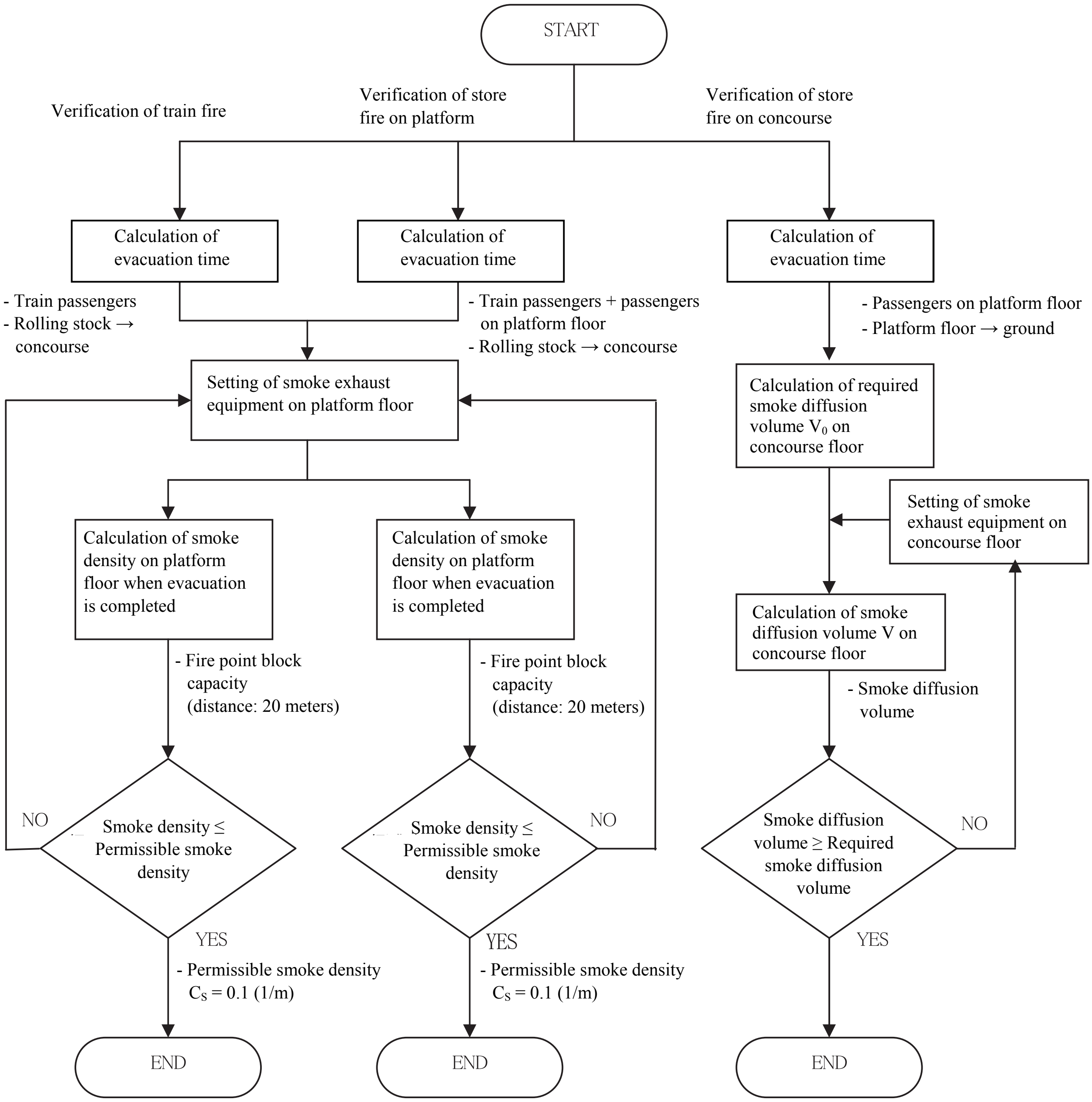


Fig. 29.8 Flow of verification for an ordinary fire

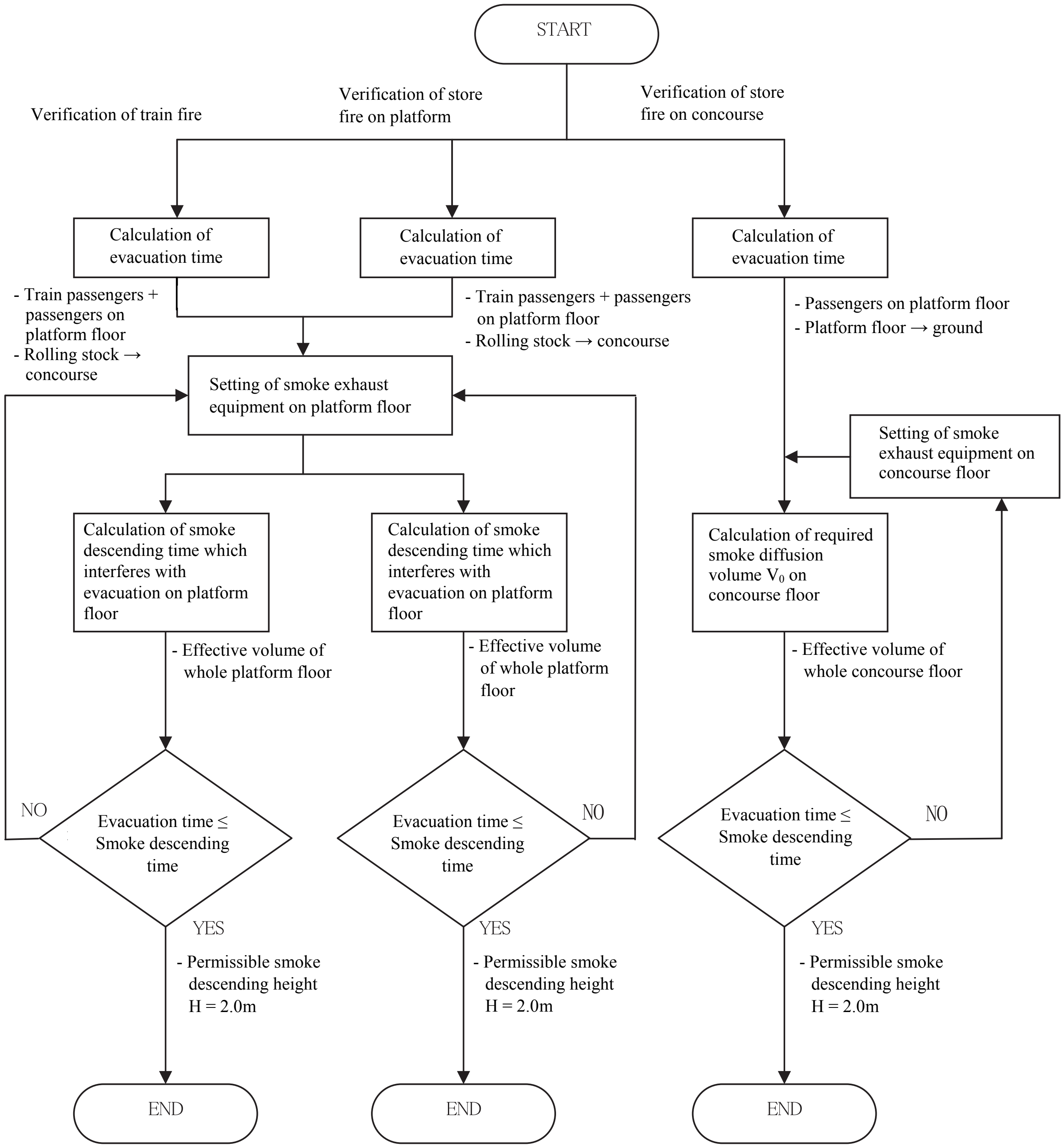


Fig. 29.9 Flow of verification for a large fire

Type		Stipulation				Fire prevention standards of underground railway (station area)	Fire Service Act				Building Standard Law	
		Railway	Fire-fighting				(Underground shopping center)		(Rolling stock depot)			
			Under-ground shopping center	Station	Building		Necessity	Provision	Necessity	Provision	Necessity	Provision
Alarm & notification	Automatic fire alarm	○	○	○	–	Necessary	Necessary for ≥ 300 m²	Government ordinance 21-1-3	Necessary for ≥ 300 m²	Government ordinance 21-1-9	–	–
	Emergency public address system	–	○	○	–	–	Necessary	Government ordinance 24-3-1	Exempted by installing automatic fire alarm Necessary for ≥ 3rd basement	Government ordinance 24-2-2 Government ordinance 24-3-2	–	–
	Public address system	○	–	–	–	Necessary	–	–	–	–	–	–
	Communication equipment	○	○	○	–	Necessary: Fire-fighting, police, train dispatch station, electric power dispatch station, various locations in station, adjacent buildings (railway telephone + telephone)	Necessary (replaceable with telephone)	Government ordinance 23-1-1 Government ordinance 23-3	Necessary for ≥ 1000 m² (replaceable with telephone)	Government ordinance 23-1-3 Government ordinance 23-3	–	–
	Radio communication auxiliary equipment	○	○	–	–	Necessary	Necessary for ≥ 1000 m²	Government ordinance 29-3-1	–	–	–	–
Evacuation guidance	Evacuation passage (two-way)	○	–	–	○	Necessary	–	–	–	–	Necessary depending on evacuation distance	Government ordinance 121
	Emergency lighting	○	–	–	○	Necessary (floor surface 1 lux or more)	–	–	–	–	Necessary (floor surface 1 lux or more)	Government ordinance 126-4 Government ordinance 126-5
	Exit lighting	○	○	○	–	Necessary	Necessary	Government ordinance 26-1-1, 2	Necessary	Government ordinance 26-1-1, 2	–	–
Fire prevention	Fire door	○	–	–	○	Partition with station of other line, underground shopping center, platform stairs Fire door, two-stage falling shutter	–	–	–	–	Area partition Partition for different use Designated fire preventive equipment	Government ordinance 112
	Interior finishing limitation	○	○	–	○	Noncombustible	Goods subject to fire prevention	Act 8, 3-1	–	–	Quasi-noncombustible	Government ordinance 128-4
Early fire-extinguishing	Fire extinguisher	○	○	○	–	Necessary	Necessary	Government ordinance 10-1-1	Necessary for ≥ 50 m²	Government ordinance 10-1-5	–	–
	Indoor hydrant equipment	○	○	○	–	Necessary	Necessary for ≥ 150 m²*	Government ordinance 11-1-4 Government ordinance 11-2	Necessary for ≥ 150 m²*	Government ordinance 11-1-6 Government ordinance 11-2	–	–
	Sprinkler equipment	○	○	–	–	Either is necessary: occupied room, etc.	Necessary for ≥ 1000 m²	Government ordinance 12-1-5	–	–	–	–
Fire-fighting	Connected water spray system		○	○	–		Necessary for ≥ 700 m² (replaceable with sprinkler)	Government ordinance 28-2-1 Government ordinance 28-2-3	Necessary for ≥ 700 m² (replaceable with sprinkler)	Government ordinance 28-2-1 Government ordinance 28-2-3	–	–
	Connecting water pipe	○	○	–	–	Necessary	Necessary for ≥ 1000 m²	Government ordinance 29-1-3	–	–	–	–
	Emergency plug socket equipment	○	○	–	–	Necessary	Necessary for ≥ 1000 m²	Government ordinance 29-2-1-2	–	–	–	–
Smoke exhaust	Smoke exhaust equipment	○	○	○	○	Necessary Exhaust equipment may also be used as ventilation equipment. Fire point block: Smoke diffusion volume	Necessary for ≥ 1000 m²	Government ordinance 28-1-1	Necessary for ≥ 1000 m²	Government ordinance 28-1-3	Occupied room with no window 1 m³/m³ Smoke exhaust port within 30 meters Smoke exhaust block ≤ 500 m²	Government ordinance 126-2 Government ordinance 126-3-1-9 Government ordinance 129-3-1-3 Government ordinance 126-3-1-1
	Anti-smoke hanging wall	○	○	○	○	Necessary as required: Between platform and railway track, areas such as stairs, escalators, etc.	Necessary	Regulation 30-1-[A]	Necessary	Regulation 30-1-[A]	Necessary	Government ordinance 126-2
Others	Disaster prevention general control panel	–	○	△	–	–	Necessary for ≥ 1000 m²	Regulation 12-1-8-[B]	Necessary for ≥ 5000 m² Judgment by fire chief	Regulation 12-1-8-[C]	–	–
	Control room for disaster prevention	○	○	○	–	Necessary	Necessary for ≥ 1000 m²	Regulation 12-1-8-[B]	Necessary for ≥ 5000 m² Judgment by fire chief	Regulation 12-1-8-[C]	–	–
	Air-breathing apparatus	○	–	–	–	Necessary	–	–	–	–	–	–

(Reference) Preconditions of design standards of smoke exhaust equipment formulated in 1982

With regard to the fire prevention standards of underground stations and tunnels, the incombustibility of buildings, the fire prevention standards formulated in 1975 stipulated the provision of a control room for disaster prevention and two-way evacuation passages. In addition, the standards formulated in 1982 stipulated design standards for smoke exhaust equipment. The preconditions in the design standards for smoke exhaust equipment are as follows.

1) Assumed fire
   - Train fire due to ignition of rolling stock underfloor equipment
   - Store fire caused by arson with a lighter, etc.
2) Smoke model
   - Fire smoke model based on the results of a rolling stock fire experiment in 1969 ("A-A form" rolling stock at the time of the rolling stock fire accident of the Hibiya Line in 1968)
   - Fire smoke model by a store burning experiment
3) Possibility of train traveling when a fire occurs
   - Able to travel to the next station
4) People requiring evacuation
   - Number of people requiring evacuation
     - In the case of a platform floor fire: Passengers in a train with smoke, 200% boarding during morning rush-hour
     - In the case of a concourse floor fire: Passengers waiting on a platform, 1,000 persons
   - Type of crowd: B type (general people, such as visitors to stores and offices, and passersby, who are not familiar with the position and route inside the building)
5) Configuration of station
   - Platform floor: Basement level 2, Concourse floor: Basement level 1
6) Evacuation route
   - Rolling stock→On platform→Platform stairs→Ticket gate→Concourse→
     Exit stairs→Ground
7) Method of calculating evacuation time
   - Horiuchi Theory which obtains the time necessary for all people to evacuate, based on the number of people staying and the staying time
8) Verification of evacuation safety
   - Smoke density during evacuation ≤ Permissible smoke density
     (Cs = 0.1 (1/m): Equivalent to the visible distance required for an unspecified number of people to evacuate (15 to 20 m))
9) Evacuation time to be considered in the smoke exhaust equipment design

The evacuation time to be considered in the smoke exhaust equipment design is determined to be a uniform 7 minutes for a platform fire assuming the standard station configuration model shown in **Table 29.7**, based on an investigation of the actual conditions of existing stations and by calculating the evacuation time as shown in **Table 29.8** (time required for the completion of evacuation to a concourse floor of passengers in a train of 10 cars on an opposed type platform: 6.9 minutes).

In a concourse floor fire, the number of passengers waiting for a train on a platform is assumed to be 1,000 and the evacuation time is calculated (time required for the completion of evacuation to a ground exit of passengers waiting for a train). The time is determined to be a uniform 10 minutes, allowing for a margin of safety.

Table 29.7 Preconditions of evacuation time in the standards formulated in 1982

Item \ Platform type	Opposed type		Island type		Basis for setting conditions: As per the investigation of actual conditions of underground railways
	Equivalent to 6 cars	Equivalent to 10 cars	Equivalent to 6 cars	Equivalent to 10 cars	
[1] Effective length of platform (m)	130	210	130	210	20 m per car, and a margin of 10 m
[2] Train capacity (person)	980	1,424	980	1,424	1977 report* is applied for 6 cars and 10 cars. Capacity of 8 cars is 8/10 times that of 10 cars.
[3] Number of people requiring evacuation	1,960	2,848	1,960	2,848	Passenger load factor 200%
[4] Number of stairs on platform	4	4	3	3	In an opposed type platform, 6 if there are emergency stairs, but the normal number is 4. In case of an island type, calculated from the station number.
[5] Minimum distance from getting off to the lower part of platform stairs (m)	3	3	3	3	1977 report is applied.
[6] Width of platform stairs (m)	2.83	2.83	3.04	3.04	As the widths for 10-car platform for an opposed type and 8-car for an island type are minimum as the result of inspection of the average width of normal stairs, these are used.
[7] Total width of platform stairs (m)	5.66	5.66	9.12	9.12	In case of an opposed type platform, only platform stairs on one side can be used for evacuation.
[8] Distance of platform stairs (m)	10	13	10	14	Consideration of quantity and average value of normal stairs. Average value for 10-car platform
[9] Number of ticket gates	1	2	1	2	Consideration of quantity and average value
[10] Distance from the upper part of platform stairs to the ticket gate (m)	23	17	19	24	Average value
[11] Width per ticket gate (m)	3.66	3.60	4.17	4.10	Average value
[12] Total width of ticket gates (m)	3.66	7.20	4.17	8.20	[9] x [11]
[13] Number of exit stairs	4	4	4	4	Consideration of quantity and average value. For 10 car-platform of an island type, 7 or greater is excluded as a special case.
[14] Distance from ticket gate to exit stairs (m)	60	60	61	61	As the distances of 8-car platform for an opposed type and 10-car for an island type are average values and maximum values, these are used.
[15] Width of exit stairs (m)	2.42	2.42	2.89	2.89	As widths of 6-car platform for an opposed type and 10-car for an island type are average values and minimum values, these are used.
[16] Total width of exit stairs (m)	9.68	9.68	11.56	11.56	[13] x [15]
[17] Distance of exit stairs (m)	40	40	36	36	As the distances of 10-car platform for an opposed type and 6-car for an island type are average values and maximum values, these are used.

* 1977 Report on study of underground railway optimal smoke exhaust system, March 1978, Ministry of Transport

Table 29.8 Results of calculating evacuation time in the standards formulated in 1982

Item \ Platform type	Opposed type		Island type	
	Equivalent to 6 cars	Equivalent to 10 cars	Equivalent to 6 cars	Equivalent to 10 cars
Passing under platform stairs (minute)	4.5	6.5	2.8	4.1
Arrival at concourse floor (minute)	4.8	6.9	3.1	4.5
Passing through ticket gate (minute)	6.7	7.2	5.9	5.0
Passing under exit stairs (minute)	7.7	8.2	6.9	6.0
Ground exit (minute)	9.0	9.6	8.1	7.2

(2) Setting the fire property model
A fire property model should be set for verifying the evacuation time as follows based on the train burning experiment and store burning experiment.

1) Fire property model of train fire
Because the characteristics of fire and smoke flow differ between an ordinary fire and a large fire, the fire property model of a train fire shall be as shown in **Table 29.9** and **Figure 29.10**, respectively.
The fire property model for an ordinary fire was set at a smoke speed of C (m^3/minute-m) and was made the same model as the standards formulated in 1975.
With regard to the fire property model in a large fire, the train burning experiment, etc. showed that as the temperature of smoke generated is high, the smoke tends to form a layer on the ceiling, flows and descends while accumulating. Therefore, it was decided to use a two-layer zone model for the evaluation which can evaluate these characteristics.

Table 29.9 Fire property model for a train fire

Assumed fire	Ordinary fire	Large fire
Model parameter	Smoke speed C (m^3/minute-m)	Heating value Q (MW)
Model setting	C = 21 (m^3/minute-m): $0 \leq t \leq 7$ minutes = 21 + 66(t-7)(m^3/minute-m): $7 < t$ minutes	Q = 5 (MW): $0 \leq t \leq 3$ minutes = 0 (MW): $3 < t$ minutes
Remarks	Same as standards formulated in 1975	Set from the train burning experiment, etc.

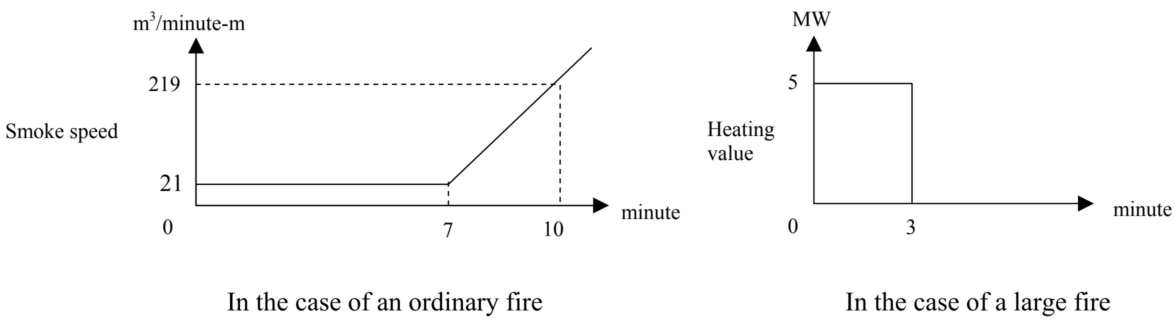


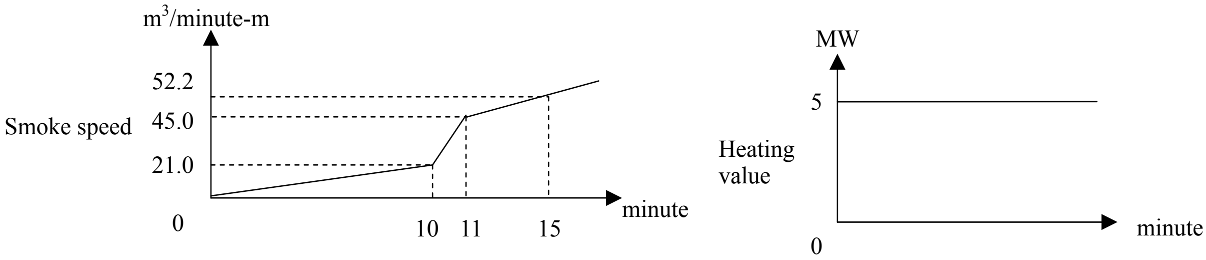
Fig. 29.10 Fire property model for a train fire

2) Fire property model for a store fire
For the fire property model for a store fire, as in a train fire, the characteristics of fire and smoke flow differ between an ordinary fire and a large fire, and so the fire property model shown in **Table 29.10** and **Figure 29.11** is used, respectively.

The fire property model for an ordinary fire was set at a smoke speed of C (m^3/minute-m) and was made the same model as the standards formulated in 1975. With regard to the fire property model in a large fire, from the store burning experiment, etc. it was decided to use a two-layer zone model for the evaluation.

Table 29.10 Fire property model for a store fire

Assumed fire	Ordinary fire	Large fire
Model parameter	Smoke speed C (m^3/minute-m)	Heating value Q (MW)
Model setting	C = 2.1t (m^3/minute-m): $0 \leq t \leq 10$ minutes 24.0t-219.0 (m^3/minute-m) : $10 < t \leq 11$ minutes 1.8t+25.2 (m^3/minute-m) : $11 < t$ minutes	Q = 5 (MW)
Remarks	Same as standards formulated in 1975	Set from the store burning experiment, etc.



In the case of an ordinary fire In the case of a large fire

Fig. 29.11 Fire property model for a store fire

(3) Method of calculating evacuation time

The principle of calculating the evacuation time is as follows.

1) Method of calculating the evacuation time

Calculate the time (time required for evacuation completion) until all people to be evacuated have evacuated to the evacuation locations, using the “method for obtaining the time required for all people to evacuate”, based on the number of queuing people and queuing time, as in the standards formulated in 1975.

Walking time: $t = \max(\sum l/v)$

l: Walking distance (m)

v: Walking speed of crowd (m/sec)

Queuing time: $T = Q/(N \times B)$

Q: Number of people requiring evacuation

N: Flowout coefficient of crowd outflow (person/m/sec)

B: Effective width such as staircase width (m)

Evacuation locations differ depending on the fire location. For example, in a platform floor fire, if a fire preventive shutter is installed under the platform stairs, the concourse floor, which is above the shutter, is an evacuation location.

