# In the Event of Fire - Use the Elevators

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## ABSTRACT

Buildings worldwide normally have instructions posted in elevators, rooms and primary circulation routes, that in the event of fire "Do Not Use the Elevators" In a modern correctly designed, installed and commissioned building this statement is fundamentally flawed, in safety terms when considering the overall building population. Why is it that in a modern building, the elevator systems considered to be unsafe in a fire situation? Is it a realistic demand to expect building occupiers to use evacuation stairs when safety procedures demand a quick efficient and safe means of evacuation from buildings in the event of an emergency, including fire? This paper will examine the risks of fire safety, affecting elevator performance in the event of intelligent and controllable emergency evacuation of a modern building.

## 1. INTRODUCTION

With 21st century instant image media coverage, viewers Worldwide appear to have a never ending appetite for any disaster and fire is the most visually dramatic to the news cameramen, it brings into homes the potential risk of death and injury. We can all identify with fire as it can affect our own places of work, entertainment or homes, we know that fire causes injury and a high proportion of the population have had minor burns from household or leisure activities. Media coverage of a nuclear accident may show the reactor or facility from a distance, but no dramatic pictures, natural disasters such as flood, earthquakes or storms although frightening and do cause loss of life and damage, in most instances natural disasters cannot be designed out, they happen. But the news media will "zero in" on events that the general public can identify with such as, polluted seas by the dumping of untreated raw sewage-as they could affect annual vacations, or fire, especially if flames can be seen licking from structural openings, people trapped on smoke billowing balconies or leaping to their death trying to escape from the building.

The general public have visions of high-rise buildings alight, where the spread of fire and associated smoke is so great and fast that people cannot outrun it and they have images of the occupants hanging from their finger tips from balconies, this vision is fuelled by the disaster movie makers and inaccurate media coverage where old library footage of fire is shown to create a front piece and make the story dramatic and newsworthy.

If these buildings had in the majority of instances had been correctly designed, local codes adhered too, fire engineered and elevators were used early in the overall evacuation strategy, building occupants most probably would not be filmed leaping to their deaths in desperation trying to escape from the flames and toxic smoke.

## 2. RISK

Since the days of the first generation skyscrapers in the 1920s, elevators have been used to transport people and things long distances vertically, it has been argued that without safe and reliable elevators, building heights would be limited to possible six stories. It is a fact that early generation elevators in buildings, including skyscrapers had problematical and unstable building power supplies which could not be relied upon in the event of an emergency.

This electrical system reliability was a major concern, for the early 20th century firefighters who would not risk life by using elevators to travel to fire floors or other levels, there are recorded instances of passengers and firefighters being trapped, maimed, injured or even losing their lives within stalled elevators. Yet in todays strict code compliance buildings, with high performance, reliability related elevator maintenance (with reported breakdowns of elevators in some countries on average below four per annum) and "built in" software control redundancy, has made the elevator systems not only very reliable but also a very safe form of vertical transportation.

Reliability and inherently built in safety have made the elevator the preferred and only safe, quick and reliable method of general vertical transportation in tall buildings, but also for population evacuation within the building population, providing an overall a performance-based building design approach is undertaken which includes the elevator systems.

Modern buildings, in countries, cities & towns that have published building codes and more importantly enforce these regulations, the probability of fire and other building related fatal failures are considered to be low, but due to building population floor loadings, expressed in terms of persons/sq metre, the consequences of a fire in an older tall structure have been significant in terms of death and injury. The following example of major fires shows the reported deaths and injuries sustained.

| DATE | BUILDING | LOCATION | STOREYS | DEATHS | INJURIES |
|---|---|---|---|---|---|
| | | | | | |
| 1970 | Conrad Hilton Hotel | Chicago | 25 | 2 | 36 |
| 1970 | Pioneer Hotel | Tucson | 11 | 28 | 38 |
| 1972 | Andraus Building | San Paulo | 31 | 16 | 375 |
| 1973 | Avianca Building | Bogata | 36 | 4 | 100 |
| 1974 | Joelma Building | San Paulo | 25 | 179 | 300 |
| 1980 | MGM Grand Hotel | Las Vegas | 700 | 85 | 700 |
| 1982 | Westchase Hotel | Houston | 13 | 12 | 3 |
| 1986 | Dupont Plaza Hotel | San Juan | 20 | 96 | 140 |
| 1991 | Meridian Plaza | Philadelphia | 38 | 3 | n/a |

***Table 1. Examples of fires in tall buildings***

It was reported that in the Joelma Building, San Paulo, Brazil *(table 1)* 300 survivors of the fire, used the elevators to make their escape from this most horrific tall building fire.