It was also decided that if a shutter is installed at another location and there is sufficient space above it, the space may be used as an evacuation location.

An evacuation route must be always passable. A connection passage with other lines may be an evacuation passage if it is always passable and passengers, etc. can evacuate by means of a two-stage falling shutter, etc. even when a fire occurs.

In calculating the evacuation time, in general, if passengers evacuate from a platform floor to a concourse floor in a train fire, the time until they pass a fire door or shutter installed at the platform stairs may be used (not necessarily to the concourse floor). However, this assumes that there is sufficient space ahead of the fire door or shutter in consideration of passengers queuing there.

In a concourse fire, if there is a fire door or shutter on the passage between a store and the ground, the time until passengers pass there may be used (not necessarily to the ground).

According to “Report of Study Group on Large Station Sections and Deep Underground Subways” (March 1991 (Ministry of Transport)), when planning a station deep underground, the installation of a safety compartment (compartmentalized space for fire prevention) where passengers, etc. can evacuate temporarily must be studied. If passengers, etc. can evacuate to this safety compartment, they can evacuate to the ground with sufficient lead time. The safety compartment must be not only an area where all passengers, etc. to be evacuated can stay temporarily, but also a psychologically calming space and environment. Smoke exhaust equipment to maintain the environment of the safety compartment for securing a descending current, as well as equipment for direct evacuation to the ground must be installed. Fatigue of evacuees must be considered such as the use of an elevator or escalator, and fire-fighting by a fire company must also be considered.

2) Setting of type of crowd

The type of crowd shall be Type B shown in **Table 29.11** as in the standards formulated in 1975.

Currently, there is no effective means of evaluating the effect of many people with limited movement on the evacuation time. When the evacuation time for various types of crowd was simulated, it was found that the evacuation time for a load factor of 150% or more in Type B was almost equal to that for a load factor of 100% in Type A. In calculating the evacuation time in an underground station, queuing time is dominant rather than walking time, and the type of crowd has little effect on the evacuation time.

In calculating the evacuation time stipulated in the Building Standard Law, values similar to Type B in Table 29.11 are used.

Table 29.11 Motion ability of people requiring evacuation

Type	Illustration		Motion ability of crowd			
			Walking speed (m/sec)		Flowout coefficient (person/m/sec)	
			Horizontal	Stairs	Horizontal	Stairs
Type A	People who cannot easily act on their own	Seriously ill person, senile person, babies and infants, feebleminded person, disabled person, etc.	0.8	0.4	1.3	1.1
Type B	General people who are not accustomed to the position, routes, etc. in the building	Hotel visitors, etc., visitors to a store, office, etc., passersby	1.0	0.5	1.5	1.3
Type C	Persons in good health who know the position, routes, etc. in the building	Workers, employees, guards, etc. in the building	1.8	0.8	1.8	1.4

Source: 1977 Report on study of underground railway optimal smoke exhaust system, March 1978, Ministry of Transport

3) Determination of the number of people requiring evacuation

The number of people requiring evacuation when verifying evacuation safety shall be as shown in **Table 29.12** in the three major metropolitan areas, based on an investigation of actual conditions of the train load factor during rush-hour in underground railways and the number of passengers on platforms.

The number of passengers waiting on platforms, which is correlated with train capacity, is calculated according to the train load factor.

- As a result of investigating the load factor (per hour during rush-hour) in trains on lines having underground stations in FY2003, there was no line exceeding 200%. Considering the future declining birthrate and aging population, 200% is unlikely to be exceeded. If an oncoming train stops at a station when a fire occurs, passengers are not allowed to get off and the oncoming train travels to the next station and passengers evacuate there. Therefore, the case in which an oncoming train other than a train on fire stops at a station and passengers in the oncoming train evacuate at a station where a fire occurs, is ignored.

- With regard to an intermediate station from which a train starts, it was decided to add 50% of the load factor to passengers waiting on a platform (a train on fire) based on the investigation of actual conditions. With regard to a station from which no train starts during rush-hour, even if there was a train starting from that station, it was determined that the number of people requiring evacuation need not be included for the verification.

- For areas other than the three major metropolitan areas, the number of people requiring evacuation was set to 75% of the values set for the three major metropolitan areas, and the number of passengers waiting on platforms was considered to decrease in that proportion.

Table 29.12 Set values of people requiring evacuation (3 major metropolitan areas)

Type	Load factor (%)	
	Terminal station *2	General stations other than the left
Passengers in a train on fire	200	200
Oncoming train	—	—
Passengers waiting on platform (train on fire)	100	50
Passengers waiting on platform (oncoming train)	50	25

*1: The three major metropolitan areas refer to the existing urban areas (special wards, Musashino City and Mitaka City of Tokyo Metropolis, Kawaguchi City of Saitama Prefecture, Yokohama City and Kawasaki City of Kanagawa Prefecture) provided for in Article 2 of the National Capital Region Development Act (Act No. 83 of 1956); the existing urban areas (Kyoto City of Kyoto Prefecture, Osaka City, Moriguchi City, Higashiosaka City and Sakai City of Osaka Prefecture, Kobe City, Amagasaki City, Nishinomiya City and Ashiya City of Hyogo Prefecture) provided for in Article 2 of the Kinki Region Development Act (Act No. 129 of 1963); and the area (Nagoya City of Aichi Prefecture) specified in the attachment of "Order for Enforcement of the Act concerning national financial special measures for the development of suburban development areas of the national capital region, Kinki region and Chubu region" out of urban areas provided for in Article 2 of the Chubu Region Development Act (Act No. 102 of 1966).

*2: A terminal station refers to a station where the average number of passengers getting on and off per day is 100,000 or more.

(Reference) Theory of evacuation time calculation and points to be noted

(1) Outline of the theory

If the exit of a room is not wide enough for the number of people using that exit to evacuate, a queue of evacuees forms behind the exit. If the exit width is B (m) and the number of evacuees using the exit to leave the room is Q (persons), the queuing time T (sec) at the exit is given by the equation below, assuming that people near the exit begin to move out at the start of evacuation.

$$T = Q / (N \times B)$$

(N: Flowout coefficient of crowd outflow (persons/m/sec))

where N x B (persons/sec) is the velocity of crowd outflow of evacuees at the exit. Accordingly, the last evacuee leaves the room for safety by the exit T seconds after the queue at the exit has gone.

Also, if a room has two or more exits that can be used for evacuation, it shall be assumed that the numbers of evacuees from respective gates are divided in proportion to the exit width (B) such that evacuation from all exits is completed at almost the same time, since if the queue at any one of the exits disappears, the remaining people will probably rush to that exit.

The evacuation route at an underground station is a continuation of passenger walkways and stairways, such as train doorway to platform to platform stairway to ticket barrier to stairway to the ground outside. By calculating the amounts of walking time t along the respective passageways and stairways and the amounts of queuing time T at the train's doorways, bottom of the platform stairway, ticket barrier and bottom of the exit stairway where queues are likely to form, and appropriately adding up such times as described later in the order of the evacuation route, it is possible to estimate the time to evacuate out of the underground station.

The walking speed of evacuees and the flowout coefficient of crowd outflow used for calculating the walking time t and the queuing time T on the evacuation route are set in advance as shown in Fig. 29.11 based on various measured values. In the study report on which the Fire Fighting Standards for Underground Railways established in 1975 are based, the evacuation time is calculated for a type B crowd and the walking speed of evacuees and flowout coefficient of crowd outflow are set accordingly. In estimating the evacuation time specified in the Building Standard Law, necessary values equivalent to those for a type B crowd are set. Therefore, when calculating the evacuation time at an underground station, the walking speed and outflow coefficient of a type B crowd shall be applied.

(2) Calculation of evacuation time at an uncomplicated underground station

An uncomplicated underground station at which the number of evacuees (persons) is the number of train passengers and there is only one evacuation route from the train's doorways to the ground is assumed. The walking time t and queuing time T are distributed along the evacuation route as shown in **Fig. 29.12** below.

Train's doorways	→→→ Platform	Bottom of platform stairway	→→→→→→→→→ Platform stairway	Concourse	Ticket barrier	→→→ Concourse	Bottom of exit stairway	→→→→ Exit stairway	Exit to ground
T_1	t_1	T_2	t_2	t_3	T_3	t_4	T_4	t_5	

Fig. 29.12 Typical evacuation route at uncomplicated underground station

Referring to the above, as the velocity of crowd outflow of evacuees (persons/sec) in the evacuation route from the train's doorways to the ground does not fall below the minimum of the velocities of crowd outflow N_i x B_i (persons/sec) from four congestion points, the maximum queuing time in the evacuation route will be the queuing time T at the queue point where the velocity of crowd outflow N_i x Bi becomes the lowest, provided that the number of evacuees Q is constant. Also, as the maximum queuing time in the evacuation route does not exceed the maximum value of T_1 as shown in **Fig. 29.13**, the time tr from evacuation from the train's doorways to the ground can be calculated by the following equation.

$$t_r = \sum^{i=1\sim5} t_i + T_{i\text{-}max}$$

$$= \sum^{i=1\sim5} t_i + Q／(N_i \times B_i)_{-min}$$

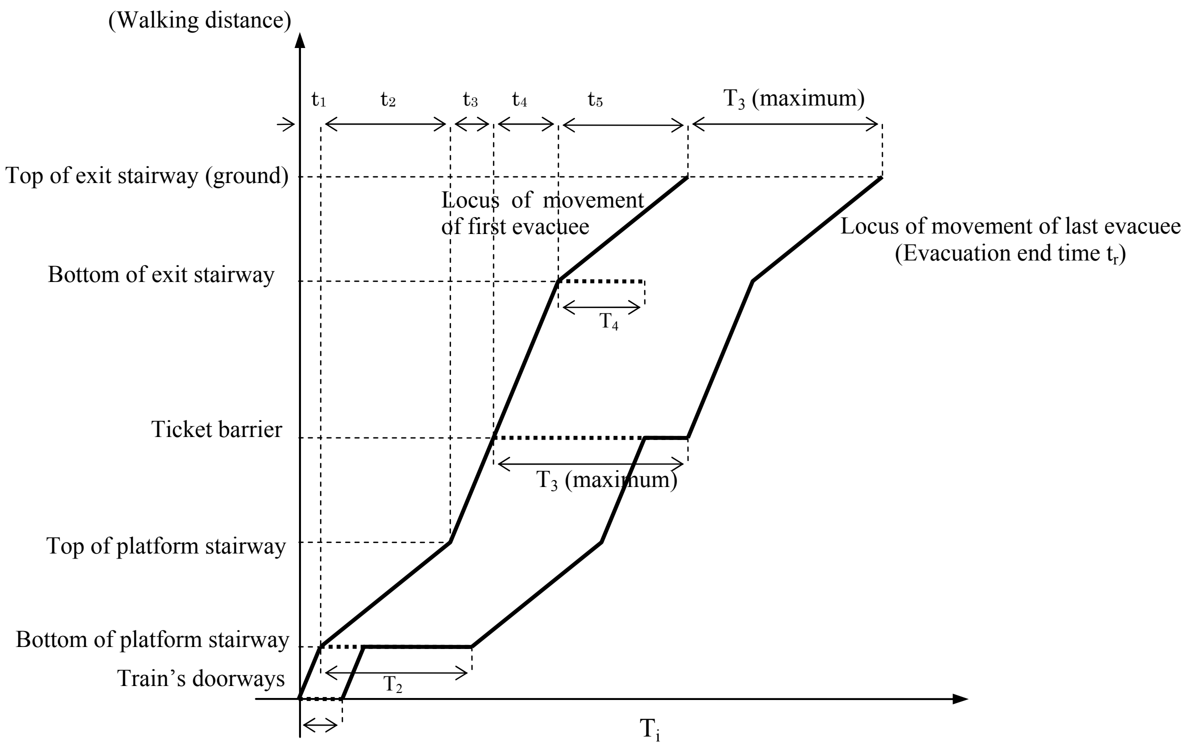


Fig. 29.13 Loci of movements of first and last evacuees

Among the required walking times, t_1 will have various values because the distance from the doorways of the train to the bottom of the platform stairway varies. However, the minimum $t_{1\text{-min}}$ of these times is generally used for the following reason.
Consider that the time from the start of evacuation to the last evacuee reaching the bottom of the platform stairway is calculated as $T_1 + t_{1\text{-max}}$, and that the time from the start of evacuation to the first evacuee reaching the bottom of the platform stairway and the queue disappearing is calculated as $t_{1\text{-min}} + T_2$. Generally, these times are assumed to be related as shown below from the sizes of platforms and platform stairways at underground stations:

$$T_1 + t_{1\text{-max}} < t_{1\text{-min}} + T_2$$

indicating that the queue at the bottom of the platform stairway has not yet disappeared when the last evacuee reaches it.
Therefore, the following equation is generally used for calculating the evacuation end time t_r mentioned above.

$$t_r = t_{1\text{-min}} + \sum_{i=2\sim5} t_i + T_{i\text{-max}}$$

$$= t_{1\text{-min}} + \sum_{i=2\sim5} t_i + Q / (N_i \times B_i)_{\text{-min}}$$

(3) Calculation of evacuation time at underground station with branched evacuation route
An underground station where the number of evacuees Q (persons) is the number of passengers and there are two evacuation routes from the train's doorways to the ground as shown in **Fig. 29.14** is assumed.

Train's doorways	→→→	Bottom of platform stairway	→→→→→→→→		Ticket barrier	→→	Bottom of exit stairway	→→→	Exit to ground
			Platform stairway	Concourse		Concourse		Exit stairway	
	Platform								
		T_{2A}	t_{2A}	t_{3A}	T_{3A}	t_{4A}	T_{4A}	t_{5A}	
		Bottom of platform stairway			Ticket barrier		Bottom of exit stairway		Exit to ground
			Platform stairway	Concourse		Concourse		Exit stairway	
	→→→		→→→→→→→→			→→		→→→	
T_1	$t_{1\text{-min}}$	T_{2B}	t_{2B}	t_{3B}	T_{3B}	t_{4B}	T_{4B}	t_{5B}	

Fig. 29.14 Typical two-branch evacuation route

Suppose that there are two evacuation routes, an upper one (route A) and a lower one (route B), which do not merge into one at a midway point between the bottom of the platform stairway and the ground, and that evacuees from the train take these two routes from the platform.
In this case, the numbers of evacuees Q to the two evacuation routes will be distributed in proportion to the velocity of crowd outflow at the bottom of the two platform stairways so that the queues at the bottom of the two platform stairways disappear at almost the same time. Accordingly, using,

$$\text{(Number of evacuees to route A) } Q_A = Q\times(N_{2A}\times B_{2A})/(N_{2A}\times B_{2A} + N_{2B}\times B_{2B})$$

$$\text{(Number of evacuees to route B) } Q_B = Q\times(N_{2B}\times B_{2B})/(N_{2A}\times B_{2A} + N_{2B}\times B_{2B})$$

$N_{2A}\times B_{2A}$: Velocity of route A crowd outflow at bottom of platform stairway
$N_{2B}\times B_{2B}$: Velocity of route B crowd outflow at bottom of platform stairway

the evacuation end time in each route is calculated and the longer time is taken as the evacuation end time at that station.

(4) Calculation of evacuation time at underground station with two evacuation routes merging into one midway
Consider an underground station where the number of evacuees Q (persons) is the number of train passengers and there is a mid-level stairway from the train's doorways to the ticket barrier and two evacuation routes to the ground as shown in **Fig. 29.15**.

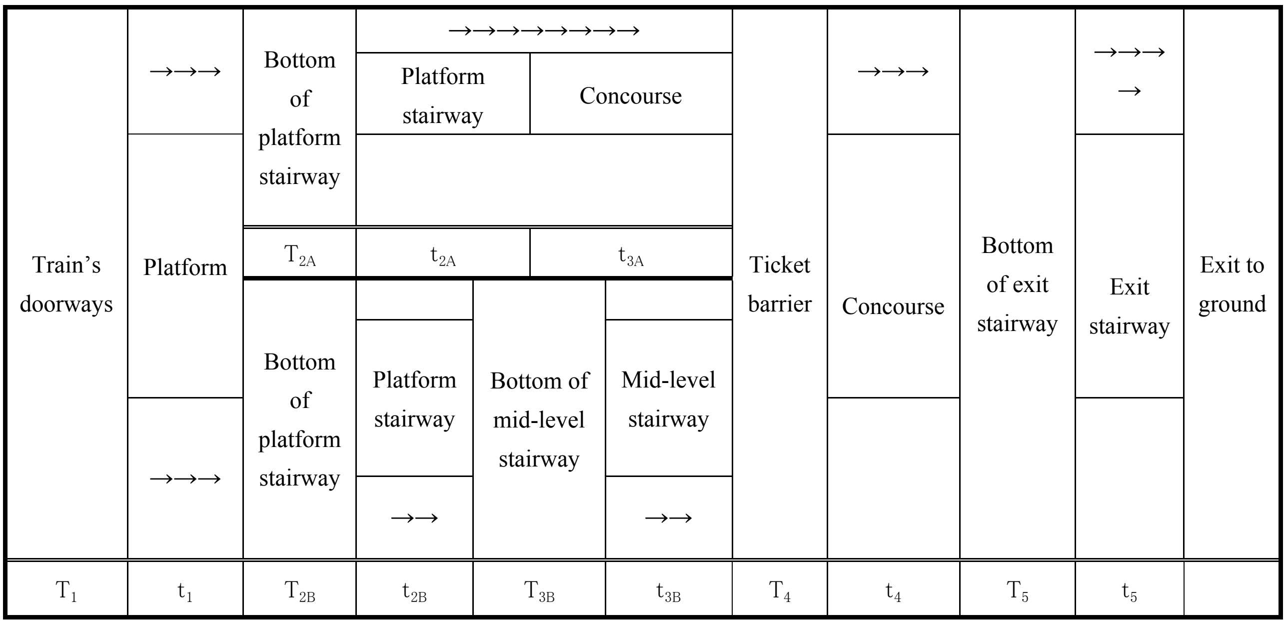


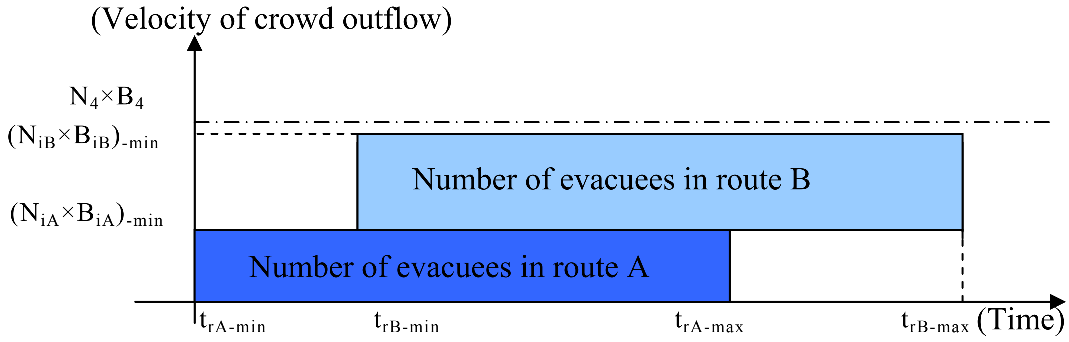
Fig. 29.15 Typical example of two evacuation routes merging into one

Suppose that there are two evacuations routes, an upper route (A) for direct evacuation to the ticket barrier by one stairway and a lower route (B) for evacuation by two stairways via a mid-level stairway, then the time when the last evacuee passes the ticket barrier that is the route merging point will be influenced by the following two factors.

[1] Difference between minimum velocity of crowd outflow in each route and velocity of crowd outflow at route merging point (ticket barrier)
[2] Difference in time to reach the ticket barrier between the two routes

Regarding the time when the last evacuee passes the ticket barrier that is the merging points of the two routes, various cases can be considered including the following. Therefore, in order to obtain the queuing time T_4 at the merging point and the time when the last evacuee passes the merging point, it is necessary to draw graphs as shown below and determine the influence of [1] and [2].

1) Where the total of minimum values of velocity of crowd outflow in the routes is less than the velocity of crowd outflow at the ticket barrier



N_4 x B_4 : Velocity of crowd outflow at ticket barrier
$(N_{iA}$ x $B_{iA})_{-min}$: Minimum velocity of route A crowd outflow
$(N_{iB}$ x $B_{iB})_{-min}$: Minimum velocity of route B crowd outflow
t_{rA-min} : Time until first evacuee in route A passes ticket barrier from start of evacuation
t_{rB-min} : Time until first evacuee in route B passes ticket barrier from start of evacuation
t_{rA-max} : Time until last evacuee in route A passes ticket barrier from start of evacuation
t_{rB-max} : Time until last evacuee in route B passes ticket barrier from start of evacuation

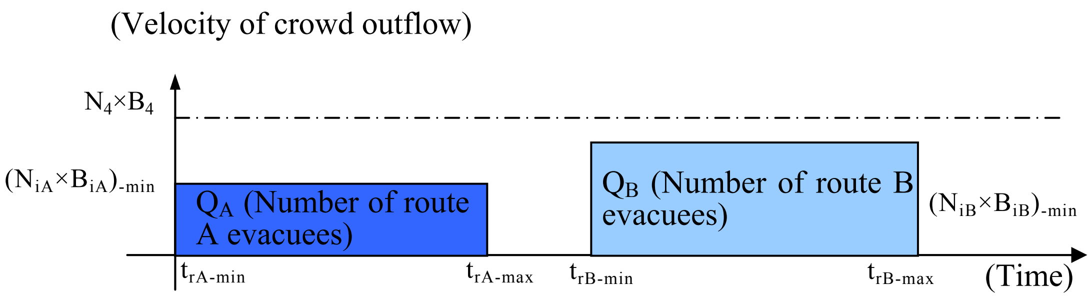
Fig. 29.16 Ticket barrier passing times in case of N_4 x $B_4 \geq (N_{iA}$ x $B_{iA})_{-min} + (N_{iB}$ x $B_{iB})_{-min}$

As is clear from **Fig. 29.16**, no queue forms at the ticket barrier where evacuees in the two routes meet in this case. Therefore, the time when the last evacuee passes the ticket barrier that is the merging point is the time t_{rB-max} when the last route B evacuee passes the ticket barrier.
Incidentally, for the evacuation time t_r up to the ground exit of that underground station, it is necessary to consider adding the queuing time T_5 at the bottom of the exit stairway to the value obtained by adding concourse walking time T_4 and exit stairway walking time t_5 to t_{rB-max}. Generally, as the velocity of crowd outflow at the bottom of the exit stairway is larger than that at the ticket barrier, an allowance of T_5 is rarely required, but if the velocity of crowd outflow at the bottom of the exit stairway is smaller than the total of the minimum velocities of crowd outflow for the two routes, it is necessary to allow for T_5 as described below.

2) Where the total of the minimum velocities of crowd outflow in the two routes is larger than the velocity of crowd outflow at the ticket barrier and the minimum velocity of crowd outflow in the leading route is smaller than that at the ticket barrier
In this situation, there are three cases to consider as shown in **Fig. 29.17** according to the difference in time taken to reach the ticket barrier between the two routes.

[1] Case where no queue forms because of a large difference in ticket barrier passing time of the leading evacuee between the two routes

i) Evacuees in the two routes do not meet at the ticket barrier



ii) Evacuees in the two routes meet at the ticket barrier

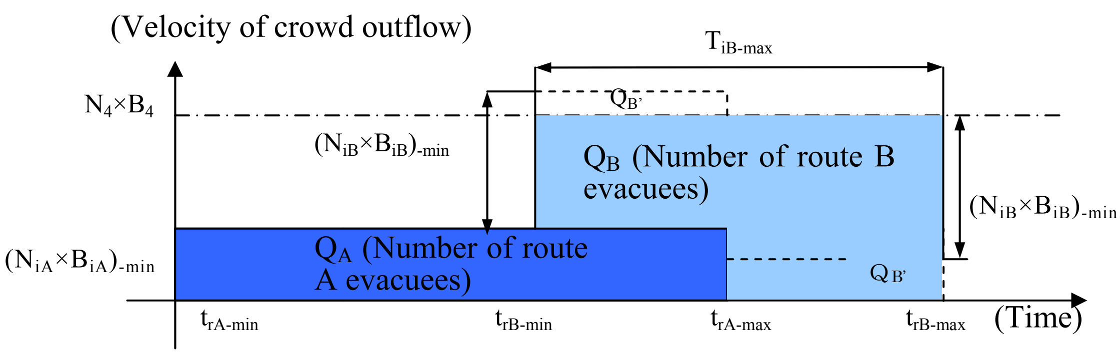
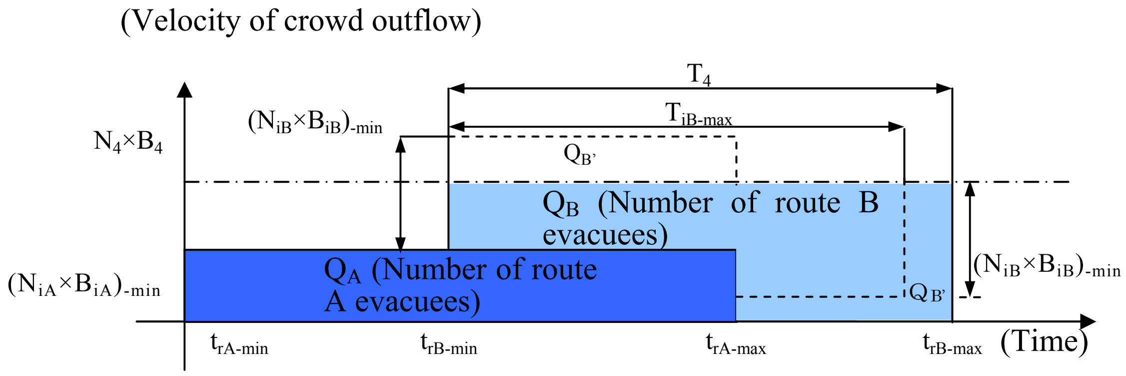


Fig. 29.17 Ticket barrier passing time in case of $N_4 \times B_4 < (N_{iA} \times B_{iA})_{-min} + (N_{iB} \times B_{iB})_{-min}$ [1]

[2] Case where a queue forms because of a small difference in ticket barrier passing time of the leading evacuee between the two routes



N_4 x B_4	: Velocity of crowd outflow at ticket barrier
$(N_{iA}$ x $B_{iA})_{-min}$	: Minimum velocity of crowd outflow in route A
$(N_{iB}$ x $B_{iB})_{-min}$	: Minimum velocity of crowd outflow in route B
t_{rA-min}	: Time from start of evacuation to first route A evacuee passing ticket barrier
t_{rB-min}	: Time from start of evacuation to first route B evacuee passing ticket barrier
t_{rA-max}	: Time from start of evacuation to last route A evacuee passing ticket barrier
t_{rB-max}	: Time from start of evacuation to last route B evacuee passing ticket barrier
$Q_{B'}$	: Number of evacuees held at ticket barrier
T_4	: Queuing time at ticket barrier

Fig. 29.17 Ticket barrier passing time in case of N_4 x $B_4 < (N_{iA}$ x $B_{iA})_{-min} + (N_{iB}$ x $N_{iB})_{-min}$ [2]

In case [1], the time when the last evacuee passes the ticket barrier that is the route merging point is the same as that in case 1). In case[2], however, it is necessary to take the queuing time at the ticket barrier into account, that is, the time t_{rB-min} when the first route B evacuee passes the ticket barrier plus the queuing time T_4 at the ticket barrier. T_4 is obtained from the following equation:

$$T_4 = \{Q - (t_{rB-min} - t_{rA-min}) \times (N_{iA} \times B_{iA})_{-min}\} / (N_4 \times B_4)$$

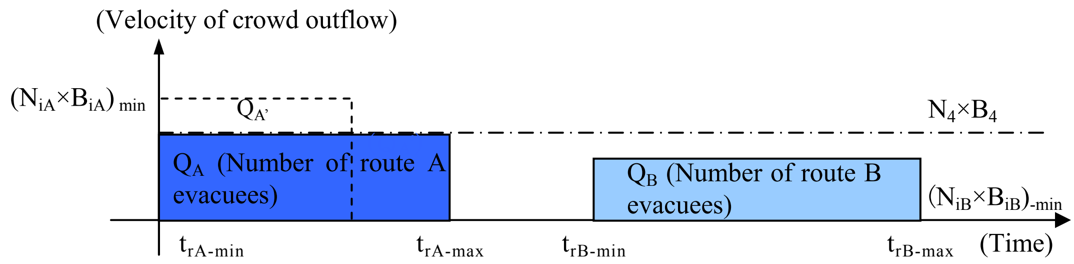
Accordingly, the value of $(t_{rB-min} + T_4)$ or t_{rB-max}, whichever is the larger, is the time when the last evacuee passes the ticket barrier that is the route merging point.

3) Where the total of the minimum values of the velocities of crowd outflow in the two routes is larger than the velocity of crowd outflow at the ticket barrier and the minimum velocity of the first route crowd outflow is larger than the velocity of crowd outflow at the ticket barrier

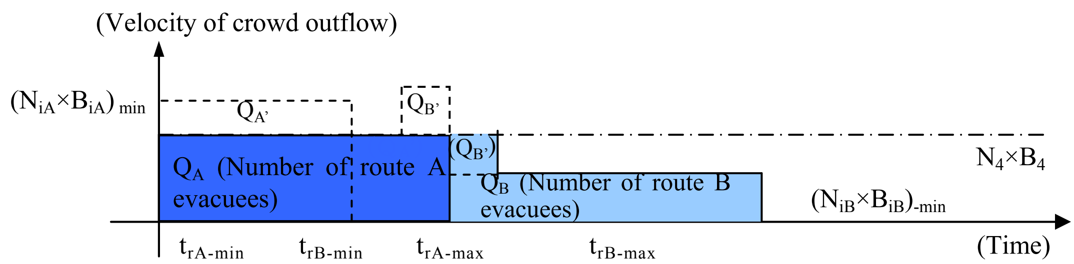
In this situation as well, there are three cases as shown in **Fig. 29.18** according to the difference in time taken to reach the ticket barrier between the two routes.

[1] Case where no queue forms because of a large difference in ticket barrier passing time of the first evacuee between the two routes

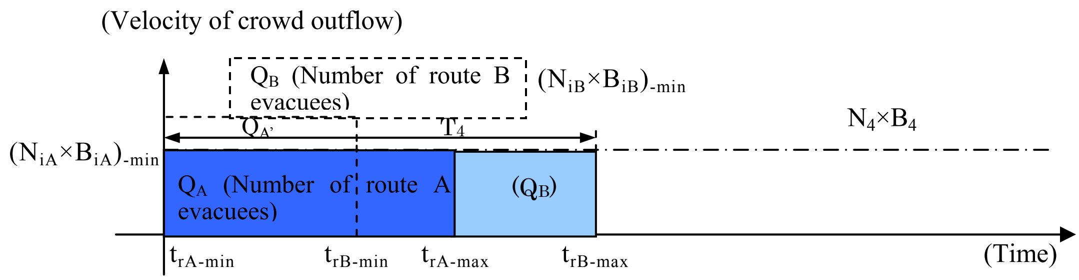
i) Where evacuees in the two routes do not meet at the ticket barrier



ii) Where evacuees in the two routes meet at the ticket barrier



[2] Case where a queue forms because of a small difference in ticket barrier passing time of the first evacuee between the two routes



N_4 x B_4 : Velocity of crowd outflow at ticket barrier
$(N_{iA}$ x $B_{iA})_{-min}$: Minimum velocity of route A crowd outflow
$(N_{iB}$ x $B_{iB})_{-min}$: Minimum velocity of route B crowd outflow
t_{rA-min} : Time from start of evacuation to first route A evacuee passing ticket barrier
t_{rB-min} : Time from start of evacuation to first route B evacuee passing ticket barrier
t_{rA-max} : Time from start of evacuation to last route A evacuee passing ticket barrier
t_{rB-max} : Time from start of evaluation to last route B evacuee passing ticket barrier
$Q_{A'}$, $Q_{B'}$: Number of evacuees held at ticket barrier
T_4 : Queuing time at ticket barrier

Fig. 29.18 Ticket barrier passing time in case of N_4 x B_4 < $(N_{iA}$ x $B_{iA})_{-min}$

In case [1], the time when the last evacuee passes the ticket barrier that is the route merging point is the same as that in case (1). In case [2], however, it necessary to take the queuing time at the ticket barrier into account, that is, the time $t_{rA\text{-}min}$ when first route A evacuee passes the ticket barrier plus the holding T_4 at the ticket barrier. T_4 is obtained from the following equation:

$$T_4 = Q / (N_4 \times B_4)$$

Accordingly, the value of ($t_{rA\text{-}min} + T_4$) or $t_{rB\text{-}max}$, whichever is the larger, is the time when the last evacuee passes the ticket barrier that is the route merging point.

(5) How to check the queuing space

An average station equipped with fire doors or shutters at the bottom of platform stairways has sufficient space beyond the fire doors or shutters so that the queue of evacuees does not reach as far as the fire door or shutter.

If the queue of evacuees could reach the first door or shutter as shown in **Fig. 29.19**, it is necessary to check and determine whether there is sufficient queuing space beyond the fire door or shutter as described below.

Also, taking into account the possibility of the queue reaching as far as the fire door or shutter as well, the evacuation completion time (time until all evacuees have passed the fire door or shutter) will be calculated to check the evacuation safety. By using this check method, it is possible to evaluate the effect of reducing the evacuation completion time (time when all evacuees have passed the fire door or shutter), etc. and to reflect it in the design of smoke exhaust facilities.

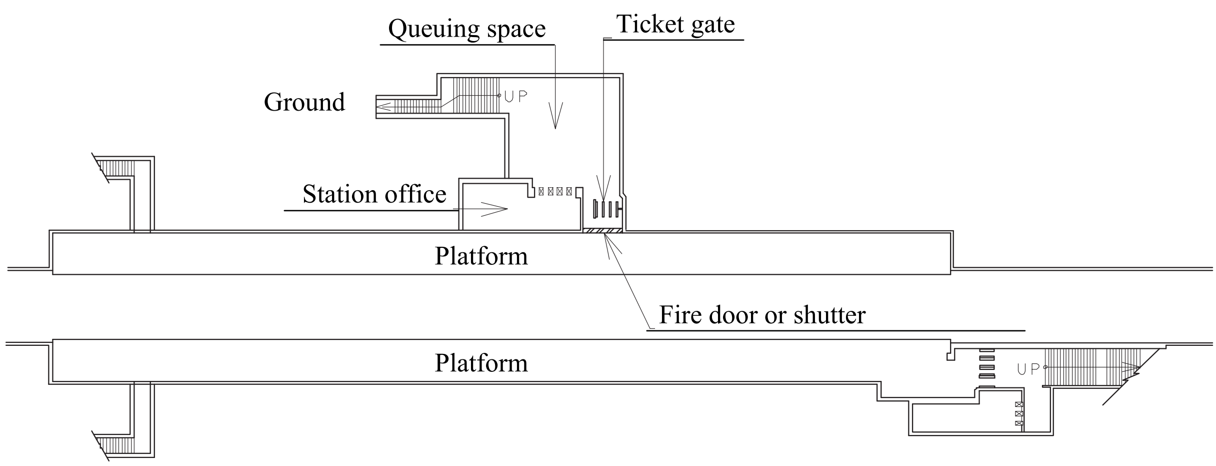


Fig. 29.19 Typical station where passenger queue could reach fire door or shutter

The following is the case where a queue from the origin can affect the fire door or shutter.

Maximum number of persons held: n_{max} (persons) ≥ A/a (persons)

n_{max} : Maximum number of persons held

$n_{max} = Q - V \times t$

Q : Number of evacuees (persons) passing origin of queue

V : Velocity of crowd outflow (persons/sec) at origin of queue

$V = N \times B$

N : Flowout coefficient of crowd outflow (persons/m/sec)

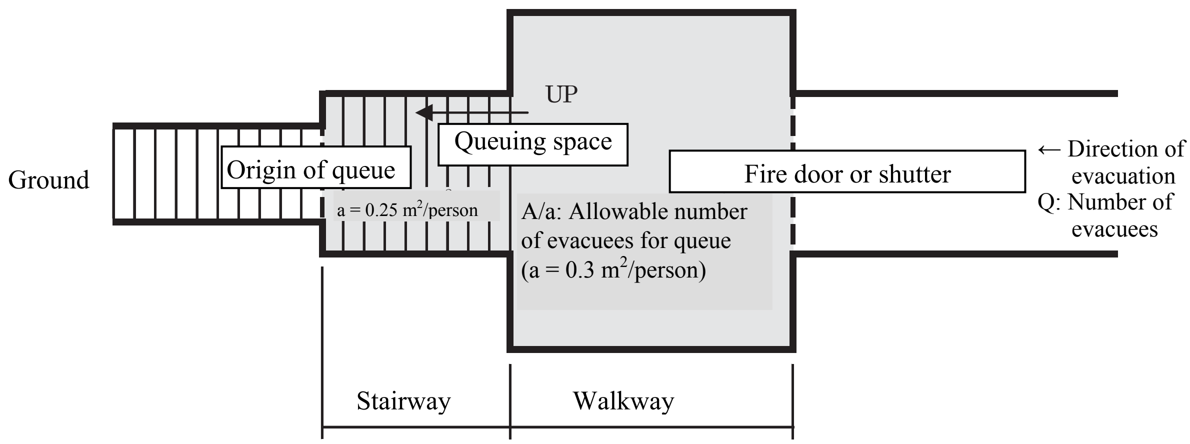
B : Effective width of stairway, etc.

t : Time from arrival of first evacuee to arrival of last evacuee (sec)

A : Effective floor area of space used as shelter (m^2)

a : Area required to accommodate the queue (m^2/person)

For the area required to accommodate the queue (m^2/person), 0.25 m^2/person should be used for stairways and 0.3 m^2/person for walkways, by referring to the public notice pursuant to the Building Standard Law (2000 Ministry of Construction Public Notice No. 1441 on Specification of Calculation Methods, Etc. Pertaining to Verification Methods for Determining Safe Evacuation of a Floor).



* Shaded portion is to be used as accommodation space for queue

The evacuation completion time (all evacuees have passed the fire door or shutter) is the time when [number of evacuees passing the origin of the queue (Q) – allowable number of persons (A/a) in the queue accommodation space] persons have passed the origin of the queue.

(6) Notes on calculating the evacuation time

Before calculating the evacuation time, it is necessary to measure the widths of places where a queue of evacuees is likely to form such as stairways and ticket barriers, as well as walking distances within the underground station. Factors that influence the calculation of evacuation time are given below, and must be taken into consideration when conducting the measurements.

[1] The minimum walking distance on the platform shall be the horizontal distance from the bottom of the platform stairway (or ticket barrier) to the nearest car door with the train in the normal stop position. If the number of cars and the position of car doors differ among trains, the maximum horizontal distance from the bottom of the platform stairway (or ticket barrier) to the nearest car door shall be taken.

[2] The walking distance between the stairway and ticket barrier or between stairways shall be the center-to-center distance. (See **Fig. 29.20** on the next page.)

[3] The walking distance between the ticket barrier and exit stairway at a station with two or more exit stairways shall be the maximum distance in principle. (See **Fig. 29.20** on the next page.)

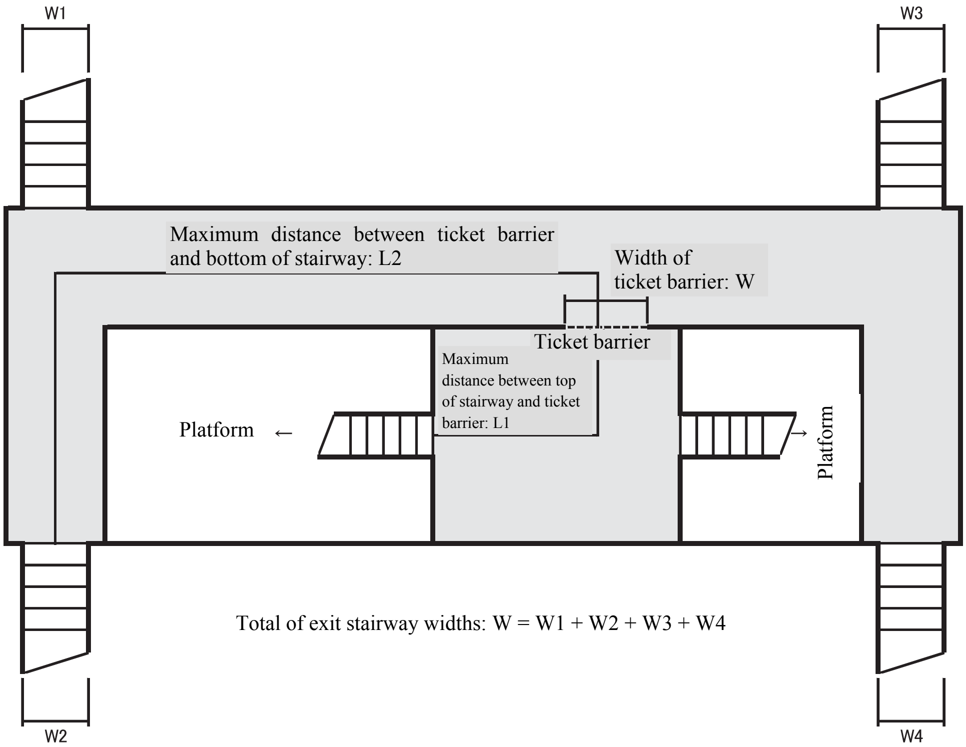
If the total of the velocities of crowd outflow on exit stairways does not meet the minimum velocity of crowd outflow in the evacuation route even excluding the effective width of the exit stairway farthest from the ticket barrier, that is, if the queuing time in the evacuation route cannot be determined at the bottom of the exit stairway farthest from the ticket barrier even when the effective width of that exit stairway is excluded, the evacuation time may be calculated using the next farthest walking distance to the next farthest exit stairway.

[4] The effective width between the insides of handrails shall be taken as the width of the stairway. For a stairway that changes in width midway, the smallest width shall be taken. For escalators, only the effective width of escalators out of operation and escalators that move in the evacuating direction (usually the upward direction) during the morning rush hour shall be added. (If an escalator is included in the evacuation route, measures to prevent people from descending the escalator while it is out of operation is a prerequisite for such escalator.)

[5] The width of the ticket barrier shall the total of the widths of openings that evacuees can pass through, such as the effective widths of automatic ticket-reading gates.

[6] The evacuation route involved in the evacuation time calculation shall be selected by taking into consideration the certainty of route availability, zone for boarding and alighting passengers during rush hour, etc.

Station with one ticket barrier



Station with two ticket barriers

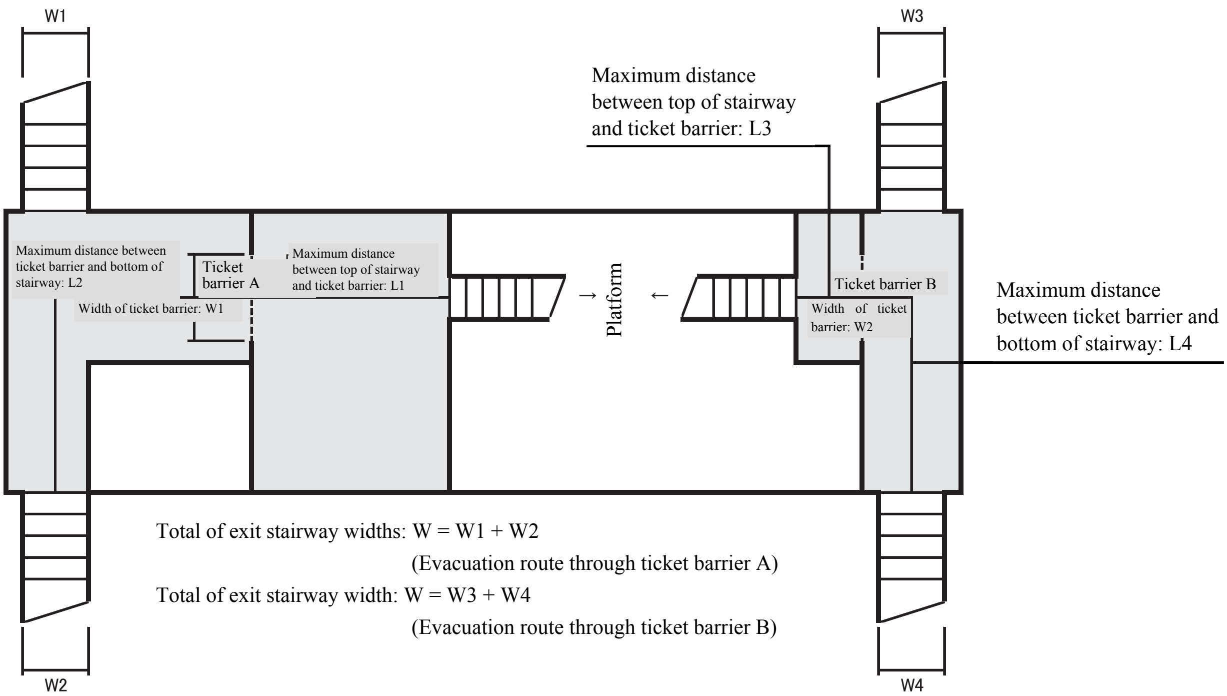


Fig. 29.20 Calculation of walking distance

(Reference) Setting the number of evacuees

The number of evacuees used for evacuation safety verification was set according to the results of fact-finding investigations of passenger load factor and numbers of on-platform passengers during rush hour in an underground railway and passenger boarding and alighting surveys at various stations of the Tokyo Metro Ginza Line shown in **Table 29.13.**

Table 29.13 Reference Data Used for Setting the Number of Evacuees

Unit: Passenger load factor (%)

Type of station			Passengers in train on fire (A)	Passengers on platform (from train on fire) (B)	Passengers on platform (from train in opposite direction) (C)	(B)+(C)	(A) +(B)+(C)	Station name
Assumed fire	Ordinary fire		Train			Concourse station store	Platform store	
	Large fire					Concourse station store	Train Platform store	
Standard station	Setting for ordinary station (Packed train + cars with normal number of boarding and alighting passengers)		200	50	25	75	275	
		Fact-finding survey	166	19	6	25	191	Kanda
			158	27	6	33	191	Mitsukoshimae
			175	18	7	25	200	Kyobashi
			208	23	18	41	249	Toranomon
			216	44	13	57	273	Tameike-sanno
			166	25	7	32	198	Aoyama-itchome
	Setting for terminal station (Packed train + cars with large number of boarding and alighting passengers)		200	100	50	150	350	
		Fact-finding survey	130	94	41	135	265	Nihombashi
			138	89	37	126	264	Shinbashi
			177	79	22	101	278	Akasaka-mitsuke
			118	103	11	114	232	Omote-sando
			33	121	0	121	154	Shibuya
Special station	Intermediate station with first train departure (Packed train + cars with large number of boarding and alighting passengers)		(200)	(100) +50	(50)	(150) +50	(350) +50	
		Fact-finding survey	77	154	52	206	283	Ueno

* Fact-finding data of Tokyo Metro Ginza Line shown are survey results obtained during morning rush hour. Stations at which train occupancy is more than 150% or passengers boarding and alighting there account for more than 75% were identified and the values measured at such stations with respect to the top, second and third most packed trains were averaged.