A review of these and other tall building fires, came to a significant number of design-based conclusions, which also have common links to the building life support system failures:

- Partial or no automatic sprinkler systems
- No fire detection or alarm systems
- Lack of enclosed, fire rated stairways
- Flammable wall & ceiling linings
- Inadequate compartmentation between floors.

Evaluation of the available data on these sample buildings as indicated in *table 1*, was that the building types were either apartments or hotels with high population densities and during the hours of darkness the quick and safe evacuation of the building population was not feasible, due to a significantly high proportion of the occupants being asleep and delayed early warning detection of the outbreak of the fire.

## 2. HISTORY

To understand how a new concept in intelligent fire evacuation of a building by elevators can be applied, the history of fire related incidents and how they have affected British building codes, is essential, similar history related instances are contained in many Counties fire regulations and building codes, a selection of major British instances can be summarised as:

- Theatre Royal, Exeter, England (1887)
  This fire caused 186 deaths and influenced the Public Health Act 1890 for the provision of safe means of ingress and egress in places of public resort.

- Empire Palace Theatre, Edinburgh, Scotland (1911)
  A fire broke out in the stage area and deaths occurred, but the safety curtain was lowered, in the time (2½ minutes) the orchestra played the National Anthem, 3000 people safely left the theatre *(The commonly accepted evacuation maximum time of 2½ minutes to evacuate from a fire compartment, most probably had its origin here).*

- Kings Cross Underground Station, London (1987)
  This fire caused 31 deaths had its origins under an escalator. This led to a total review of fire controls to underground stations.

Most if not all building codes disregard elevators as a means of escape during an emergency situation including fire, Why? Is it because of historical influences? Code makers lack of knowledge of reliable and safe elevator systems? Arguments still used by code makers and enforcing authorities has not altered since the first tall buildings were occupied. The weak arguments against elevator use in a fire can be summarised as; the elevators apparent limited capacity, delay and possible failure.

Although the Firefighting lift code, *British Standard BS 5588* does recognise that a suitably designed elevator and more importantly a protected elevator can be used under stringent management control, so that disabled persons can be evacuated from a building. This same standard does give guidelines for the safe and reliable design of firefighting lifts, these lifts have to operate as they are vital to the life support strategy of buildings. They have to operate every time and first time, in the event of an emergency including fire. They also have to operate within the hostile environment of a building fire, which may contain, i.e. hot smoke, soot, dampness and water.

If it is considered acceptable for a firefighters and the disabled to use the elevator(s) in fire situations, why not the general population?

Providing the elevator(s), building envelope and mechanical and electrical services are correctly designed, installed, commissioned and maintained, to work in hostile conditions why cannot they be used for evacuation purposes?

Behavioural scientists have established that the majority of building occupants will tend to adopt habits when entering and exiting familiar locations including buildings. Therefore, in the event of an emergency situation, the location and finding of emergency exits and stairs can, will and has caused confusion, not only on entering but exiting in unfamiliar surroundings.

Poor signage is an added negative factor in emergency evacuation conditions, signs that give poor instructions and that are poorly designed and located are not only confusing but can be an added danger to the building population in an emergency evacuation condition, therefore evacuation by elevators due to their physical location becomes a positive factor within the evacuation strategy. It therefore becomes a logical progression, that the elevator system is used to assist emergency evacuation in modern designed buildings.

Modern elevator control systems adopt a subsystem control command structure, which on receipt of a signal from the building life support or management systems by the activation of a local break glass, smoke, heat or fire detector, the elevators will express return non-stop to a designated safe floor. At this safe floor the passengers will unload and the elevators "locked out" until the fire signal is cleared from the system. This signal deactivation is usually achieved by the physical checking of the detector and the surrounding areas, in the instances of false alarms, the elevators are put back into general circulation mode

However when a positive fire signal incident occurs, valuable population evacuation time is lost as the elevators are homed and "locked out". The fact that the emergency services are going to take a variable period of time to reach the building, and take command appears not to be an important factor! In a city centre, during normal working hours, 5 to 10 minutes would be considered a good response time for the emergency services to reach the building, all lost valuable evacuation time.