Table 29.14 shows the results of questionnaires conducted on the congestion rate between underground stations.
In three large city districts, there is no section in which the congestion rate during one rush hour exceeds 200%. In other areas, there is no section in which the congestion rate exceeds 150%. Accordingly, in the evacuation safety verification, the number of evacuees in areas other than the three large city districts was set at 75% of the value set for the three large city districts (150%/200% in percentage of congestion).

Table 29.14 Congestion between Sections of Underground Railways

Railway operator	Line and Section	Congestion (%)
Hokkaido Railway Company	Chitose Line (New Chitose Airport – Minami Chitose)	93.0
	Chitose Line (Minami Chitose – New Chitose Airport)	99.0
Sapporo City Transportation Bureau	Nanboku Line (Nakajima Koen – Susukino)	101.8
	Tozai Line (Kikusui – Bus Center Mae)	139.9
	Toho Line (Kita Jusan Jo Higashi – Sapporo)	124.8
Sendai City Transportation Bureau	Namboku Line (Kita-sendai – Kita-yobancho)	169.6
Tokyo Metro Co., Ltd.	Ginza Line (Akasaka-mitsuke – Tameike-sanno)	168.0
	Marunouchi Line (Shin-otsuka – Myogadani)	157.0
	Hibiya Line (Minowa – Iriya)	172.0
	Tozai Line (Kiba – Monzen-nakacho)	197.0
	Chiyoda Line (Machiya – Nishi-nippori)	189.0
	Yurakucho Line (Higashi-ikebukuro – Gokokuji)	176.0
	Hanzomon Line (Shibuya – Omote-sando)	174.0
	Namboku Line (Komagome – Hon-komagome)	140.0
Tokyo Metropolitan Government Bureau of Transportation	Toei Asakusa Line (Oshiage – Honjo Azumabashi)	134.0
	Toei Mita Line (Nishi Sugamo – Sugamo)	130.7
	Toei Shinjuku Line (Shinjuku – Shinjuku 3-Chome)	121.5
	Toei Oedo Line (Nakai – Higashi Nakano)	141.5
Transportation Bureau, City of Yokohama	Blue Line (Bandobashi – Isezaki-chojamachi)	150.0
Seibu Railway Co., Ltd.	Seibu-Yurakucho Line (Shin-Sakuradai – Kotake-Mukaihara)	83.0
Keisei Electric Railway Co., Ltd.	Oshiage Line (Keisei Hikifune – Oshiage)	155.0
Keio Corporation	Keio Line (Hatsudai – Shinjuku)	125.0
Odakyu Electric Railway Co., Ltd.	Odawara Line (Setagaya-daita – Shimokitazawa)	189.0
Keihin Electric Express Railway Co., Ltd.	Honsen line (Shinagawa – Sengakuji)	123.0
Tokyu Corporation	Den-en-toshi Line (Ikejiri-ohashi – Shibuya)	198.0
Sagami Railway Co., Ltd.	Sotetsu main line (Yamato)	130.0
Hokuso Railway Co., Ltd.	Hokuso Kodan Line (Yagiri – Shin Shibamata)	136.6

Railway operator	Line and Section	Congestion (%)
Toyo Rapid Railway Co., Ltd.	Toyo Rapid Line (Higashi Kaijin – Nishi Funabashi)	94.2
Narita Airport Rapid Railway Co., Ltd.	Narita Airport Line (Keisei Narita – Airport Terminal 2)	94.0
Tokyo Waterfront Area Rapid Transit, Inc.	Rinkai Fukutoshin Line (Oimachi – Shinagawa Seaside)	93.6
Saitama Railway Corporation	Saitama Kohsoku Railway Line (Kawaguchimotogo – Akabaneiwabuchi)	89.0
Nagano Electric Railway Co., Ltd.	Nagano Line (Hongo – Zenkohji Shita)	149.6
Transportation Bureau City of Nagoya	No. 1 Line (Higashiyama Line) (Nagoya – Fushimi)	158.0
	No. 2 Line (Meijo Line) (Kanayma – Higashi Betsuin)	141.0
	No. 3 Line (Tsurumai Line) (Kawana – Gokiso)	146.0
	No. 4 Line (Nishi Takakura – Kanayama)	72.0
	No. 6 Line (Sakura-dori Line) (Kokusai Center – Marunouchi)	127.0
Nagoya Railroad Co., Ltd.	Nagoya Line (Sanno – Sako)	137.0
West Japan Railway Company	Tozai Line (Kyobashi – Kitashinchi)	94.0
Osaka Municipal Transportation Bureau	Midosuji Line (Namba – Shinsaibashi)	177.1
Kyoto Municipal Transportation Bureau	Karasuma Line (Kyoto – Gojo)	138.7
Kintetsu Corporation	Namba Line (Uehonmachi – Nipponbashi)	125.0
	Osaka Line (Tsuruhashi – Uehonmachi)	101.0
	Nara Line (Shin-Omiya – Nara)	32.0
	Nagoya Line (Komeno – Nagoya)	148.0
Hankyu Corporation	Kyoto Line (Saiin – Omiya)	79.5
Hanshin Electric Railway Co., Ltd.	Main line (Noda – Fukushima)	109.1
Sanyo Electric Railway Co., Ltd.	Main line (Nishidai – Itayado)	64.0
Kobe Electric Railway Co., Ltd.	Arima Line (Nagata – Minatogawa)	123.0
Kobe Rapid Transit Railway Company, Limited	Tozai Line (Shinkaichi – Kosoku Kobe)	83.2
	Nanboku Line (Minatogawa – Shinkaichi)	91.6
Kita-Osaka Kyuko Railway Company, Limited	Nanboku Line (Senri-chuo – Momoyama-dai)	67.7
Hiroshima Rapid Transit Co., Ltd.	Hiroshima Shin-Kotsu No. 1 Line (Hondori – Johoku)	144.0
Fukuoka City Transportation Bureau	Kuko Line (No. 1 Line) (Ohorikoen – Akasaka)	142.0
Kobe City Transportation Bureau	Seishin-Yamate Line (Myohoji – Itayado)	155.8
	Kaigan Line (Komagabayashi – Karumo)	70.4

*Shaded parts are congestion exceeding 150%.

(7) How to check the evacuation safety

The calculated evacuation time at each station will be used to check the evacuation safety at the station.

In the case of an ordinary fire, as is the case with the standards established in 1975, the checking is done according to the consistency of smoke (depreciation coefficient) on the platform as calculated from a model of smoke spreading evenly in the fire-point block or the volume of smoke spread in the concourse.

In the case of a large fire, the checking will be done according to the height from the floor surface to the bottom of the lower smoke layer as calculated from a tow-layer zone model of smoke spreading and accumulated in the upper layer.

1) Checking of ordinary fire at a platform

The consistency of smoke Cs at the evacuation completion time shall be calculated using the applicable equation below with the volume of the fire-point block at the platform set in accordance with existing relevant standards, to confirm that it is below 0.1 (1/m), which corresponds to the unobstructed view distance (= 20 m) necessary for evacuees.

Incidentally, although it has been confirmed that an unobstructed view can be obtained even if the smoke consistency is 0.2 (1/m) or so thanks to improved ease of recognition of evacuation guide signs and experiments of bodily sensation of smoke consistency, a smoke consistency of 0.1 (1/m) was applied to ensure evacuation safety for passengers as is the case with the standards established in 1975.

[1] Car fire

Where evacuation completion time is less than 7 minutes

$Cs=21\cdot(1-e^{-Ve\cdot t/V})/Ve$

Where evacuation completion time exceeds 7 minutes

$Cs=(66\cdot V\cdot e^{-Ve\cdot(t-7)/V}-21\cdot Ve\cdot e^{-Ve\cdot t/V}+66\cdot Ve\cdot t-441\cdot Ve-66V)/Ve^{2}$

[2] Station stall fire

Where evacuation completion time is less than 10 minutes

$Cs=2.1\cdot(Ve\cdot t-V+V\cdot e^{-Ve\cdot t/V})/Ve^{2}$

Where evacuation completion time is 10 to 11 minutes

$Cs=\{(24\cdot V-21\cdot Ve)\cdot e^{-Ve\cdot(t-10)/V}+24\cdot Ve\cdot t-198\cdot Ve-26.1\cdot V+2.1\cdot V\cdot e^{-10\cdot Ve/V}\}/Ve^{2}$

Where evacuation completion time exceeds 11 minutes

$Cs=\{(1.8\cdot V-45\cdot Ve)\cdot e^{-Ve\cdot(t-11)/V}+1.8\cdot Ve\cdot t+91.2\cdot Ve-27.9\cdot V+2.1\cdot V\cdot e^{-10\cdot Ve/V}$
$+(24\cdot V-21\cdot Ve)\cdot e^{-Ve/V}\}/Ve$

Cs : Consistency of smoke (1/m)
V : Fire-point block volume or smoke spread volume (m^3)
Ve : Ventilation rate of smoke exhaust facility (m^3/min)
t : Evacuation completion time (min.)

A smoke exhaust facility shall be installed on the platform which is capable of exhausting more than 5,000 m^3/h against a fire-point block volume taking into account the minimum amount of exhaust specified in the standards established in 1975 (in case the fire-point block volume is more than 1,114 m^3, the required number of times of ventilation per hour is 5 times).

As the downward connection walkway from the platform is used as an evacuation route, if there are hanging walls, etc. between the railway tracks, the range of the fire-point block used for checking a car fire shall be as far as the location of the hanging walls and the opposite railway space cannot be regarded as a fire-point block. In case of a platform fire, if the ceiling of a platform surrounded by hanging walls that project downward between the platform and railway track has no smoke outlet, the consistency of smoke on the platform may increase or the smoke fall time may become shorter than assumed. If there is a smoke outlet in the ceiling, smoke can be removed effectively, so hanging walls will need to be installed, depending on the method of smoke exhaust including the structure of the station, direction of air current when smoke is exhausted, position of smoke outlet and so forth.

2) Checking an ordinary concourse fire
The required smoke spread volume V_o in the concourse that provides smoke consistency Cs = 0.1 (1/m) shall be obtained from the equation below to check that the smoke spread volume V in the concourse calculated separately according to evacuation time exceeds V_o at the evacuation end time.

Where evacuation end time is less than 10 minutes

$$V_o = 10.5\, t^2$$

Where evacuation end time is 10 to 11 minutes

$$V_o = 120t^2 - 2{,}190t + 10{,}950$$

Where evacuation end time exceeds 11 minutes

$$V_o = 9t^2 + 252t - 2{,}481$$

V_o : Required volume of smoke spread (m^3)
t : Evacuation end time (min.)

(Reference) Setting of allowable smoke consistency in ordinary fire

For passengers to evacuate safely through fire smoke, they must be able to recognize the evacuating direction with the aid of guide lights, etc. and not have to reduce their walking speed due to the smoke.
Since it is known that the consistency of smoke (depreciation coefficient) that does not affect the passenger walking speed is less than 0.2 (1/m) as shown in **Fig. 29.21** and that the unobstructed view distance necessary for unspecified persons (visitors to department stores and underground shopping malls) to evacuate is generally 15 to 20 m with reflector-type signs as the basic guiding aid, the Fire Fighting Standards for Underground Stations established in 1975 specify that the allowable consistency of smoke be 0.1 (1/m) on the basis of **Fig. 29.22**.
The allowable smoke consistency in an ordinary fire has proved to provide a sufficient unobstructed view even it is about 0.2 (1/m), thanks to improved ease of recognizing evacuation guide signs and experiments of bodily sensation of smoke consistency, so it shall be set at 0.1 (1/m) as is the case with the 1975 fire fighting standards to ensure the evacuation safety of passengers.

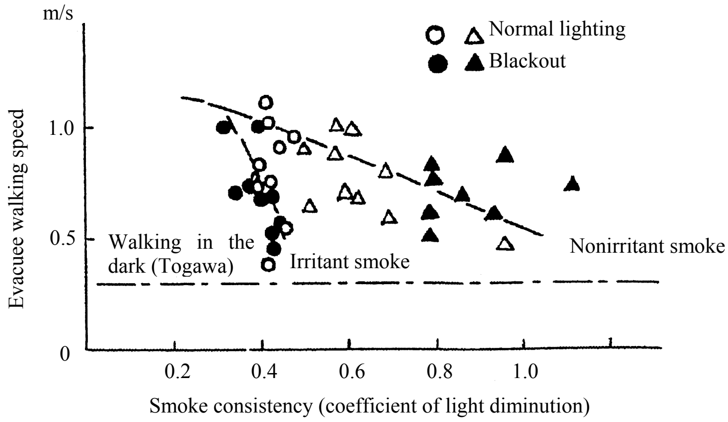


Fig. 29.21 Walking speed and smoke consistency in irritant/nonirritant smoke

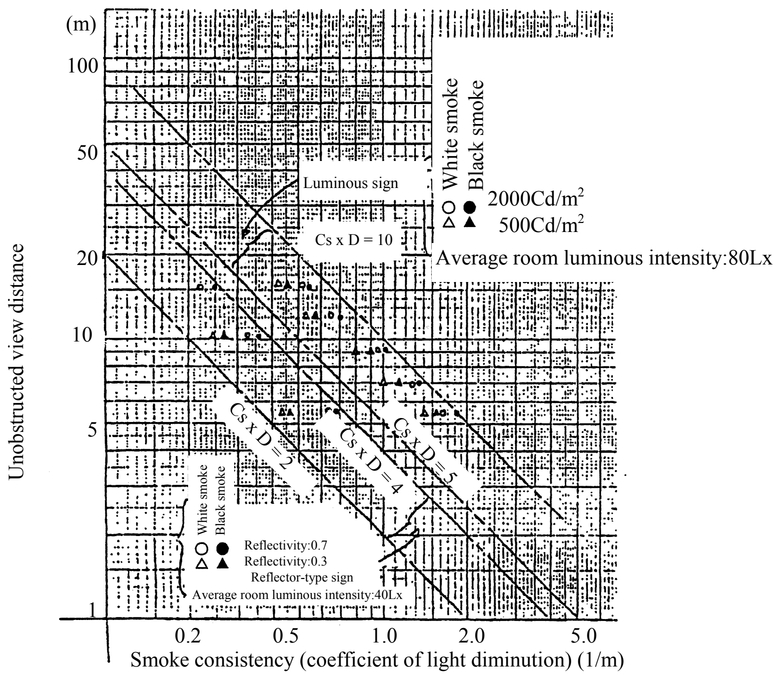


Fig. 29.22 Maximum visible distance of commercial guide signs in smoke

(Extract of fiscal 1977 Subway Smoke Exhaust System Optimization Study Report released by the Ministry of Transport in March 1978)

3) Checking the smoke fall time (in case of large fire)
The time t_o taken for the smoke of a large fire to fall to 2 m, the level which hinders evacuation, shall be obtained from the equation below to check that it is longer than the evacuation end time. Incidentally, the outward flow rate of smoke used for checking car fires and the amount of smoke generated, etc. used for checking concession store fires were set based on car combustion experiment data and the two-layer zone smoke flow model.

[1] Car fire and station store fire at platform

$t_o=V_E/(V_s-Ve')$ $V_E=(A_E-Av')\times L$

$Ve'=Ve\times(A_E-Av')/(A_o-Av)$

where $t_o = \infty$ if $V_s - Ve' \leq 0$

- V_E : Effective volume (m^3) of entire platform at 2.0 m or higher than platform floor surface
- V_s : Outward flow rate of smoke/generation of smoke, etc. at 300 m^3/min
- Ve' : Effective smoke exhaust rate (m^3/min) with respect to effective volume V_E of entire platform
- A_E : Sectional area (m^2) rectangular to track of platform at 2.0 m or higher than platform floor surface excluding stairway, columns, etc. where smoke does not diffuse
- Av' : Sectional area (m^2) of car at 2.0 m or higher than platform floor surface
- L : Overall length of platform (m)
- Ve : Ventilating capacity (m^3/min) of smoke exhaust facility at entire platform
- A_o : Sectional area (m^2) rectangular to track in fire-point block volume calculation
- Av : Sectional area (m^2) of car (including underfloor portion)

Since the fire characteristics model assumes 5.0 MW of heat generation and 3 minutes of burning time, smoke will not be generated anew after three minutes of burning. However, as smoke continues to flow out due to the difference in pressure between the car and the platform, it was considered that the outflow of smoke would continue after the end of burning.

[2] Concourse fire

$t_o=V'/(V_s-Ve')$ $V'=(Af-At)\times(H-2)$

$Ve'=Ve\times(H-2)/H$

where $t_o = \infty$ if $Vs - Ve' \leq 0$

Also, $t_o = \infty$ if $t_o \geq 3$ without a station store in the concourse.

- V' : Volume of smoke spread not taking into account the smoke exhaust facility ventilating capacity (m^3)
- V_s : Generation of smoke, etc. at 300 (m^3/min)
- Ve' : Effective smoke exhaust rate (m^3/min)
- Af : Floor area of concourse story (m^2)
- At : Area (m^2) where smoke does not diffuse (columns, etc.) in concourse
- H : Concourse ceiling height (m)
- Ve : Ventilating capacity of concourse smoke exhaust facility (m^3/min)

It is advisable that t_o at an underground station where a complicated flow of smoke is anticipated, such as where the platform ceiling is open and is at the same height as the concourse ceiling, should be calculated separately according to the calculation of Predicting Smoke Transport Based on Two-Layer Zone Model, etc.
Also, for checking on a large fire, the height of floor to ceiling is assumed to be less than 4.5 m. In the case of a larger space where the generation of smoke V_s is likely to be larger than 300 m^3/min due to the smoke spreading, it is necessary to adequately evaluate the flow of smoke, etc. separately using the calculation of Predicting Smoke Transport Based on Two-Layer Zone Model, etc.

(Reference) Outward flow rate of car fire smoke in checking the evacuation safety in a large fire

When checking the evacuation safety at a platform in an assumed large-origin car fire by the simplified method, it is necessary to use not the generation of smoke, etc. in the car but the outward flow rate of smoke to the platform from the car.
As the fire characteristics model of an assumed large-origin car fire assumes heat generation of 5.0 MW, burning area of 5 m^2 and burning time of 3 minutes, smoke will not be generated anew after 3 minutes of burning, but smoke will continue to flow out from the car to the platform. This phenomenon has been observed in car burning experiments; a continuing outflow of smoke at approximately 2 m^3 per second even 10 minutes after the fire started.
This is assumed to be because, owing to a difference in gas density due to the difference in smoke layer thickness and temperature between the fire starting car and the platform, a difference in pressure occurs near the door, which is an opening between the two spaces, as shown in **Fig. 29.23** and remains there even after the burning ends.
Using the fire characteristics model, the flow of smoke was calculated for the car and platform shown in Fig. 29.23 according to the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002). As shown in **Fig. 29.24** and **Fig. 29.25**, the results indicate that for the platform, the smoke layer falls even after 3 minutes of burning due to the outflow of smoke from the car.
In view of these results, the outward flow of smoke from the car on fire in the simplified checking of evacuation safety in a large fire was set as 300 m^3 per minute, which is 60 times the maximum value of approximately 5 m^3/second based on car burning experiment data and calculation by the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002), and is assumed to remain after 3 minutes of burning.

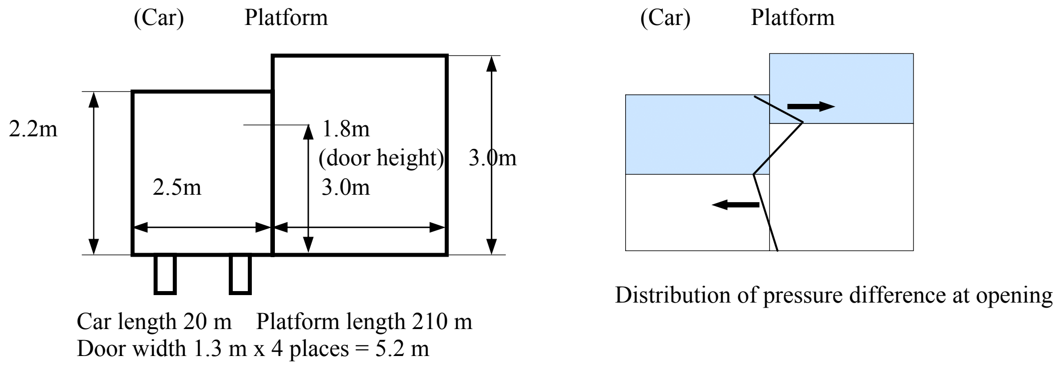


Fig. 29.23 Distribution of pressure difference at opening in two-layer zone environment

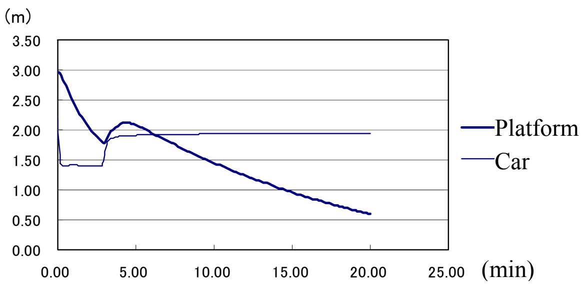


Fig. 29.24 Change of smoke layer bottom height

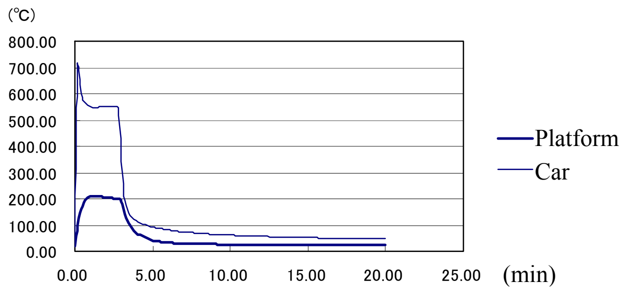


Fig. 29.25 Change of smoke layer temperature

(Reference) Simplified method for checking the evacuation safety in a large fire

(1) Checking the evacuation safety in a large fire by the simplified method

The evacuation safety in a large fire, such as an incendiary fire, at an underground station is checked using the time to taken for the smoke to fall to a level that hinders evacuation based on a two-layer zone model of smoke spreading upward and accumulating.

While it is possible to calculate the height of the smoke layer from the floor surface at the evacuation end time using the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002) developed mainly by the Building Research Institute (BRI) of the Ministry of Construction, a difference may arise in the accuracy of the check among railway operators depending on how the program is used. To avoid this risk, the simplified method described below has been developed for checking the evacuation safety in a large fire without using the program. However, when calculating to at an underground station where a complicated movement of smoke is anticipated due to the platform ceiling being open and at the same level as the concourse ceiling or for other reasons, the program shall be used for detailed checks.

(2) Foundation for smoke outflow rate and generated volume of smoke, etc. (V_s)

The smoke outflow rate and generated volume of smoke, etc., V_s, for use in the simplified calculation were set at 300.0 m^3/min. in the case of both a car fire and a station store fire for the following reasons.

[1] Car fire

As the maximum value of smoke outflow rates measured in a car burning experiment was approximately 5.0 m^3/second and the maximum smoke outflow rate calculated using the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002) using the fire characteristics model (heat generation of 5.0 MW, burning area of 5 m^2 and burning time of 3 minutes) set based on the abovementioned experiment was also approximately 5.0 m^3/second, a value equivalent to 60 times the maximum flow rate was taken as a gas outflow for 1 minute.

[2] Station store fire

Using the fire characteristics model shown in **Fig. 29.26** determined based on a station store burning experiment, the generated volume of smoke, etc. was calculated using the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002). As a result, the maximum calculated value was approximately 5.0 m^3/second, so a value equivalent to 60 times the maximum value was taken as the generation of smoke, etc. for 1 minute.

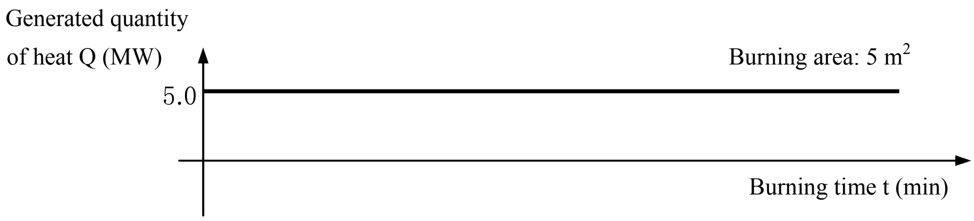


Fig. 29.26 Fire characteristics model of concession stand fire

(3) Comparison of check results between simplified method and calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002)

Table 29.15 compares the check results between the simplified method and calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002). The quantity of heat, etc. used in the program was based on the model in Fig. 29.28.

Table 29.15 Comparison of Check Results between Simplified Method and Calculation Program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002)

Station name (with or without station store)	Area of concourse (m^2)	Height of concourse ceiling (m)	Evacuation end time (min)	Smoke exhaust rate (m^3/min)		Time (min) required by smoke layer bottom to fall to 2.0 m above floor *Values in parentheses are the required smoke exhaust rate (m^3/min).	
						Simplified method	BRI2002
Station concourse A (without station store)	105.5	2.4	7.93	At present	120.0	0.15	0.16
				After improvement (proposed)	See left	3.01* <1,716>	20.00≥ <1,308>
Station concourse B (with station store)	649.4	2.44	3.91	At present	200.0	1.08	1.16
				After improvement (proposed)	See left	3.93 <1,260>	4.00 <1,144>

* At concourse without station store, as time t_o is calculated as $t_o \geq 3$ (min) and can be checked as $t_o = \infty$, improvement is possible.

The above shows that the check results by the simplified method are somewhat on the safe side compared with those obtained using the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002). Therefore, checking the evacuation safety in a large fire by using the simplified method poses no risk.

(Reference) Tow-layer zone smoke flow model

The two-layer zone smoke flow model is used to evaluate physical properties of a fire with respect to two smoke layers, i.e., an upper layer of high-temperature smoke and a lower layer of relatively low-temperature smoke as shown in **Fig. 29.27**, which are assumed to be present in the space inside the building when a fire breaks out, and is suitable for pre-calculation of the flow of smoke, such as accumulated smoke, in an early stage of the fire. This model represents data of smoke flow based on the following hypotheses.

[1] Any space in the building is filled with two layers (upper and lower) of smoke.
[2] The upper and lower layers of smoke are separated by a horizontal interface.
[3] Temperature, chemical concentration, etc. are evenly distributed inside each layer, thanks to active mixing.
[4] The transition of mass between the layers occurs only by fire plumes and opening jets.
[5] The transition of thermal energy between the layer is caused by the transfer of radiant heat from the surrounding walls and convective heat transfer, in addition to fire plumes and opening jets.
[6] Direct radiation of heat from the source of the fire is ignored.
[7] Spaces in the building remain constant in volume.
[8] Radiant heat transfer with other space layers is ignored.

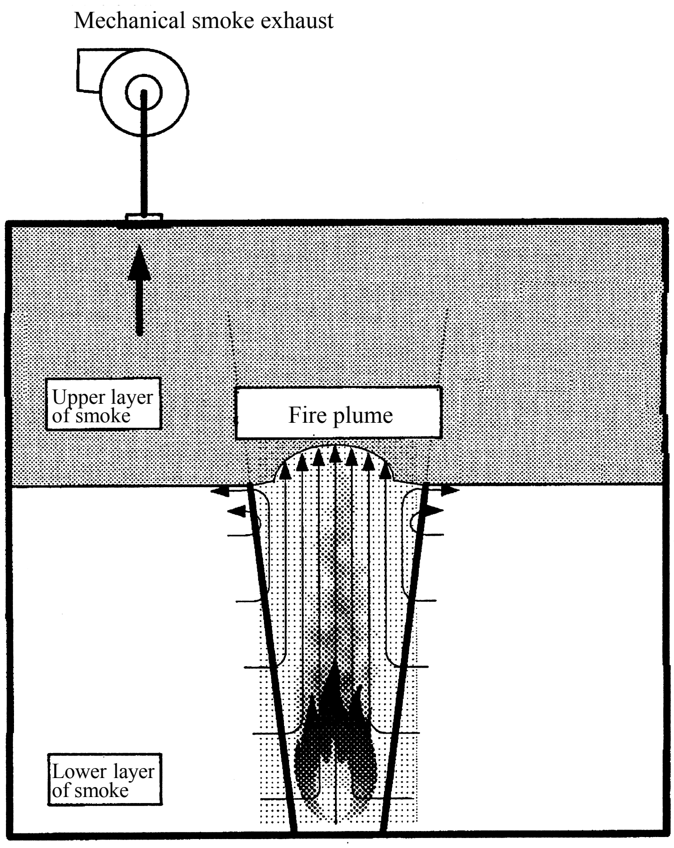


Fig. 29.27 Concept of layer zone smoke flow model

(Reference) Practical example of two-layer zone smoke flow model analysis

(1) Overview of calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002)

The calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model (BRI2002) (hereafter called "this program") is a modified version of the calculation program developed by the Building Research Institute of the Ministry of Construction as the leader in the general engineering development project of the Ministry of Construction (Development of Fire Protection Design Method for Buildings) (1982 – 1986) and is distributed by the Building Research Promotion Association. This program is extensively used for research on the characteristics of smoke flow in buildings and studies for practical smoke control plans for buildings and is applicable for pre-calculating smoke movement in such spaces as cars, platforms and concourses at an underground station.

The program can calculate predicted values for the height of the lower smoke layer (bottom height of smoke layer) in each room, the temperature of the upper smoke layer (smoke layer temperature) in each room, mass flow velocity of smoke at openings, etc. from various data about the building (areas and heights of various rooms, areas of openings between rooms, size of origin of fire, amount of smoke exhaust, etc.) at designated time intervals. Available as an .exe file, the program contains various pre-calculated values through integration of simultaneous differential equations, which are basic equations for the two-layer zone model, using the Runge-Kutta method.

(2) Usage of this program

1) Procedure

The procedure for using this program is outlined below.

[1] Various underground station-related data to be calculated are input in the formats given from the next page onward. Input text files are saved under the file name [INP.DAT] in the same folder as that of the program (BRI2002.EXE).

[2] The program (BRI2002.EXE) is executed.

[3] Predicted values are output to the same folder at designated time intervals as the following text files:

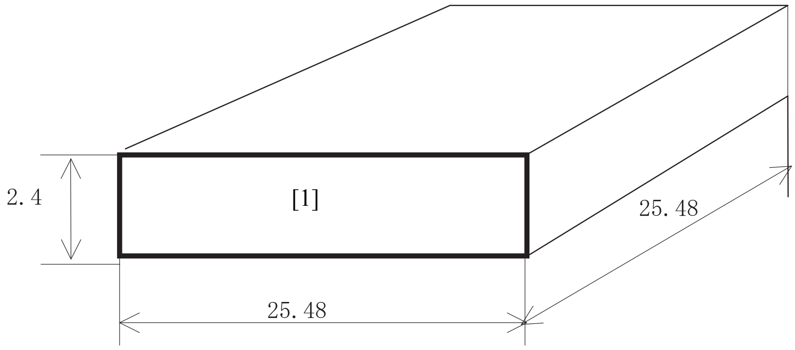
HEIGHT.DAT	: Thickness of lower layer (bottom of smoke layer)	(m)
TEMPSM.DAT	: Temperature of upper lower (smoke layer)	(°C)
TEMPAR.DAT	: Temperature of lower layer	(ºC)
FLOWRT.DAT	: Mass flow velocity at opening	(kg/s)
PRSROM.DAT	: Pressure in room at floor level	(Pa)
PRSDEF.DAT	: Pressure difference between upper and lower ends of opening	(Pa)
SMCEFF.DAT	: Mechanical smoke exhaust efficiency	
SIMPLE.DAT	: Simple output data (wall surface temperatures of upper and lower layers, typical chemical substance concentrations, etc.)	
DETAIL.DAT	: Detailed output data	

Incidentally, the time taken from running the calculation to outputting the files is approximately 1 minute for output data up to approximately 20 minutes from the start of fire. Also, output data can be freely processed using tabular calculation programs, etc.

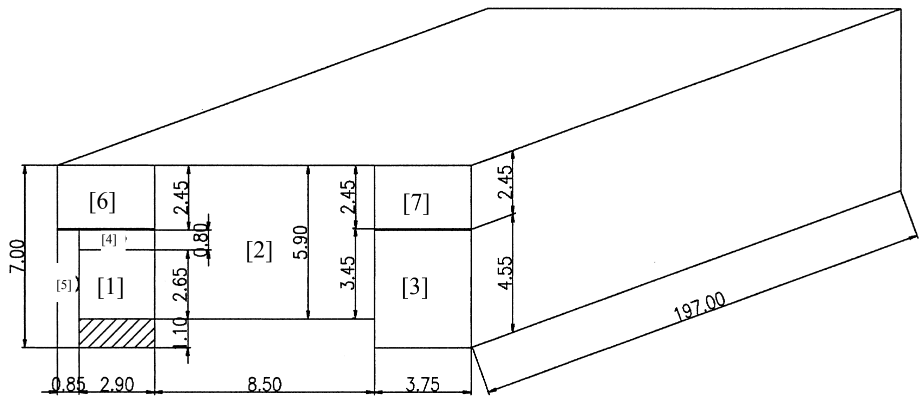
(3) Example of calculating the smoke fall time

Model	Smoke exhaust	Space	Time for smoke layer bottom to fall to 2.0 m above floor
Model 1	200 m^3/min	[1]	70 seconds
Model 2	0 m^3/min	[6], [7]	110 seconds

Model 1: Concourse station store fire
(Input data)
Area: 649 m^2
Ceiling height: 2.4 m
Smoke exhaust: 200 m^3/min



Model 2: Car fire at platform with open ceiling
(Input data)
Structural dimensions: As shown below
Smoke exhaust: 0 m^3/min



2.4 Checking the Evacuation Safety from Other Than a Fire

In an ordinary fire, even if the density of smoke has reached the allowable level of 0.1 (1/m), after 30 minutes to 1 hour the concentrations of toxic gases will have fallen considerably to below dangerous levels. Therefore, safety from toxic gases others than smoke is not checked.

In a large fire, lives will not be threatened unless smoke descends to the height of evacuees. Likewise, simulations, etc. have confirmed that, for the assumed heat generation, the effects of radiant heat will not hinder evacuation safety.

(Reference) Evacuation safety from radiant heat

(1) Calculation of radiant heat

Radiant heat to which an evacuee is exposed from a plane where smoke has evenly accumulated (infinite space) is given by the following equation.

$q = F \cdot \varepsilon \cdot E$

q: Radiant heat from plane (W/m^2)
F: Shape modulus (1.0 for an infinite space)
ε: Emissivity of plane (1.0 for a black body; 0.8 for ceiling surface with a safety margin. And 0.1 for smoke layer since it mostly consists of CO2 and water vapor.)
E: Radiant intensity (W/m^2)

$E = \sigma \cdot T^4$

σ: Stefan-Boltzmann constant (W/m^2k^4) 5.6696 $\times 10^{-8}$
T: Absolute temperature of plane (K)

(2) Allowable standard for safety from radiant heat

The safety of an evacuee from radiant heat can be checked by the following equation.

$\int I^2 dt \leq 10$ where $I = q - 2$ in case of $q > 2$
$I = 0$ in case of $q \leq 2$

Accordingly, if radiant heat to which the evacuee is exposed is 2 kW/m^2, the evacuee is considered to be safe, irrespective of exposure time.

As to radiant heat from the ceiling surface, if the surface temperature is 180°C, the radiant heat to which the evacuee is exposed is as calculated below and if it is lower than the ceiling temperature, the evacuee is considered to be safe from radiant heat.

$q=1.0\times0.8\times5.6696\times10^{-8}\times(180+273)^4\times10^{-3}=1.91(\ kW/m^2) \leq 2(\ kW/m^2)$

As to radiant heat from the smoke layer, if the smoke layer temperature is 490°C, the radiant heat to which the evacuee is exposed is as calculated below and if it is lower than the smoke layer temperature, the evacuee is considered to be safe from radiant heat.

$q=1.0\times0.1\times5.6696\times10^{-8}\times(490+273)^4\times10^{-3}=1.92(\ kW/m^2) \leq 2(\ kW/m^2)$

(3) Evacuation safety at underground station

With respect to a car fire and station store fire, the maximum temperatures of the ceiling surface and smoke layer as calculated by the calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model using applicable fire characteristics models are less than 120°C and less than 480°C respectively as shown in **Table 29.16**. Accordingly, the evacuee is considered to be safe from radiant heat.

Table 29.16 Calculations by calculation program of Predicting Smoke Transport Based on Two-Layer Zone Model

Assumed fire	Type of platform/concourse	Maximum ceiling surface temperature	Maximum smoke layer temperature
Car fire	Opposite platform (station A)	55°C (3.0 min.)	345°C (3.0 min.)
	Island platform (station B)	32°C (3.0 min.)	213°C (3.0 min.)
Station store fire	Opposite platform (station A)	118°C (15.0 min.)	479°C (0.16 min.)
	Island platform (station B)	63°C (15.0 min.)	319°C (0.16 min.)
	Concourse (1050 m^2 in floor area; 3 m in height)	56°C (15.0 min.)	288°C (0.16 min.)

Note: Values in parentheses are elapsed time after the start of fire at the point when the maximum temperature is reached.

Reference: General Fire Protection Design Methods for Buildings 1989 – National Land Development Engineering Research Center

3. Method for Calculating Required Volume of Smoke Exhaust

The required volume of smoke exhaust at a platform is calculated as follows.

1-track single type and 2-track island platforms

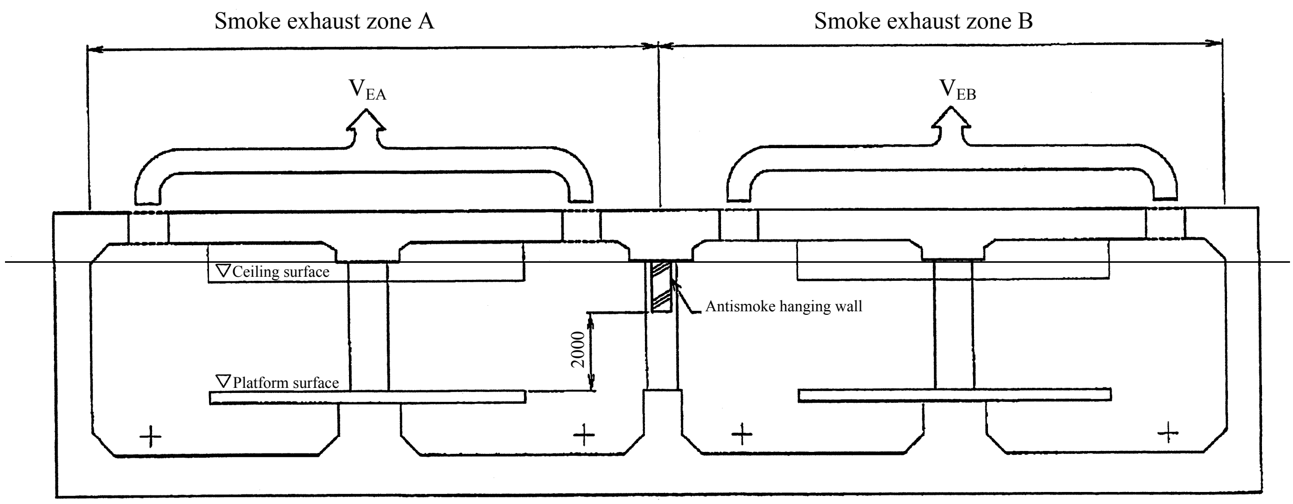
$$VE=Ve\times(V+20At)L/20V$$

2-track opposite platform

$$VE= Ve\times\{(V+20(At+Ah)\}L/20V$$

VE : Volume of smoke exhaust at platform (m^3/min)
Ve : Volume of smoke exhaust in fire-point block (m^3/min)
V : Volume of fire-point block (m^3)
At : Sectional area of car (m^2)
Ah : Sectional area of opposite platform outside of volume of fire-point block (m^2)
L : Length of platform (m)

Incidentally, in the case of platforms with three or more tracks, it is possible, as shown in **Fig. 29.28**, to plot smoke exhaust zones with antismoke hanging walls, etc. provided between tracks, to send station staff to the platform to quickly and accurately locate the fire, and to restrict smoke exhaust in the smoke exhaust zone where the fire started. In this case, the required volume of smoke exhaust from the platform may be set for each zone. It is necessary to thoroughly study and determine whether the smoke exhaust zones will properly work to let smoke out in the event of all assumed fires (car fire and station store fire).



Required volume of smoke exhaust for entire platform: V_E = Max (V_{EA}, V_{EB})

V_{EA}: Required volume of smoke exhaust for smoke exhaust zone A

V_{EB}: Required volume of smoke exhaust for smoke exhaust zone B

Fig. 29.28 Smoke exhaust at platform with smoke exhaust zones plotted

(Reference) Smoke exhaust facility at platform with three or more incoming train tracks

(1) Checking an ordinary fire

1) How to plot a fire-point block

The basic way of plotting a fire-point block is to combine an island platform and opposite platform fire-point blocks. At a platform with three or more incoming train tracks which has a larger space than the 2-track island type or 2-track opposite platform, since smoke will diffuse and passengers can easily judge the safe direction to escape, for example, the fire-point block shall be plotted in a space limited to hanging walls, etc. put up between the platform and track.

The range of the fire-point block, as shown in **Fig. 29.29 to 29.31**, shall be from the car on fire and the platform adjoining the car on fire to the place where the flow of smoke is obstructed, such as a lower ceiling. Also, hanging walls put up between tracks may be assumed to obstruct the flow of smoke.

2) How to set the volume of smoke exhaust

Assuming that the car on fire could be on any of the tracks, the range of the fire-point block in all possible cases will be set. As is the case with the ordinary 2-track island type and 2-track opposing type platforms, the volume of smoke exhaust including the volume of the entire station shall be set based on the amount of smoke exhaust per volume of the fire-point block.

3) Miscellaneous

The positions of smoke outlets are crucial for effectively exhausting smoke, and must be installed taking into account the station structure, flow of passengers, etc.

If smoke outlets are constructed so that concentrated smoke exhaust at the origin of the fire is allowed by means of a damper or the like, it is not necessary to include the whole station in the volume of smoke exhaust. The smoke exhaust zone in such a case can be assumed as shown in Fig. 29.29, where hanging walls must satisfy the smoke fall height used in checking a large fire.

(2) How to check a large fire

Smoke in a large fire tends to accumulate in the upper layer. In the case of a station with three or more tracks, while it has a larger space than an ordinary station and the diffusion of smoke is obstructed by hanging walls, etc., it can be assumed that smoke accumulates in the whole of it. However, as there are certain restrictions on the perpendicular-to-track section of the fire-point block used for checking an ordinary fire taking into account obstructions to the flow of smoke such as hanging walls, a large fire shall be checked with respect to the space containing the entire length of the platform as well based on the fire-point block used for checking an ordinary fire.

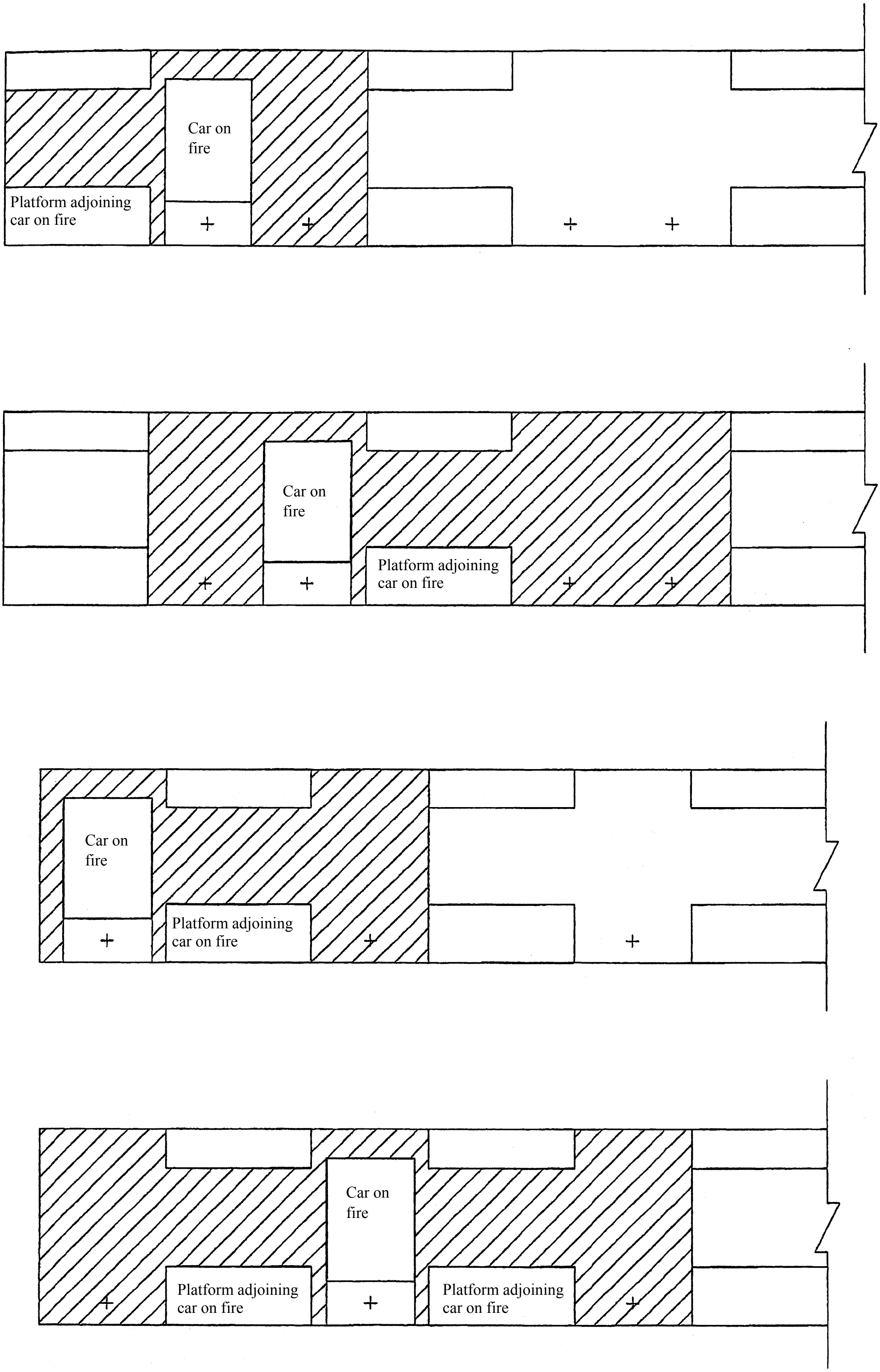


Fig. 29.29 Fire-point block of platform with three or more incoming train tracks (1)