Modern elevators and movement systems are designed to Internationally recognised norms on passenger handling during a theoretical five minute period when a "slug" of people arrives in five minutes, depending on building type it can vary between 25% of the nominal building population for a prestige office building to 10% for a hotel, these population percentages normally consider that the building is fully loaded, and do not make allowances for absences, sickness or vacancies although some design guides recommend an allowance for these variable factors. Whatever calculation method is adopted, the basic fact is that a high proportion of population in a modern correctly designed building can be evacuated quickly and in safety prior by elevators prior to the emergency services arriving and taking control of the incident. If the building has been correctly elevated based upon the theoretical full building population.

## 3. THE ELEVATOR SYSTEM

It is a design fact that modern correctly specified, installed, commissioned and maintained elevators will not catch fire unless by vandalism, when highly flammable items are deliberately ignited within the elevator car, pit or machine room.

Building codes including those associated with elevators have a vast array of safety related recommendations that overlap and intertwine with each other, in the UK there in excess of 100 of these fire safety related codes and guidance documents, not including the testing or specification of materials and fixing systems.

Consider the minimum design requirements for a firefighting lift (*as defined by British Standard BS 5588*) as a basis of a generic design of elevators that can be used for building evacuation. Although the elevator system cannot be looked at in isolation, it has to be planned and considered together with, fire engineering, construction, electrical and mechanical services.

The extremities of the elevator system are normally within the boundaries of the core area, (unless they are panoramic elevators), the core area is defined as; *the area contained by the elevator well, well walls and most importantly the elevator lobbies.*

For evacuation by elevator, the materials used in the lobbies, must have a low flameabilty, this includes any textile covering or underlay, which will not ignite, or have the effect of ignition if a hot item is placed on the covering and designed so that must not interrupt the action of any fire doors to the lobby including the elevator doors. The elevator lobby structure and fire resistance of the materials used is specified by local building regulations. However, fire separation requirements between elevator wells, machine rooms, circulation stairs and lobbies should have a fire resistance rating, e.g. not less than 60 minutes. These fire separation walls and enclosures must be of a safe and durable design that have a mechanical resistance to damage which is not significantly reduced if water from firefighters hoses or the building sprinklers are activated and jets of water are sprayed onto them.

The elevator lobbies must have a means of controlling possible hot smoke and gases developed by a fire, as it has been established that the majorities of deaths and injuries in a fire situation are as a direct result of smoke and gases being inhaled, these gases and smoke can be controlled and engineered by various design solutions including pressurisation, but are reliant on the mechanical services operating.

The modern elevator drive, control and sub-systems, are provided with some of the most sophisticated safety controls which fail to safe in the event of a very rare system failure, these safety systems are designed not only to protect the passengers who use the elevators, but also visitors and mechanics who have to come to the building.

Of these in built, safety systems, the elevator lobby doors provide the first line of defence to the building occupants, without these doors there is a major risk of serious injury from falling, trapping or crushing. For evacuation elevators the fire rated and tested lobby doors also provide a control barrier to prevent fire possibly jumping to a higher floor or machinery area.

The elevator cab has very similar requirement for the materials specification in its fabrication and construction with regard to spread of flame and toxicity as defined for use in lobby areas. It is very interesting that the code makers who drafted *BS 5588*, require that the only significant alteration to a traditional elevator cab design is that, additional splash protection is to be provided to electrical equipment on the elevator and also within the elevator well, this requirement is only for 1000mm from the fire lobby elevator door cill threshold *(figure 1)* This additional protection is as a direct consequence of the possibility of falling water droplets splashing on to the unprotected control equipment from a fire floor, possibly blowing control fuses or breakers and creating the possible hazard of a stalled elevator.

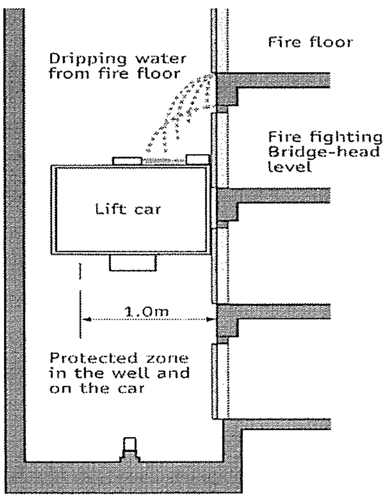


***Figure 1. Dripping water protection zone***

*BS 5588* gives no significant recommendations regarding additional protection requirements to elevator motor rooms apart from their location a risk of water ingress during fire conditions, this applies mainly to elevators whose machine rooms are in a machine below location, the electrical supply and wiring to the elevator are different to that of a normal passenger elevator in that the design and type of cables electricity supply cables should:

- Be located in a protected shaft, where possible in the elevator well; or
- Be adequately protected against the action of fire for a period not less than that required for the structural fire protection of firefighting shafts; or
- Be classified as CWZ in accordance with *British Standard BS 6387.*

In a correctly designed and constructed modern building, the firefighting elevator well is not considered a high risk area, as it is also required to run electrical circuits to elevator controls and communications to enable the elevator to run in possible hostile conditions.

## 4. THE BUILDING

The majority of buildings requiring elevators, the occupants enter at a single main entrance and use elevators to access higher levels although it is recognised that depending on the location of stairways a proportion of the next higher or lower floor level population will use the stairs.

The building construction method and materials used, must be to normal building code requirements as will be the tenants fitting out and accommodation areas.

It is recommended that the following active fire safety measures are provided:

- Automatic detection and alarm systems; manual alarm systems:
- Automatic sprinkler system (life safety system);
- Hand-held fire extinguishers;
- Wet rising main;
- Firefighting elevators;
- *Evacuation elevators;*

The following are recommended to be provided for emergencies other than fire:

Public address system, Emergency lighting system, Emergency power system and a mechanical air-conditioning system that can be adapted for smoke control purposes.

For the purposes of population evacuation by elevators, the objectives can be summarised as:

- The building population must be safeguarded so that they are ultimately able to leave the building in reasonable safety;
- That firefighters and other emergency services are able to operate efficiency and in reasonable safety;
- That any building, substructure or fittings do not endanger building occupants, including emergency services who may be in the vicinity of the building.
- That the flame spread and thermal damage from the fire origin is limited to the fire floor and one floor above.

The building evacuation by elevator design review should consider as a minimum:

Evaluate the evacuation time from a fire floor and the floor above
Consider what will be effects of smoke and heat
Consider what will be the effects on the overall building structure
Consider what will be effects and fire behaviour on floors

To achieve objective of building population evacuation by elevators, an emergency evacuation strategy must be adopted, this can be as described as detailed in the flow chart, *figure 2.*

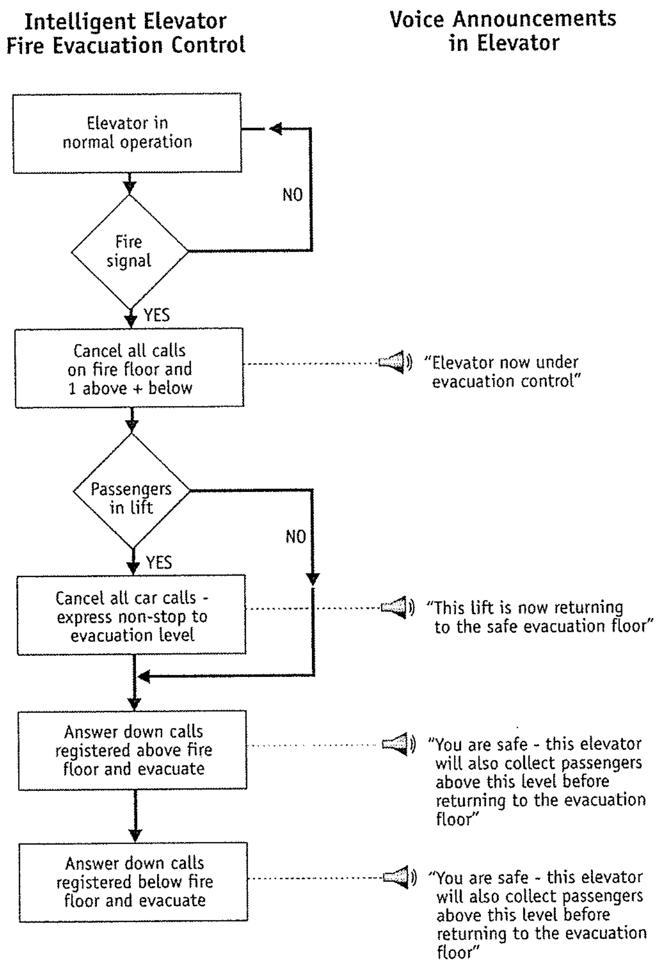


***Figure 2. Intelligent elevator fire evacuation - flow chart.***

The elevator evacuation control used in fire evacuation conditions, is a special intelligent fire collective control system that reacts to the variable fire zones. As an intelligent collective elevator control system it will know the location of the fire floor and will not serve car or landing calls registered on/to these floors, nor will it serve the next floor above the fire floor or the firefighting bridgehead floor which is below the fire *(see figure 3)*. To enable passengers already in the elevators to understand what is happening during this evacuation process intelligent voice announcements will give information and reassurance messages.

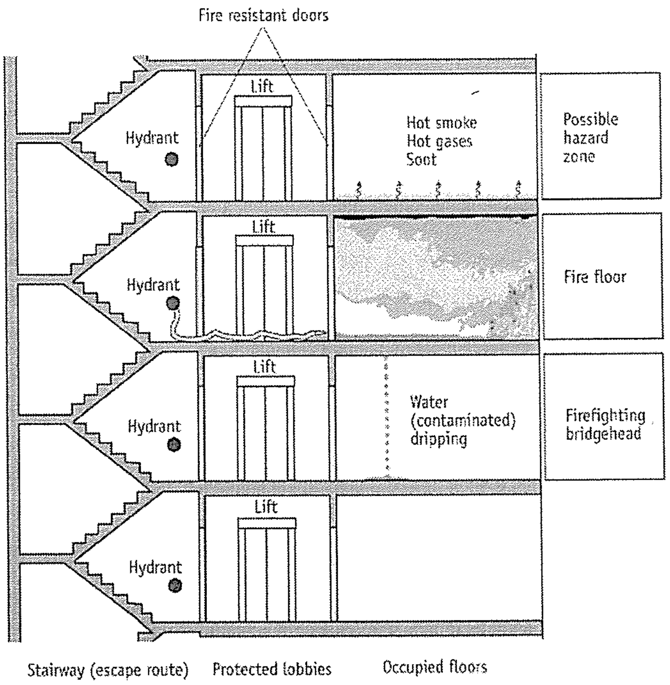


*Figure 3. Fire evacuation zones.*

## Elevator Systems

The elevator system when it is to be used for total controlled intelligent, but phased evacuation must be designed with the following critical life support systems in place;

- Reliability, Availability, Control functions and communications.

Reliability. To be reliable the elevators must initially be provided with an electrical power source, to enable the controls and drives to function. This power source should be considered as a primary supply for normal use and in the unlikely event of this failing, a secondary source shall be provided. Functionality tests on systems to be carried out at daily, weekly, monthly, bi-annually and annual inspections, not only to the elevator but on all other aspects of the building life support systems.

Availability. Availability is used in this context to establish that the elevators are available to evacuate building occupants from initially above the fire floor and then when all safe command is given to evacuate floors below the bridgehead if it is considered necessary.

Controls. The elevator controls and sub-control systems not only have to carry out the normal functions of elevator drive, i.e. starting, stopping, giving the door open and close commands in safety. But in fire evacuation conditions they have the added intelligent programable fire collective control function of determining floor levels above and below the fire floor(s) to enable safe phased evacuation.

Communication. To enable elevator fire evacuation strategy to operate successfully, a reliable and safe communication system is required, not only between the elevator cab and security command room, but within the overall of concept of emergency communication. In any building fire alarms, smoke detectors or heat sensors etc. do and will provide phantom signals, what has to be established if the alarm signal is a false or true signal, before the building including the elevators is placed in evacuation mode.

## 5. CASE STUDY

During the early hours of the 28th October 1996 a serious fire occurred on the 9th level of the 20 floor Hiroshima Motomachi High-rise apartment building, where in excess of 50% of the occupants used the elevators to escape from the fire

During the subsequent investigations, surveys were undertaken on the likelihood of evacuation by elevators based upon the characteristics of the building and its occupants, i.e. height of apartments from main level, age of apartment occupants etc.

With the relative age of the building population rising, it was expected to establish that occupants with a disability or ageism would have difficulty using evacuation stairs.

It was established from the questionnaire study that:

- The reaction of occupants after the fire, is affected by the level of the seriousness in their own fire perception.
- The likelihood of use of elevators in evacuation is fairly related to the floor height where occupants live, but is also closely related to the age of the occupants.
- Occupants are likely to choose "the route they usually use" or "a safer route" rather than a "closer route".