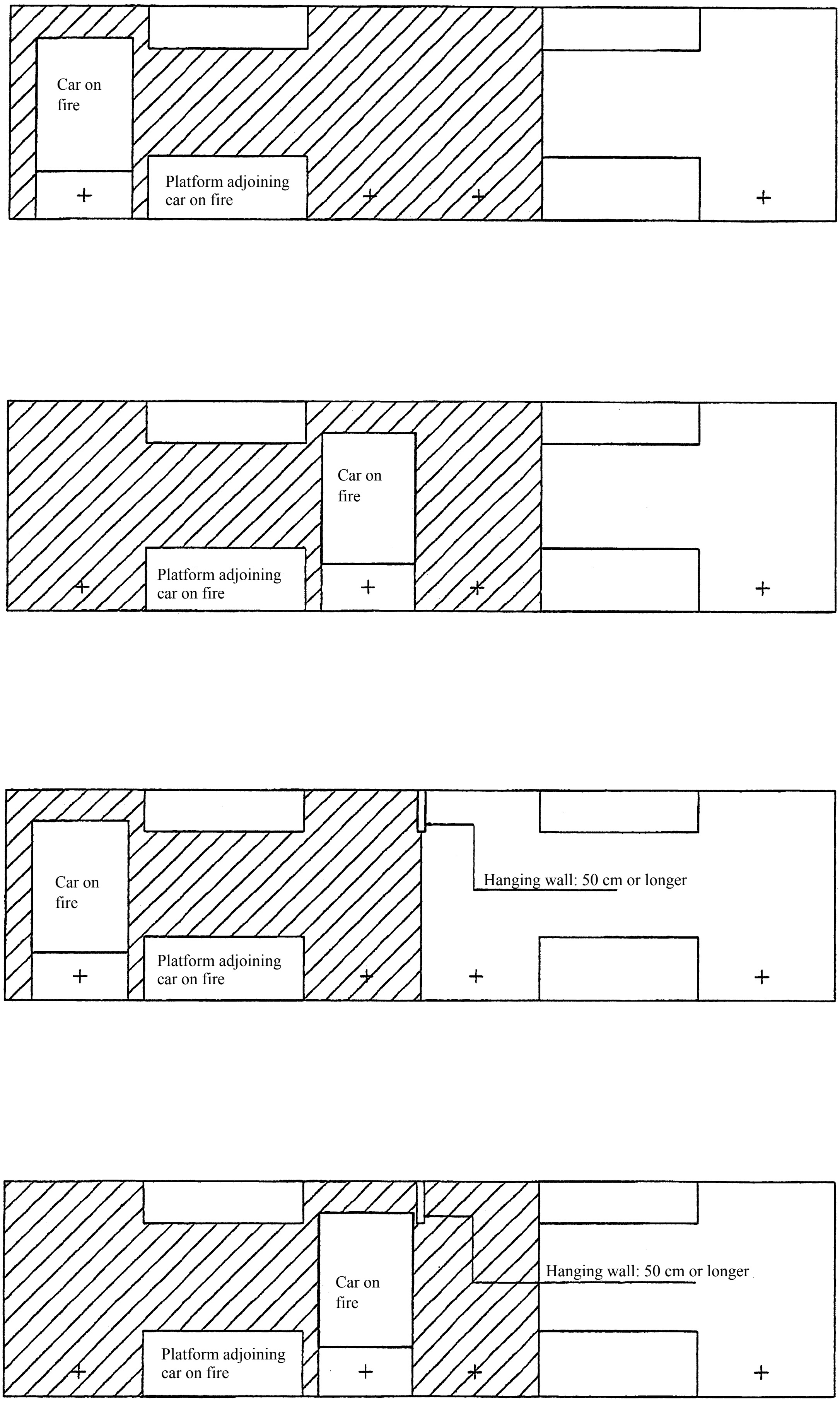


Fig. 29.30 Fire-point block of platform with three or more incoming train tracks (2)

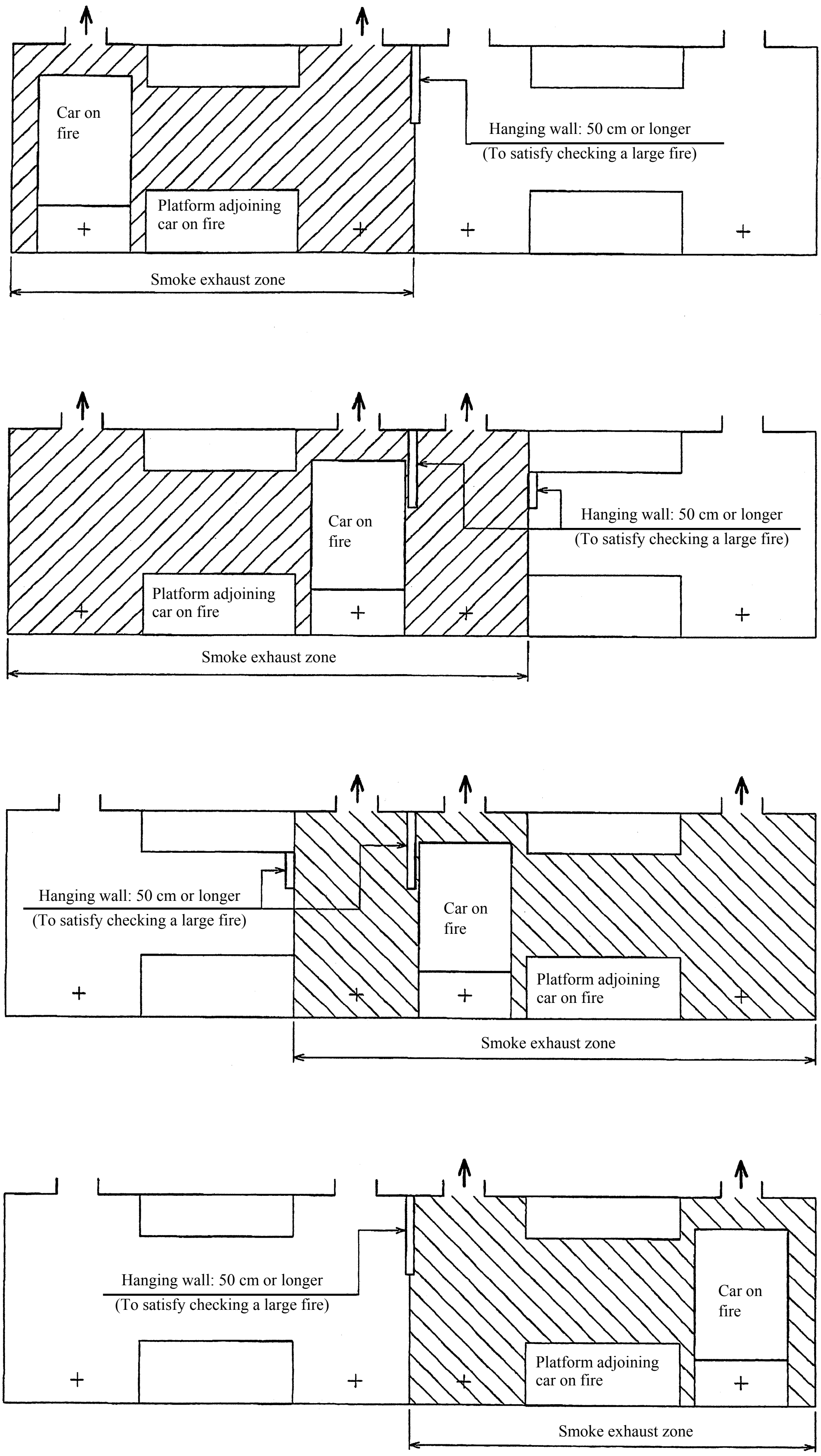


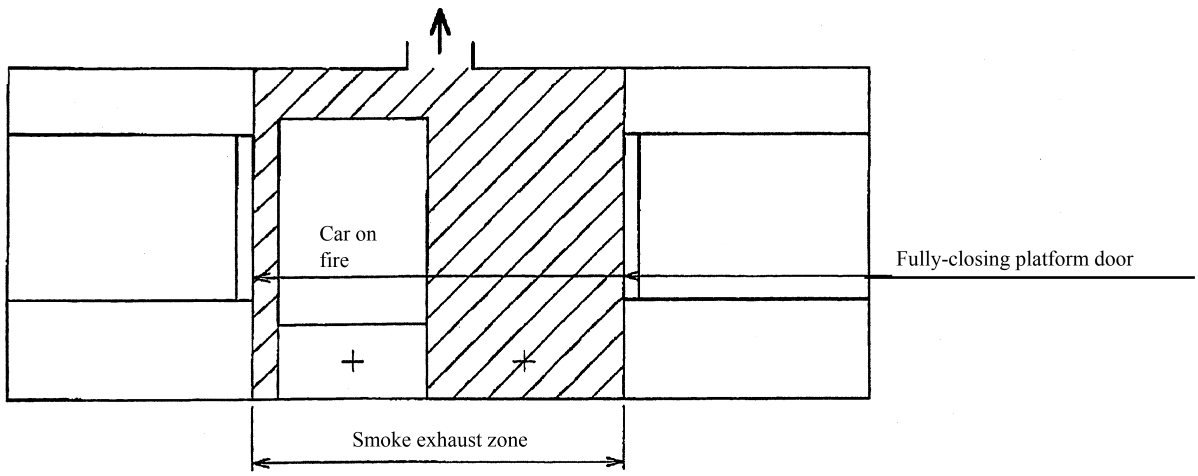
Fig. 29.31 Typical smoke exhaust zone of platform with three or more incoming train tracks

(Reference) Smoke exhaust facility at platform equipped with fully-closing platform doors

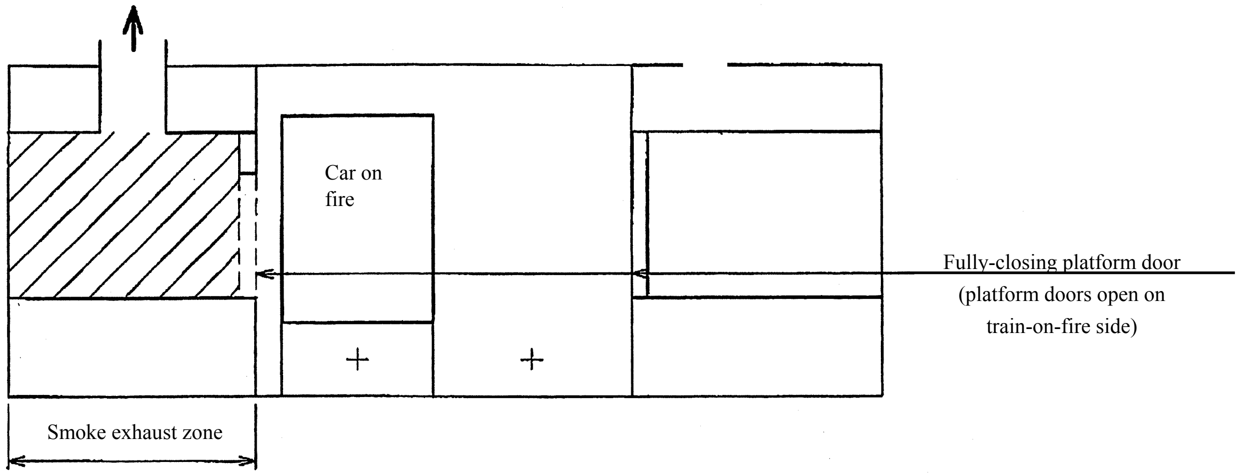
In the case of a platform equipped with fully-closing platform doors, where the flow of smoke is completely obstructed by the platform doors, this must be taken into consideration when checking a train fire and platform store fire.

(1) Checking a train fire
In the case of an ordinary fire, as its origin is assumed to be equipment under the floor of the affected car and smoke would not enter inside the car, the fire-point block can be plotted as shown in **Fig. 29.32**. In this case, through-tunnel vertical flow smoke exhaust can be used as the smoke exhaust method.
In the case of a large fire, it is assumed to be incendiary inside the car, and the car doors and platform doors are opened to allow passengers to evacuate, and smoke fills up inside the car and flows out to the platform. Accordingly, the fire-point block shall be plotted as shown in Fig. 29.32.

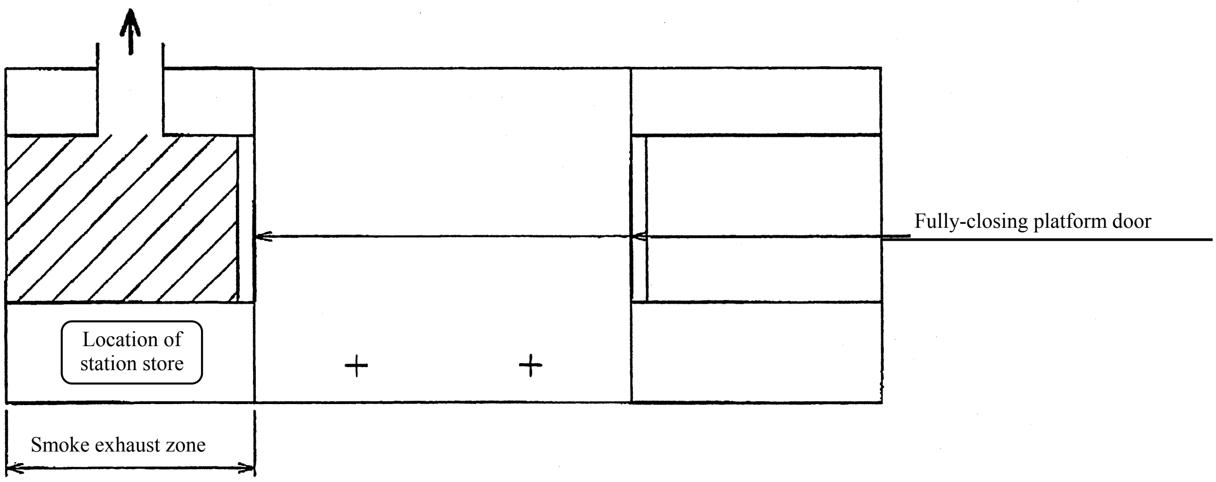
(2) Checking a platform store fire
In this case, an incendiary fire at a station store is assumed, where smoke fills the space hermetically closed with the platform doors. Accordingly, the fire-point block shall be plotted as shown in Fig. 29.32.



In case of train fire (ordinary fire)



In case of train fire (large fire)



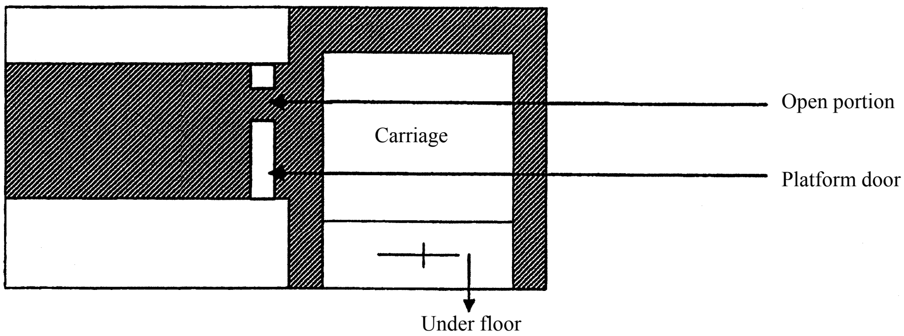
Location of station store

Fig. 29.32 Typical smoke exhaust zone at platform equipped with fully-closing platform doors

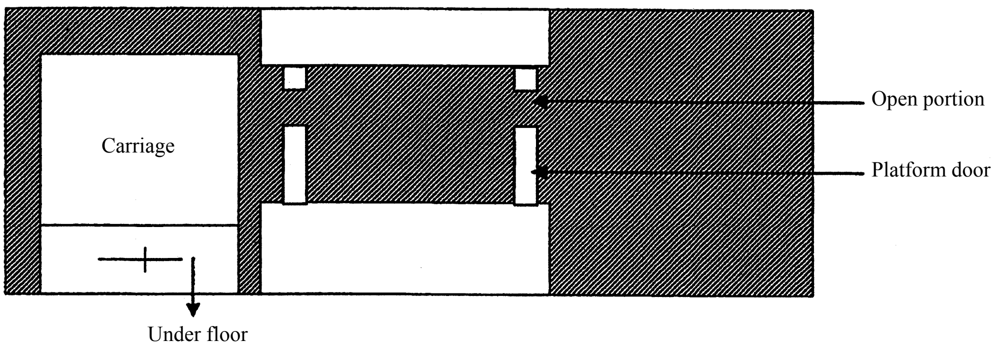
(Reference) Smoke exhaust facility at platform equipped with half-closing platform door

Even if a half-closing platform door is installed, it cannot prevent the flow of smoke because it is open in the screen top, etc. For the fire-point block calculation on both ordinary and large fires, therefore, the fire-point blocks shown in [Fig. Range of track – vertical section for determining the fire-point block, (3) Fire block volume, 4.1 Verifying the Consistency of Smoke at Platform Floor, 4. Methods of Verifying Ordinary Fires] in the attached sheet No. 7 shall be used. Such fire-point blocks are as shown in **Fig. 29.33** below.

(1) In the case of 1-track platform



(2) In the case of 2-track island type platform



(3) In the case of 2-track opposed type platform

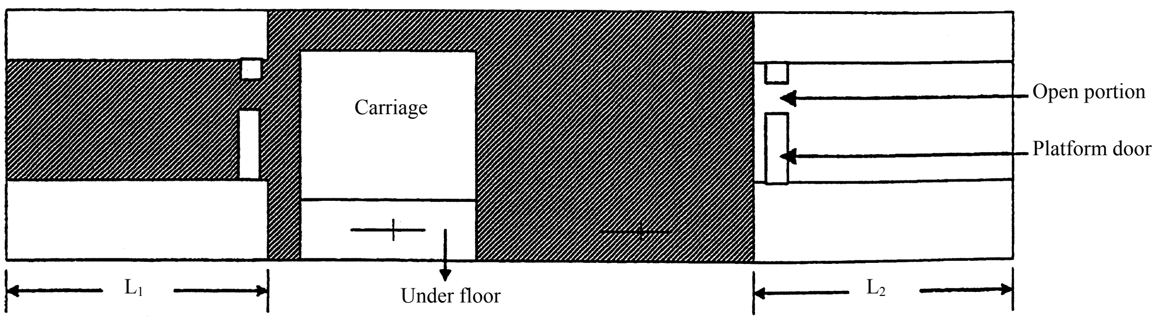


Fig. 29.33 Schematics of fire-point blocks

4. Alternative Measures in Case Smoke Exhaust Facility is Inadequate

In case the check finds that the smoke exhaust facility inadequate, alternative measures as described below should be taken and rechecked.

(1) Construction of new evacuation passageways (**Fig. 29.34**) or widening of evacuation passageways to shorten the evacuation time
New evacuation passageways are constructed or existing evacuation passageways are widened to shorten the evacuation time.

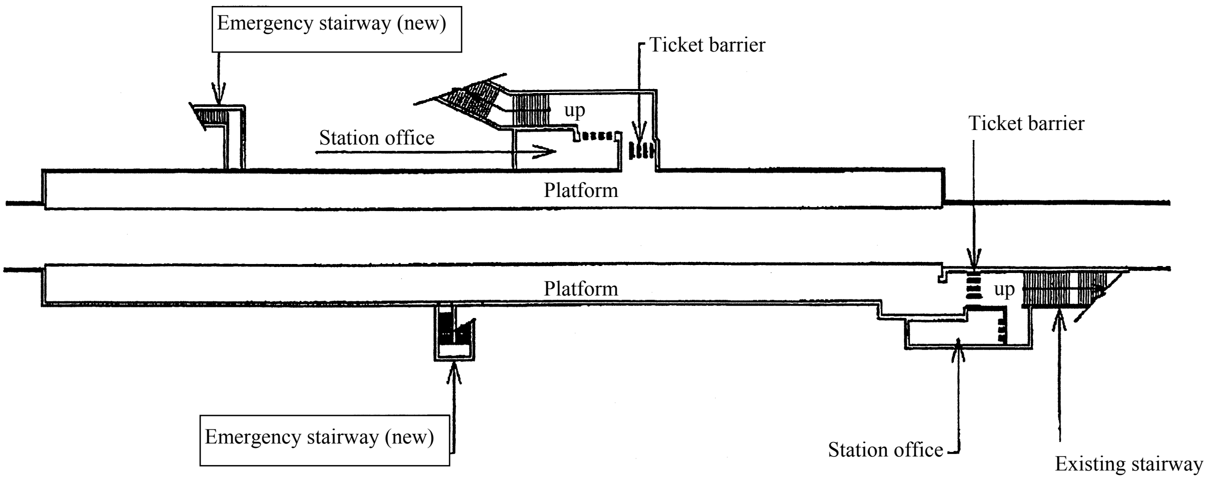


Fig. 29.34 Typical example of construction of new evacuation passageways

(2) Increase in volume of fire-point block and smoke diffusion
The ceiling is raised to increase the volumes of the fire-point block and smoke diffusion. (**Fig. 29.35**)
If the ceiling is to be provided with louvers or the like, the effective aperture rate, flow of smoke, etc. should be properly evaluated before calculating the volumes of fire-point blocks and smoke diffusion.

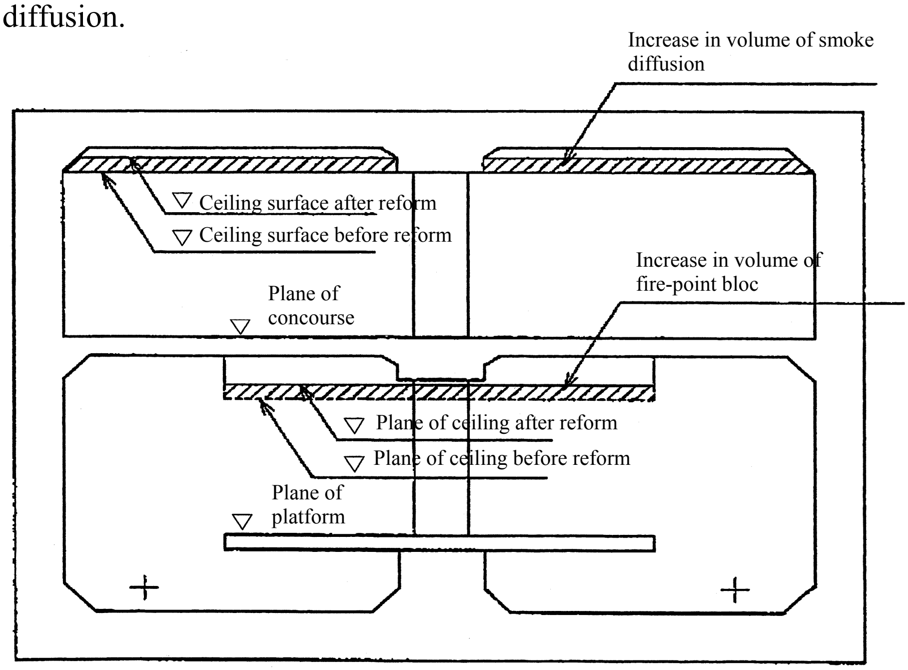


Fig. 29.35 Typical examples of increase in volume of fire-point block and smoke diffusion

(3) Demarcation of fire/smoke protection zone and installation of sprinklers for concession stand as potential origin of fire
With fire/smoke protection zone demarcated and sprinklers installed, a concession stand that is a potential origin of fire can be deemed non-existent (then it is not necessary to check a concourse fire or platform concession stand fire).

(4) Removal of concession stand as potential origin of fire
A concession stand that is a potential origin of fire is removed (then it is not necessary to check a concourse fire or platform fire).

(5) Equipment to assure evacuation safety for passengers
A fire-fighting zone is created with a fire preventive shutter or the like installed, to shorten the evacuation time to a place of safety. In this case, it is necessary to make sure that the accommodation area for evacuees stuck behind the fire preventive shutter or the like is sufficient. (**Fig. 29. 36**)

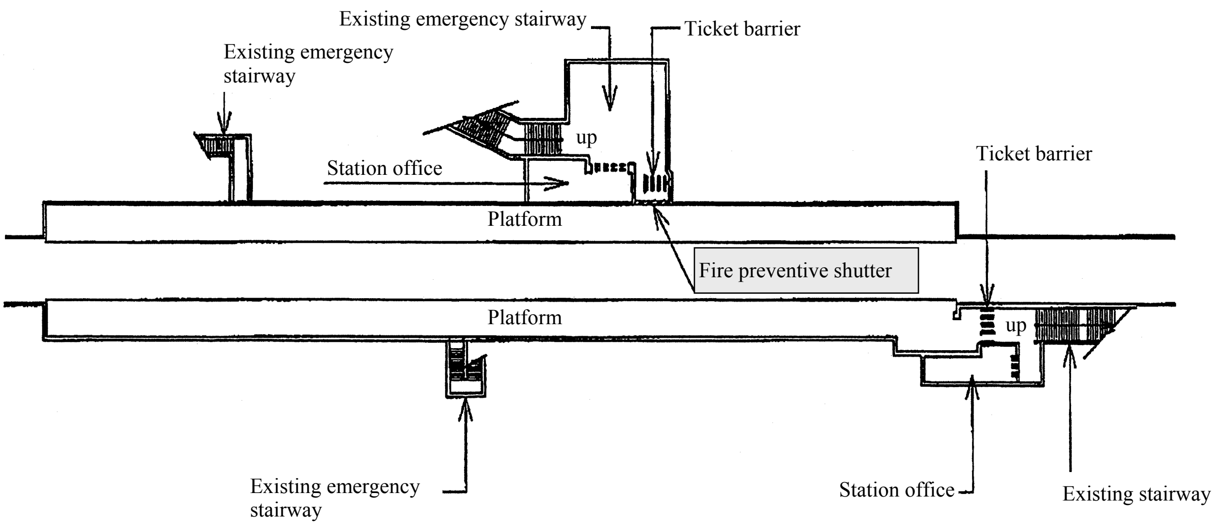


Fig. 29.36 Typical equipment to assure evacuation safety for passengers

5. Practical Example of Checking Evacuation Safety

5.1 Calculation of Evacuation Ending Time

For an underground station of a structural form having a platform at the second basement and two ticket barriers at the first basement, it is necessary to calculate the evacuation ending time with respect to the route passing through each ticket barrier. First, a practical example of calculating the evacuation ending time assuming 3,000 evacuees, which is equivalent to a train occupancy rate of 200% for a train with a capacity of 1,500 passengers, is shown below.

(1) From train doorway till passing through bottom of platform stairway

The last evacuee will take a considerable time to alight from the train. This time T_1 can be obtained from the equation below according to the number of passengers, number of train doorways and coefficient of horizontal outflow.

T_1 (queuing time) = Q (Number of evacuees) / (N (Coefficient of horizontal outflow) x
B (Train doorway width x Number of doors))

With the train doorway width x number of doors = 52.0 m as shown in calculation sheet [4], T_1 will be 38.5 seconds as shown on the right side of the calculation sheet. The cumulative time from the start of evacuation to the last evacuee arriving at the bottom of the platform stairway is the sum of T_1 and the longest transit time $t_{1(max)}$ at the platform. As $t_{1(max)}$ is 75.0 seconds, which is calculated by dividing 75.0 m, which is the maximum distance (lower place of [5] in the calculation sheet) from the train doorway to the bottom of the platform stairway, by 1.0 m/sec, which is the average horizontal walking speed, the cumulative time of T_1 plus $t_{1(max)}$ will be 113.5 seconds.

Meanwhile, congestion with following evacuees will occur at the bottom of the platform stairway immediately after the arrival of the leading evacuees, and the time T_2 necessary for the last evacuee to pass through the congested place is obtained from the number of passengers, platform stairway width and coefficient of stairway outflow as follows.

T_2 (Queuing time) = Q (Number of evacuees)/ (N (Coefficient of stairway outflow) x
B (Platform stairway width))

As the width of the platform stairway in the ticket barrier A passing route is 3.5 m plus escalator width of 1.0 m, totaling 4.5 m, and that in the ticket barrier B passing route is 4.0 m plus escalator width of 1.0 m, totaling 5.0 m, T_2 will be 242.9 seconds as shown on the right side of the calculation sheet. As the time for the first evacuee to arrive at the bottom of the platform stairway is 3.0 seconds calculated by dividing the minimum transit time $t_{1(min)}$ at the platform which is the minimum distance from the train doorway to the bottom of the platform stairway (upper place of [5] in the calculation sheet) by 1.0 m/sec. which is the average horizontal walking speed, the cumulative time from the start of evacuation to the last evacuee passing the bottom of the stairway will be $t_{1(min)}$ plus T_2, giving 245.9 seconds,

Here,

$T1 + t_{1(max)}$: 113.5 seconds < $t_{1(min)} + T_2$: 245.9 seconds

and therefore, the evacuation time until the last evacuee passes the bottom of the platform stairway is determined by the queuing time, not at the train doorway but at the bottom of the platform stairway, which will be $t_{1(min)} + T_2$: 245.9 seconds (4.1 minute).

(2) From passing the bottom of platform stairway to passing ticket barrier

Hereafter, the evacuation time to the ground will be calculated for two evacuation routes, i.e., ticket barrier A route and ticket barrier B route.

[1] Ticket barrier A route

The cumulative time T_2 from the start of evacuation to the last evacuee arriving at the ticket barrier A past the bottom of the platform stairway will be 245.9 seconds calculated in (1) plus the maximum platform stairway (or escalator) transit time t_2: 34.0 seconds and the maximum transit time of concourse within latches t_3 from the top of the platform stairway to ticket barrier A: 7.5 seconds, totaling 287.4 seconds.

To calculate the time T_3 necessary for the last evacuee to pass the ticket barrier A, it is necessary to use the number of passengers utilizing this evacuation route. The ratio of passengers utilizing this evacuation route is given by the ratio of N x B:

$(4.5 \times 1.3) \div ((5.0 + 4.5) \times 1.3) = 0.47$

Accordingly, T_3 in this evacuation route will be 242.9 seconds as shown on the right side of the calculation sheet. The time for the first evacuee to arrive at the ticket barrier A is $t_{1(min)}$ plus t_2 and t_3 or 44.5 seconds. In the light of congestion at the ticket barrier A, therefore, the cumulative time from the start of evacuation to the last evacuee passing the ticket barrier will be 44.5 seconds plus T_3 totaling 287.4 seconds.

Hence,

$$t_{1(min)} + T_2 + t_2 + t_3\text{: 287.4 seconds} = t_{1(min)} + t_2 + t_3 + T_3\text{: 287.4 seconds}$$

meaning that congestion at the ticket barrier A will disappear at the same time as the last evacuee passes the ticket barrier A, and the cumulative time up to such point will be 287.4 seconds.

[2] Ticket barrier B route

The cumulative time from the start of evacuation to the last evacuee arriving at the ticket battier B past the bottom of the platform stairway will be 245.9 seconds calculated in (1) plus the maximum platform stairway (or escalator) transit time t_2: 30 seconds and maximum transit time of concourse within latches t_3 from the top of the platform stairway to the ticket barrier B: 43 seconds, totaling 318.9 seconds.

The time T_3 necessary for the last evacuee to pass the ticket barrier B in this route is 438.6 seconds as shown on the right of the calculation sheet because the ratio of passengers utilizing this evacuation route is

$1.0 – 0.47 = 0.53$

The leading evacuee arrives at the ticket barrier B at $t_{1(min)}$ plus t_2 and t_3 or 76.0 seconds. In the light of congestion at the ticker barrier B, therefore, the cumulative time from the start of evacuation to the last evacuee passing the ticket barrier will be 76.0 seconds plus T_3 or 514.6 seconds.

Here,

$$t_{1(min)} + T_2 + t_2 + t_3\text{: 318.9 seconds} < t_{1(min)} + t_2 + t_3 + T_3\text{: 514.6 seconds}$$

meaning that the evacuation time until the last evacuee passes the ticket barrier B will be determined according to the queuing time, not at the bottom of the platform stairway but at the ticket barrier B, which will be 514.6 seconds.

Accordingly, the evacuation time until the last evacuee passes the ticket barrier in the ticket barrier B route at this station will be 514.6 seconds (8.6 minutes).

(3) From passing the ticket barrier to reaching the ground

[1] Ticket barrier A route

The cumulative time from the start of evacuation to the last evacuee arriving at the bottom of the exit stairway past the ticket barrier A will be 287.4 seconds calculated in (2) plus transit time t_4 to the bottom of the farthest exit stairway from the ticket barrier A: 63.5 seconds, or 350.9 seconds.

The time T_4 necessary for the last evacuee to pass the bottom of the exit stairway will be 206.2 seconds, which is obtained from the number of passengers utilizing this evacuation route, the total of minimum widths of the three exit stairways plus escalators, and the coefficient of stairway outflow as shown on the right side of the calculation sheet. The time until the first evacuee arrives at the bottom of the exit stairway is 108.0 seconds calculated by adding t_2, t_3 and t_4 to $t_{1(min)}$. In the light of congestion at the bottom of the exit stairway, therefore, the cumulative time from the start of evacuation to the last evacuee passing the bottom of the exit stairway will be 108.0 seconds plus T_4 totaling 314.2 seconds.

Here,

$$t_{1\,(min)} + t_2 + t_3 + T_3 + t_4\text{: 350.9 seconds} > t_{1(min)} + t_2 + t_3 + t_4 + T_4\text{: 314.2 seconds}$$

meaning that the evacuation time until the last evacuee passes the bottom of the exit stairway will be determined according to the queuing time, not at the bottom of the exit stairway but at the ticket barrier A as well, which will be 350.9 seconds.

Ultimately, the cumulative time from the start of evacuation to the last evacuee reaching the ground will be 350.9 seconds which is the cumulative time until passing the bottom of the exit stairway plus 37.0 seconds which is the exit stairway transit time t_5, totaling 387.9 seconds.

[2] Ticket barrier B route

The cumulative time from the start of evacuation to the last evacuee arriving at the bottom of the exit stairway past the ticket barrier B will be 514.6 seconds calculated in (2) and the transit time t_4 to the farthest exit stairway from the ticket barrier B: 60.5 seconds, totaling 575.1 seconds.

The time T_4 necessary for the last evacuee to pass the bottom of the exit stairway will be 238.2 seconds as obtained from the number of passengers utilizing this evacuation route, the total of minimum widths of the two exit stairways and escalators, and the coefficient of stairway outflow as shown on the right side of the calculation sheet. The time until the first evacuee arrives at the bottom of the exit stairway is 136.5 seconds calculated by adding t_2, t_3 and t_4 to $t_{1(min)}$. In the light of congestion at the bottom of the exit stairway, therefore, the cumulative time from the start of evacuation to the last evacuee passing the bottom of the exit stairway will be 136.5 seconds plus T_4, totaling 374.7 seconds.

Here,

$$t_{1(min)} + t_2 + t_3 + T_3 + t_4\text{: 575.1 seconds} > t_{1(min)} + t_2 + t_3 + t_4 + T_4\text{: 374.7 seconds}$$

meaning that the evacuation time until the last evacuee passes the bottom of the exit stairway will be determined according to the queuing time, not at the bottom of the exit stairway but at the ticket barrier B as well, which will be 575.1 seconds.

Ultimately, the cumulative time from the start of evacuation to the last evacuee reaching the ground will be the sum of 575.1 seconds which is the cumulative time until passing the bottom of the exit stairway and 59.0 seconds which is the transit time up the exit stairway t_5, giving 634.1 seconds.

Thus, the evacuation ending time until the last evacuee reaches the ground at this station will be 634.1 seconds in the ticket barrier B route.

5.2 Numbers of Evacuees and Evacuation Ending Times by Assumed Type of Fire

Since the number of evacuees and place of safety differ with every assumed fire, the evacuation ending time used for checking evacuation safety requires several evacuation time calculations described above to be determined. The numbers of evacuees and places of safety by assumed type of fire at this station, which is presumed to be an average underground station found in the three large city districts, are shown in **Table 29.17** below, and the evacuation ending times used for checking evacuation safety are shown in the same table from the calculation sheet.

Table 29.17 Numbers of Evacuees and Evacuation Ending Times by Assumed Type of Fire

Assumed type of fire		Number of evacuees (Train occupancy rate): %	Place of safety consistent with evacuation ending time used for checking	Evacuation ending time: min.	Remarks
Carriage	Ordinary fire	200	Concourse	4.7	Ticket barrier A route
	Large-origin fire	275	Concourse	6.2	Ticket barrier A route
Platform concession stand	Ordinary fire	275	Concourse	6.2	Ticket barrier A route
	Large-origin fire	275	Concourse	6.2	Ticket barrier A route
Concourse concession stand	Ordinary fire	75	Ground	6.0	Ticket barrier B route
	Large-origin fire	75	Ground	6.0	Ticket barrier B route

5.3 Checking Evacuation Safety

From the evacuation ending times by the assumed type of fire, the evacuation safety for the respective types of assumed fire at this station is checked as follows.

(1) Ordinary fire

1) Carriage fire

With evacuation ending time t = 4.7 minutes, volume of fire-point block V = 1,155 m^3 and ventilating capacity of smoke exhaust facility per volume of fire-point block Ve = 95.9 m^3/minute, the consistency of smoke Cs is obtained as:

$$Cs = 21 \cdot (1 - e^{-Ve \cdot t/V}) / Ve$$
$$= 21 \times (1 - e^{-95.9 \times 4.7 / 1{,}155}) / 95.9$$
$$= 0.071 < 0.1 \text{ (acceptable)}$$

2) Platform concession stand fire

With evacuation end time t = 6.2 minutes, volume of fire-point block V = 1,155 m^3 and ventilating capacity of smoke exhaust facility per volume of fire-point block Ve = 95.9 m^3, the consistency of smoke Cs is obtained as:

$$Cs = 2.1 \cdot (Ve \cdot t - V + V \cdot e^{-Ve \cdot t/V}) / Ve^2$$
$$= 2.1 \times (95.9 \times 6.2 - 1{,}155 + 1{,}155 \times e^{-95.9 \times 4.7 / 1{,}155}) / (95.9)^2$$
$$= 0.030 < 0.1 \text{ (OK)}$$

3) Concourse concession stand fire

From evacuation ending time t = 6.0 minutes, the required volume of smoke diffusion V_o is

$V_o = 10.5\ t^2$
$= 10.5 \times (6.0)^2$
$= 378.0$

In comparison, if the concourse floor area is 1,050 m^2 and concourse ceiling is 2.8 m high because there is no smoke exhaust facility for the concourse at this station, the volume of smoke diffusion V is

$V = 1{,}050 \times (2.8 – 2)$
$= 840.0 > 378.0$ (OK)

(2) Large-origin fire

1) Carriage and platform concession stand fires

Supposing
Evacuation time t = 6.2 minutes
the track right-angled sectional area of the platform higher than 2.0 m from platform floor and area minus stairways, columns and other places where smoke is not diffused $A_E = 31.63\ m^2$,
the sectional area of carriage more than 2.0 m higher than platform floor $A_V' = 2.02\ m^2$,
the overall length of platform L = 210.0 m,
the ventilating capacity of smoke exhaust facility at entire platform Ve = 1,007.0 m^2/min.
the track right-angled sectional area Ao in fire-point block volume calculation = 68.70 m^2, and
the sectional are of carriage (including under floor) Av = 10.50 m^2,
then the effective amount of smoke exhaust Ve' as opposed to effective volume of platform is

$Ve' = Ve \times (A_E – A_V') / (A_o – A_V)$
$= 1{,}007 \times (31.63 – 2.02) / (68.70 – 10.50)$
$= 512.3 > 300.0$ (Vs: generation amount of smoke, etc.).

Accordingly, the time t_o (min.) required for smoke and gases generated from a large-origin train fire to fall to a smoke layer bottom level of 2.0 m from the floor surface hindering evacuation will be t_o (min) = ∞ (OK)

2) Concourse concession stand fire

As this station has no smoke exhaust facility for concourse, the time to (min) required for smoke and gases generated in a train fire of large-origin to fall to a smoke layer bottom level of 2.0 m from the floor surface hindering evacuation will be

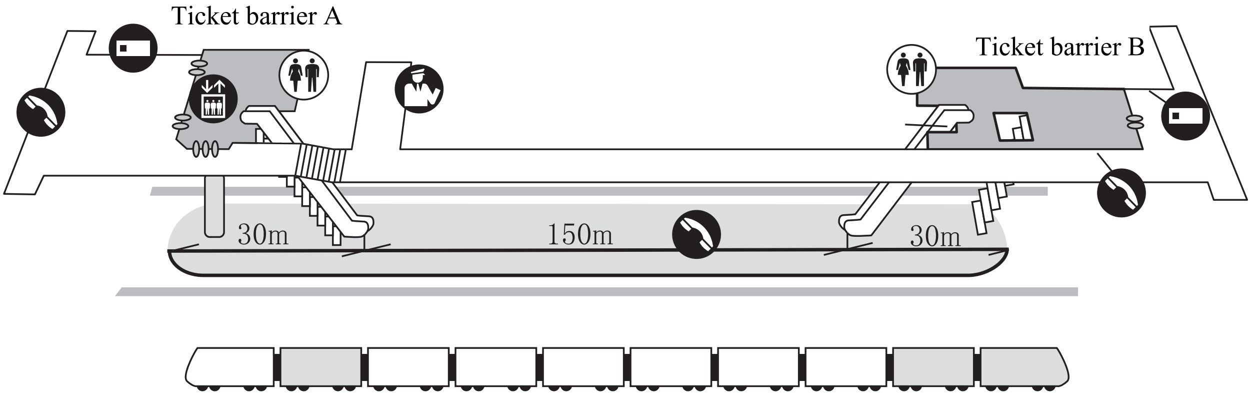
$t_o = V' / (V_s – Ve')$
$= 840.0 / 300.0$
$= 2.8 <$ evacuation ending time = 6.0 minutes (not acceptable)

As a corrective measure, it is possible to increase the concourse for the volume of smoke diffusion or to install a smoke exhaust facility at the concourse. Incidentally, if an exhaust facility is installed, its ventilation capacity Ve (m^3/min) must be as follows.

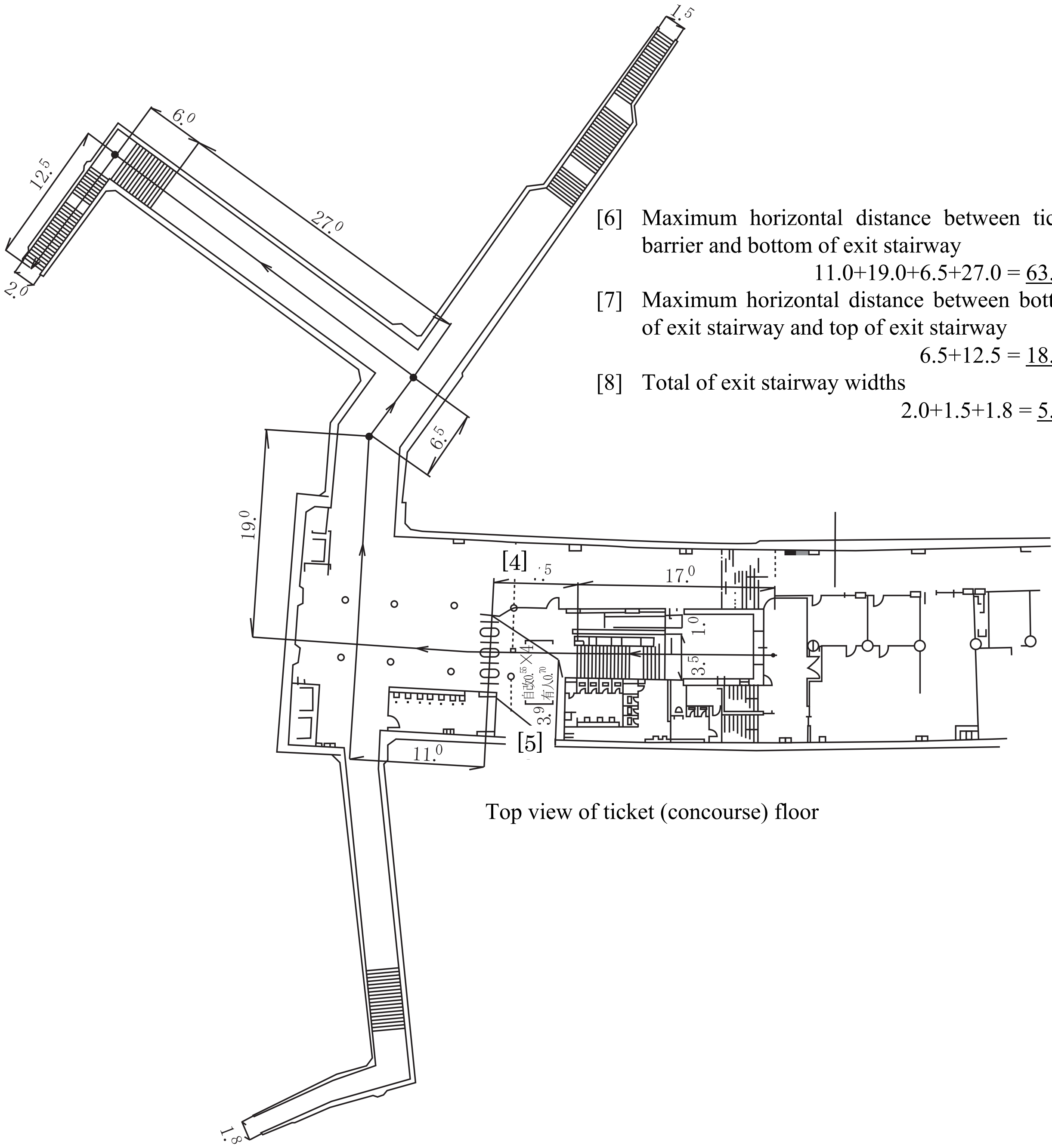
From $6.0 = 840.0 / (300.0 – Ve \times (2.8 – 2.0) / 2.8)$
$Ve = (300.0 \times 6.0 – 840) \times 2.8 / (0.8 \times 6.0)$
$= 560.0$ (m^3/min.)

Also, it is possible to suppress the increase of smoke diffusion volume or smoke exhaust facility ventilation capacity by increasing the width of ticket barrier B which is a maximum queuing point to shorten the evacuation ending time.