From the data collected it was established that approx. 50% of the occupants whose age was above 60 years used the elevators for evacuation, and the average age of building occupants was 61.64 years

The conclusions of this local survey made the following statement: "*It is important to examine the strategy to use the elevator for evacuation under the consideration of the relation between total number of evacuees and the capacity of the elevators*".

From original data, it has been possible to simulate the evacuation of a similar apartment building by elevator using controls with intelligence for the evacuation, i.e. that the evacuation by elevator is systematically and intelligently phased from above the fire floor and when cleared and made safe, it is then systematical and intelligently evacuated from below the firefighting bridgehead. All as described in *figure 2* using the fire evacuation collective control system.

What can be established from this elevator/fire simulation is, that in this building the floors directly above the fire floor are evacuated faster when using intelligent elevator fire evacuation controls. The fire/elevator *(see table 2)* simulation indicates that the safe floor nearest the fire floor, the elevator arrives within 43 seconds, when this is related to a conventional elevator collective control, the safe floor nearest the fire floor, people waiting for evacuation will have to wait 254 seconds as the elevator will collect from highest floor down, leaving those nearest the fire floor to last.

| | Fire Collective Control | Conventional Collective |
|---|---|---|
| | | |
| Level | Lift arrives after (sec) | Lift arrives after (sec) |
| 20 | 226 | 71 |
| 19 | 204 | 94 |
| 18 | 181 | 116 |
| 17 | 159 | 138 |
| 16 | Answered | Answered |
| 15 | 132 | 165 |
| 14 | 110 | 187 |
| 13 | 88 | 209 |
| 12 | 66 | 231 |
| 11 | 43 | 254 |
| 10 | No calls | No calls |
| 9 (Fire floor) | No calls | No calls |
| 8 (Bridgehead) | No calls | No calls |
| 7 | 289 | 288 |
| 6 | Answered | Answered |
| 5 | 316 | 315 |
| 4 | Answered | Answered |
| 3 | 342 | 342 |
| 2 | Answered | Answered |
| 1 | No calls | No calls |

***Table 2. Fire evacuation collective control Vs conventional collective control.***

The evacuation elevator/fire simulation indicates that the evacuation by elevator from floors nearest and above the fire floor is not only faster, but is also a feasible design solution, which must be considered as viable modern design option, providing the other life safety and fire engineering safeguards are in place and operational.

## 6. CONCLUSIONS

With commercial building population densities increasing, apartment building population age groupings rising coupled with overall mobility concerns, the need for elevators with intelligent and programable control systems linked to the total building evacuation strategy is essential.

The only viable, new building evacuation concept for the 21st Century, is to use the intrinsically safe and reliable elevator systems, to evacuate systematically and in safety.

In modern correctly designed, engineered, tested and commissioned buildings, life support information notices, should now be reworded to read;

"IN THE EVENT OF FIRE **USE** THE ELEVATORS"

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## REFERENCES

BS 5588 Fire precautions in the design, construction and use of buildings: Part 5: 1991: Code of practice for firefighting stairs and lifts (London: British Standards Institution)

CIBSE Guide D Transportation systems in buildings 1993 (London: The Chartered Institution of Building Services Engineers)

Johnson P. Safety in the Towering Inferno, Tap Tall Buildings Seminar (Kuala Lumpur 1997)

Department of the Environment, Design principles of fire safety 1996 (London)
ASME International The 2nd Symposium on Elevators, Fire and Accessibility, Baltimore, Maryland, USA (1995)

NIST -GCR -94-656 Human Factors Considerations for the Potential Use of Elevators Fire Evacuation of FAA Air Traffic Control Towers (United States Department of Commerce Technology Administration (1994)

Howkins R. Elevator Core Areas; A Comparison with Existing Structures and Those of the Future. Proceedings of the 3rd International Conference "Conquest of Vertical Space in the 21st Century. London. The Concrete Society (E&FN SPON) (1997)

Ferguson A and Law M International Conference on Performance-Based Codes & Fire Safety Design Methods. Case Study - Project Summary, Maui Hawaii (1999)

Ebihara M, Notake H, Sekizawa A, Nakahama S and Ikehata. Study on Feasibility of Evacuation in Fire Consideration of Disabled People - Case Study for the Evacuation in the Hiroshima Motomachi High-rise Apartments. Poster Session International Association of Fire Safety Science 6th Symposium. Poitiers (1999)

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