Schematic of XX Line XX Station



Ticket barrier A at XX station



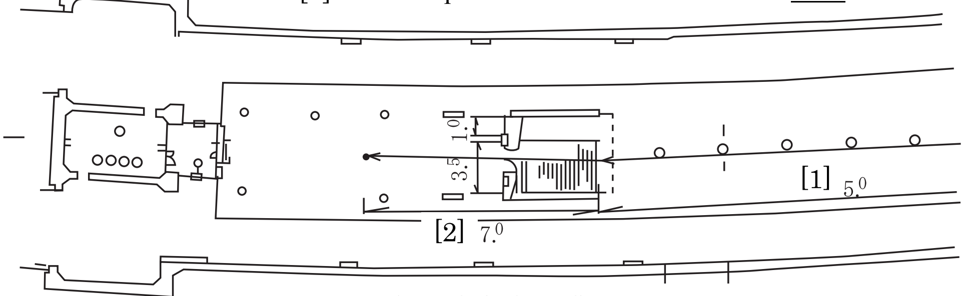
[6] Maximum horizontal distance between ticket barrier and bottom of exit stairway
11.0+19.0+6.5+27.0 = 63.5m

[7] Maximum horizontal distance between bottom of exit stairway and top of exit stairway
6.5+12.5 = 18.5m

[8] Total of exit stairway widths
2.0+1.5+1.8 = 5.3m

Top view of ticket (concourse) floor

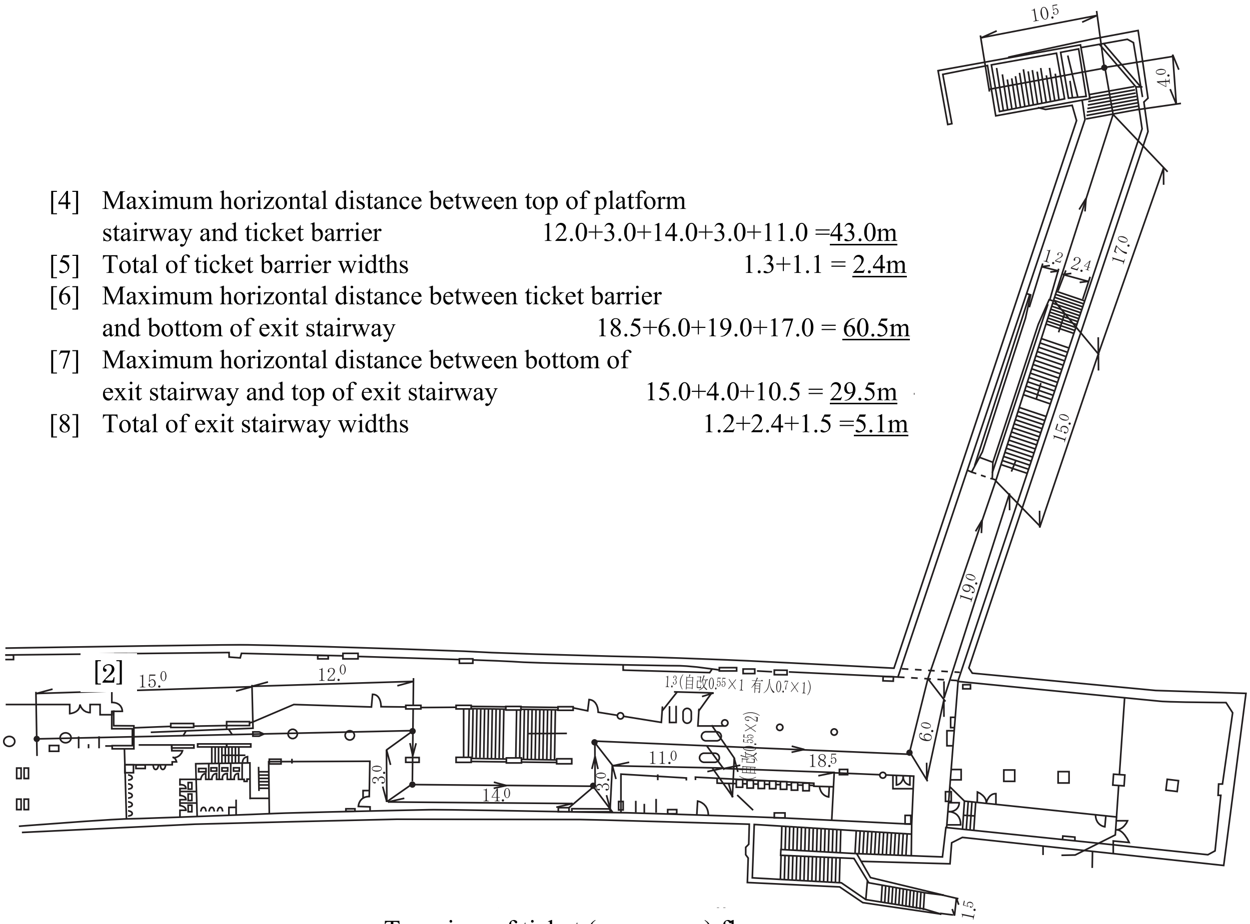
[3] Total of platform stair widths: 3.5+1.0 = 4.5m



Top view of platform floor

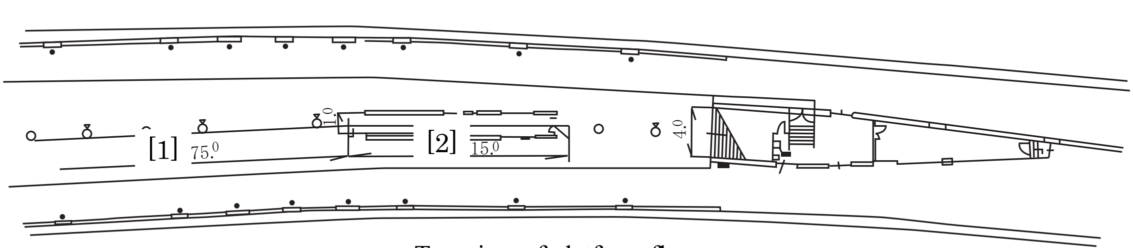
Ticket Barrier B at XX Station

[4] Maximum horizontal distance between top of platform stairway and ticket barrier 12.0+3.0+14.0+3.0+11.0 =43.0m
[5] Total of ticket barrier widths 1.3+1.1 = 2.4m
[6] Maximum horizontal distance between ticket barrier and bottom of exit stairway 18.5+6.0+19.0+17.0 = 60.5m
[7] Maximum horizontal distance between bottom of exit stairway and top of exit stairway 15.0+4.0+10.5 = 29.5m
[8] Total of exit stairway widths 1.2+2.4+1.5 =5.1m



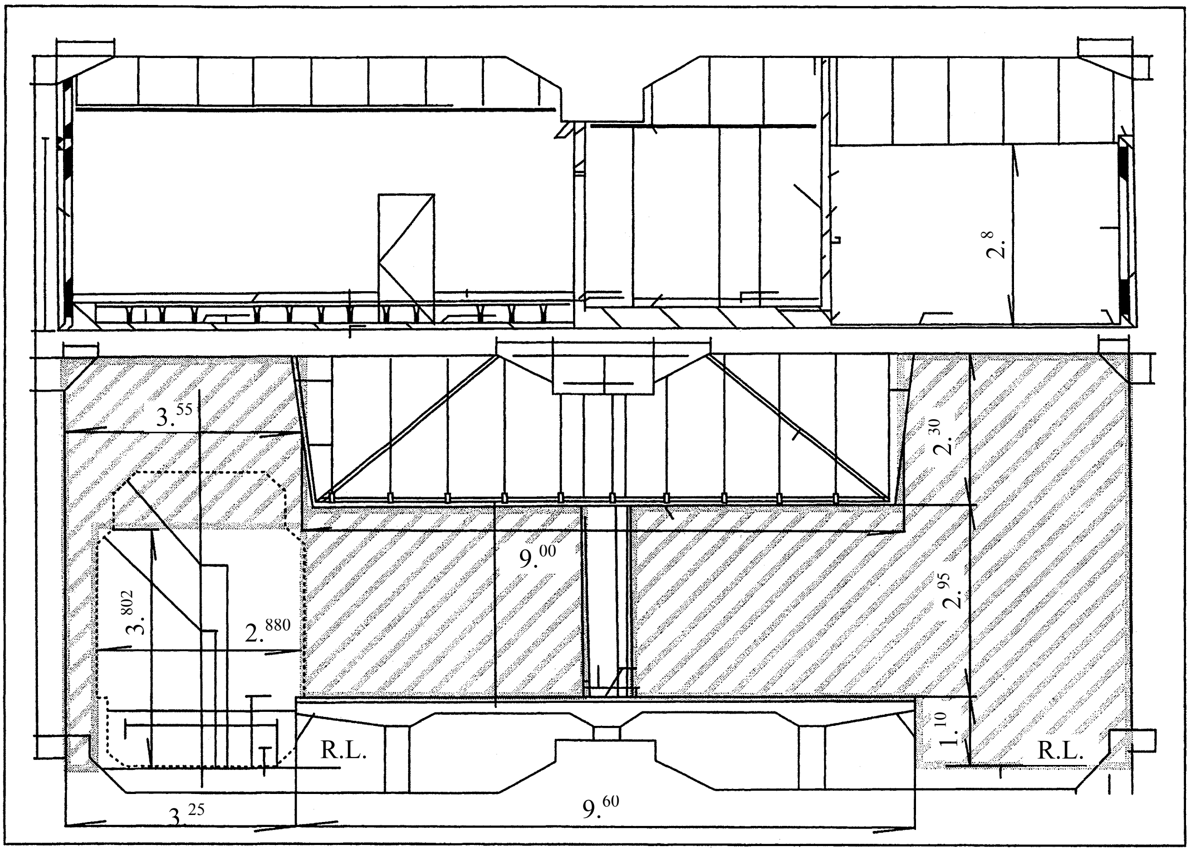
Top view of ticket (concourse) floor

[3] Total of platform stair widths: 1.0+4.0 = 5.0m



Top view of platform floor

Standard Sectional View of XX Station



 :Sectional area of fire-point block ($57.75m^2$)

Accordingly
(Volume of fire-point block) = 57.75 x 20 = $\underline{1{,}155.0m^3}$

Evacuation Time Calculation (Ticket Barrier A Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		200.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier A side)	(Total including Es)	4.50	m
[8]	Platform stairway length (ticket barrier A side)	(Maximum)	17.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier A side)	(Maximum)	7.50	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier A width	(Total)	3.90	m
[12]	Distance between ticket barrier A and exit stairway	(Maximum)	63.50	m
[13]	Number of exit stairways		3.00	places
[14]	Exit stairway width	(Total including Es)	5.30	m
[15]	Exit stairway length	(Maximum)	18.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/m/s
Coefficient of stairway outflow	1.30	persons/m/s

3. Evacuation time calculation

Location			Calculation		Result
Carriage doorway	queuing time	T1=	1,500 × 2 ÷ 1.5 ÷ 52.00	=	38.5 seconds
↓					
Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0 seconds
↓		t1(max)=	75.0 ÷ 1.0	=	75.0 seconds
↓					
← Bottom of platform stairway	queuing time	T2=	1,500 × 2 ÷ 1.3 ÷ 9.5	=	242.9 seconds
↓					
Ticket barrier A side stairway	transit time	t2=	17.0 ÷ 0.5	=	34.0 seconds
↓					
Concourse A	transit time	t3=	7.5 ÷ 1.0	=	7.5 seconds
↓					
Ticket barrier A	queuing time	T3=	1,500 × 2 × 0.47 ÷ 1.5 ÷ 3.9	=	242.9 seconds
↓					
Walkway	transit time	t4=	63.5 ÷ 1.0	=	63.5 seconds
↓					
Bottom of exit stairway	queuing time	T4=	1,500 × 2 × 0.47 ÷ 1.3 ÷ 5.3	=	206.2 seconds
↓					
Exit stairway	transit time	t5=	18.5 ÷ 0.5	=	37.0 seconds
↓					
Ground					

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	113.5 seconds	
	t1(min)+T2	=	245.9 seconds	: 4.1 minutes
Passing top of platform stairway	245.9+t2	=	279.9 seconds	: 4.7 minutes
Passing ticket barrier A	245.9+t2+t3	=	287.4 seconds	: 4.8 minutes
	t1(min)+t2+t3+T3	=	287.4 seconds	
Passing bottom of exit stairway	287.4+t4	=	350.9 seconds	: 5.8 minutes
	t1(min)+t2+t3+t4+T4	=	314.2 seconds	
Reaching ground	350.9+t5	=	387.9 seconds	: 6.5 minutes

→ Ticket barrier B route

Evacuation Time Calculation (Ticket Barrier B Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		200.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier B side)	(Total including Es)	5.00	m
[8]	Platform stairway length (ticket barrier B side)	(Maximum)	15.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier B side)	(Maximum)	43.00	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier B width	(Total)	2.40	m
[12]	Distance between ticket barrier B and exit stairway	(Maximum)	60.50	m
[13]	Number of exit stairways		2.00	places
[14]	Exit stairway width	(Total including Es)	5.10	m
[15]	Exit stairway length	(Maximum)	29.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/m/s
Coefficient of stairway outflow	1.30	persons/m/s

3. Evacuation time calculation

	Carriage doorway	queuing time	T1=	1,500 × 2 ÷ 1.5 ÷ 52.00	=	38.5	seconds
	↓						
	Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0	seconds
	↓		t1(max)=	75.0 ÷ 1.0	=	75.0	seconds
	↓						
←	Bottom of platform stairway	queuing time	T2=	1,500 × 2 ÷ 1.3 ÷ 9.5	=	242.9	seconds
↓	↓						
↓	Ticket barrier B side stairway	transit time	t2=	15.0 ÷ 0.5	=	30.0	seconds
↓	↓						
↓	Concourse B	transit time	t3=	43.0 ÷ 1.0	=	43.0	seconds
↓	↓						
↓	Ticket barrier B	queuing time	T3=	1,500 × 2 × 0.53 ÷ 1.5 ÷ 2.4	=	438.6	seconds
↓	↓						
↓	Walkway	transit time	t4=	60.5 ÷ 1.0	=	60.5	seconds
↓	↓						
↓	Bottom of exit stairway	queuing time	T4=	1,500 × 2 × 0.53 ÷ 1.3 ÷ 5.1	=	238.2	seconds
↓	↓						
↓	Exit stairway	transit time	t5=	29.5 ÷ 0.5	=	59.0	seconds
↓	↓						
↓	Ground						

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	113.5	seconds		
	t1(min)+T2	=	245.9	seconds	:	4.1 minutes
Passing top of platform stairway	245.9+t2	=	275.9	seconds	:	4.6 minutes
Passing ticket barrier B	245.9+t2+t3	=	318.9	seconds	:	8.6 minutes
	t1(min)+t2+t3+T3	=	514.6	seconds		
Passing bottom of exit stairway	514.6+t4	=	575.1	seconds	:	9.6 minutes
	t1(min)+t2+t3+t4+T4	=	374.7	seconds		
Reaching ground	575.1+t5	=	634.1	seconds	:	10.6 minutes

→ Ticket barrier A route

Evacuation Time Calculation (Ticket Barrier A Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		275.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier A side)	(Total including Es)	4.50	m
[8]	Platform stairway length (ticket barrier A side)	(Maximum)	17.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier A side)	(Maximum)	7.50	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier A width	(Total)	3.90	m
[12]	Distance between ticket barrier A and exit stairway	(Maximum)	63.50	m
[13]	Number of exit stairways		3.00	places
[14]	Exit stairway width	(Total including Es)	5.30	m
[15]	Exit stairway length	(Maximum)	18.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/m/s
Coefficient of stairway outflow	1.30	persons/m/s

3. Evacuation time calculation

Carriage doorway	queuing time	T1=	1,500 × 2.75 ÷ 1.5 ÷ 52.00	=	52.9	seconds
↓						
Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0	seconds
↓		t1(max)=	75.0 ÷ 1.0	=	75.0	seconds
↓						
← Bottom of platform stairway	queuing time	T2=	1,500 × 2.75 ÷ 1.3 ÷ 9.5	=	334.0	seconds
↓						
Ticket barrier A side stairway	transit time	t2=	17.0 ÷ 0.5	=	34.0	seconds
↓						
Concourse A	transit time	t3=	7.5 ÷ 1.0	=	7.5	seconds
↓						
Ticket barrier A	queuing time	T3=	1,500 × 2.75 × 0.47 ÷ 1.5 ÷ 3.9	=	334.0	seconds
↓						
Walkway	transit time	t4=	63.5 ÷ 1.0	=	63.5	seconds
↓						
Bottom of exit stairway	queuing time	T4=	1,500 × 2.75 × 0.47 ÷ 1.3 ÷ 5.3	=	283.6	seconds
↓						
Exit stairway	transit time	t5=	18.5 ÷ 0.5	=	37.0	seconds
↓						
Ground						

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	127.9	seconds	
	t1(min)+T2	=	337.0	seconds	: 5.6 minutes
Passing top of platform stairway	337.0+t2	=	371.0	seconds	: 6.2 minutes
Passing ticket barrier A	337.0+t2+t3	=	378.5	seconds	: 6.3 minutes
	t1(min)+t2+t3+T3	=	378.5	seconds	
Passing bottom of exit stairway	378.5+t4	=	442.0	seconds	: 7.4 minutes
	t1(min)+t2+t3+t4+T4	=	391.6	seconds	
Reaching ground	442.0+t5	=	479.0	seconds	: 8.0 minutes

→ Ticket barrier B route

Evacuation Time Calculation (Ticket Barrier B Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		275.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier B side)	(Total including Es)	5.00	m
[8]	Platform stairway length (ticket barrier B side)	(Maximum)	15.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier B side)	(Maximum)	43.00	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier B width	(Total)	2.40	m
[12]	Distance between ticket barrier B and exit stairway	(Maximum)	60.50	m
[13]	Number of exit stairways		2.00	places
[14]	Exit stairway width	(Total including Es)	5.10	m
[15]	Exit stairway length	(Maximum)	29.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/m/s
Coefficient of stairway outflow	1.30	persons/m/s

3. Evacuation time calculation

Location			Calculation		Result	
Carriage doorway	queuing time	T1=	1,500 × 2.75 ÷ 1.5 ÷ 52.00	=	52.9	seconds
↓						
Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0	seconds
↓		t1(max)=	75.0 ÷ 1.0	=	75.0	seconds
↓						
← Bottom of platform stairway	queuing time	T2=	1,500 × 2.75 ÷ 1.3 ÷ 9.5	=	334.0	seconds
↓						
Ticket barrier B side stairway	transit time	t2=	15.0 ÷ 0.5	=	30.0	seconds
↓						
Concourse B	transit time	t3=	43.0 ÷ 1.0	=	43.0	seconds
↓						
Ticket barrier B	queuing time	T3=	1,500 × 2.75 × 0.53 ÷ 1.5 ÷ 2.4	=	603.1	seconds
↓						
Walkway	transit time	t4=	60.5 ÷ 1.0	=	60.5	seconds
↓						
Bottom of exit stairway	queuing time	T4=	1,500 × 2.75 × 0.53 ÷ 1.3 ÷ 5.1	=	327.5	seconds
↓						
Exit stairway	transit time	t5=	29.5 ÷ 0.5	=	59.0	seconds
↓						
Ground						

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	127.9	seconds		
	t1(min)+T2	=	337.0	seconds	:	5.6 minutes
Passing top of platform stairway	337.0+t2	=	367.0	seconds	:	6.1 minutes
Passing ticket barrier B	337.0+t2+t3	=	410.0	seconds	:	
	t1(min)+t2+t3+T3	=	679.1	seconds	:	11.3 minutes
Passing bottom of exit stairway	679.1+t4	=	739.6	seconds	:	12.3 minutes
	t1(min)+t2+t3+t4+T4	=	464.0	seconds		
Reaching ground	739.6+t5	=	798.6	seconds	:	13.3 minutes

→ Ticket barrier A route

Evacuation Time Calculation (Ticket Barrier A Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		75.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier A side)	(Total including Es)	4.50	m
[8]	Platform stairway length (ticket barrier A side)	(Maximum)	17.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier A side)	(Maximum)	7.50	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier A width	(Total)	3.90	m
[12]	Distance between ticket barrier A and exit stairway	(Maximum)	63.50	m
[13]	Number of exit stairways		3.00	places
[14]	Exit stairway width	(Total including Es)	5.30	m
[15]	Exit stairway length	(Maximum)	18.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/m/s
Coefficient of stairway outflow	1.30	persons/m/s

3. Evacuation time calculation

Location			Calculation		Result
Carriage doorway	queuing time	T1=	1,500 × 0.75 ÷ 1.5 ÷ 52.00	=	14.4 seconds
↓					
Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0 seconds
↓		t1(max)=	75.0 ÷ 1.0	=	75.0 seconds
↓					
← Bottom of platform stairway	queuing time	T2=	1,500 × 0.75 ÷ 1.3 ÷ 9.5	=	91.1 seconds
↓					
Ticket barrier A side stairway	transit time	t2=	17.0 ÷ 0.5	=	34.0 seconds
↓					
Concourse A	transit time	t3=	7.5 ÷ 1.0	=	7.5 seconds
↓					
Ticket barrier A	queuing time	T3=	1,500 × 0.75 × 0.47 ÷ 1.5 ÷ 3.9	=	91.1 seconds
↓					
Walkway	transit time	t4=	63.5 ÷ 1.0	=	63.5 seconds
↓					
Bottom of exit stairway	queuing time	T4=	1,500 × 0.75 × 0.47 ÷ 1.3 ÷ 5.3	=	77.3 seconds
↓					
Exit stairway	transit time	t5=	18.5 ÷ 0.5	=	37.0 seconds
↓					
Ground					

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	89.4 seconds		
	t1(min)+T2	=	94.1 seconds	:	1.6 minutes
Passing top of platform stairway	94.1+t2	=	128.1 seconds	:	2.1 minutes
Passing ticket barrier A	94.1+t2+t3	=	135.6 seconds	:	2.3 minutes
	t1(min)+t2+t3+T3	=	135.6 seconds		
Passing bottom of exit stairway	135.6+t4	=	199.1 seconds	:	3.3 minutes
	t1(min)+t2+t3+t4+T4	=	185.3 seconds		
Reaching ground	199.1+t5	=	236.1 seconds	:	3.9 minutes

→ Ticket barrier B route

Evacuation Time Calculation (Ticket Barrier B Route at XX Line XX Station)

1. Train and station configuration data

[1]	Train passenger capacity	(10-carriage equivalent)	1,500.00	persons
[2]	Train occupancy rate		75.00	%
[3]	Door width	(per door)	1.30	m
[4]	Total door width of train		52.00	m
[5]	Distance between train and bottom of platform stairway	(Minimum)	3.00	m
		(Maximum)	75.00	m
[6]	Number of platform stairways		3.00	places
[7]	Width of platform (ticket barrier B side)	(Total including Es)	5.00	m
[8]	Platform stairway length (ticket barrier B side)	(Maximum)	15.00	m
[9]	Distance between top of platform stairway and ticket barrier (ticket barrier B side)	(Maximum)	43.00	m
[10]	Number of ticket barriers		2.00	places
[11]	Ticket barrier B width	(Total)	2.40	m
[12]	Distance between ticket barrier B and exit stairway	(Maximum)	60.50	m
[13]	Number of exit stairways		2.00	places
[14]	Exit stairway width	(Total including Es)	5.10	m
[15]	Exit stairway length	(Maximum)	29.50	m

2. Crowd behavior ability — Class B

Average horizontal walking speed	1.00	m/s
Average stairway walking speed	0.50	m/s
Coefficient of horizontal outflow	1.50	persons/ m/s
Coefficient of stairway outflow	1.30	persons/ m/s

3. Evacuation time calculation

Location			Calculation		Result
Carriage doorway	queuing time	T1=	1,500 × 0.75 ÷ 1.5 ÷ 52.00	=	14.4 seconds
↓					
Platform	transit time	t1(min)=	3.0 ÷ 1.0	=	3.0 seconds
↓		t1(max)=	75.0 ÷ 1.0	=	75.0 seconds
↓					
← Bottom of platform stairway	queuing time	T2=	1,500 × 0.75 ÷ 1.3 ÷ 9.5	=	91.1 seconds
↓					
Ticket barrier B side stairway	transit time	t2=	15.0 ÷ 0.5	=	30.0 seconds
↓					
Concourse B	transit time	t3=	43.0 ÷ 1.0	=	43.0 seconds
↓					
Ticket barrier B	queuing time	T3=	1,500 × 0.75 × 0.53 ÷ 1.5 ÷ 2.4	=	164.5 seconds
↓					
Walkway	transit time	t4=	60.5 ÷ 1.0	=	60.5 seconds
↓					
Bottom of exit stairway	queuing time	T4=	1,500 × 0.75 × 0.53 ÷ 1.3 ÷ 5.1	=	89.3 seconds
↓					
Exit stairway	transit time	t5=	29.5 ÷ 0.5	=	59.0 seconds
↓					
Ground					

(Evacuation time for last evacuee)

Passing bottom of platform stairway	T1+t1(max)	=	89.4 seconds		
	t1(min)+T2	=	94.1 seconds	:	1.61 minutes
Passing top of platform stairway	94.1+t2	=	124.1 seconds	:	2.1 minutes
Passing ticket barrier B	94.1+t2+t3	=	167.1 seconds		
	t1(min)+t2+t3+T3	=	240.5 seconds	:	4.0 minutes
Passing bottom of exit stairway	240.5+t4	=	301.0 seconds	:	5.0 minutes
	t1(min)+t2+t3+t4+T4	=	225.8 seconds		
Reaching ground	301.0+t5	=	360.0 seconds	:	6.0 minutes

→ Ticket barrier A route