PROTECTED ELEVATORS FOR EGRESS AND ACCESS DURING FIRES IN TALL BUILDINGS

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The events of September 11, 2001 have generated renewed interest in the use of protected elevators for egress and access. U.S. building codes contain requirements for accessible elevators for assisted evacuation of people with disabilities. Firefighter lifts, required in tall buildings in some countries, are being discussed to improve both the safety and efficiency of firefighting operations. The desire for increased egress capacity of tall buildings to facilitate simultaneous evacuation has rekindled interest in elevators as a secondary means of egress for all occupants. Elevators used for each of these purposes share many of the same design characteristics and the need for an extraordinary level of safety and reliability.

HISTORY

The development of the passenger elevator is tied directly to the emergence of tall buildings. While various types of freight lifts were found in warehouses and factories these were considered too dangerous to move people. In 1854 Elisha Graves Otis demonstrated an automatic safety brake that changed the landscape. Within a few years his steam elevators had eliminated one of the major limits to building height. But while elevators proved to provide one of the safest forms of transportation there were instances where people were killed while using elevators during building fires. Heat sometimes activated call buttons bringing cars to the fire floor where smoke prevented the doors from closing (light beams are used to detect people in the doorway) and water in the shaft sometimes shorted out safety devices. Thus the use of elevators for occupant egress or fire department access was discouraged.

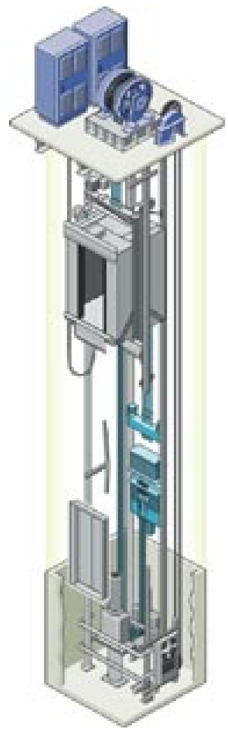

Figure 1 - Typical electric elevator

In the 1973 the elevator industry developed a system that recalls the elevators and takes them out of service if smoke is detected in the lobbies, machine room, or hoistway. Mandated in the *Safety Code for Elevators and Escalators*[1] (ASME A17.1) for all (automatic) passenger elevators this system involves two, distinct phases of emergency operation. In Phase 1, the detection of smoke or heat in specific locations results in the elevators being immediately recalled to the ground floor (unless this is where smoke was detected), the doors open, and the elevators are locked out of service. The responding fire department can then choose to use the elevators under manual control of a firefighter in the car by use of a special firefighter key, in what is called Phase 2 operation. While Phase 2 is sometimes used to evacuate people with disabilities, some fire department “standard operating procedures” for high-rise firefighting depend on the stairs for access, staging, and operations. ASME publishes a *Guide for Emergency Personnel*[2] (A17.4) that includes detailed instructions for firefighters’ service operation.

CURRENT REQUIREMENTS FOR EMERGENCY USE ELEVATORS

All U.S. building codes contain a requirement for accessible elevators as a part of the accessible means of egress in any building with an accessible floor above the third floor. These requirements are all identical, being extracted from the ADA Accessibility Guidelines (ADAAG) and mandated under the Americans with Disabilities Act (ADA).

A recent survey[3] by the International Organization for Standardization (ISO) TC178 Committee identified at least twelve countries that require firefighter lifts in tall buildings (generally those exceeding 30 m in height) to provide for fire department access and to support operations as well as to evacuate people with disabilities. England has such a requirement supported by a British Standard (BS 5588 Part 5)[4] requiring firefighter lifts in buildings exceeding 18 m (60 ft) in height. Firefighter lifts are also provided in the Petronas Towers, the world's tallest buildings in Kuala Lumpur, Malaysia.

The NFPA's Life Safety Code (NFPA 101)[5] includes provisions for egress elevators to be provided as a secondary means of egress for air traffic control towers where the small footprint prohibits two, "remote" stairs. These are secure facilities not open to the public and with limited numbers of occupants.

While the above requirements exist for elevators for emergency use by firefighters and people with disabilities, there are currently no codes or standards in the world for egress elevators for use by building occupants. There is, however, an example of a structure that uses elevators as the primary means of egress and fire service access. This is the Stratosphere Tower in Las Vegas, Nevada (Fig 2). Essentially an eleven-story building sited atop an 250 m (800-foot) tower, it has a single emergency stair that is considered impractical. Thus the four, double deck elevators are designed for emergency use. One is reserved for use by the fire department with the remaining three used under manual control to evacuate all occupants from the two lower floors that are designed as areas of refuge. Occupancy of the tower is limited to the number of people that can be evacuated by the elevators in one hour[6].

Figure 2 - Stratosphere Tower in Las Vegas

COMMON CHARACTERISTICS

Whether for access by the fire service or for egress, elevators provided for use in fire emergencies share several characteristics intended to assure safety and reliability. They are required to be installed in a smokeproof hoistway constructed to a 2-hr fire resistance and pressurized against smoke infiltration. Enclosed lobbies are required on every floor, which are also 2-hr (1-hr in fully sprinklered buildings) and pressurized. In fact, the lobby is crucial to safe operation since elevator doors are particularly susceptible to jamming under even mild pressure differences. Thus, the smoke control system should pressurize the shaft and lobby together so that there is a minimal pressure difference across the door.

The lobbies are provided with a 2-way communication system to the building fire command center so that people in the lobby can be informed of the status of any impending rescue. Emergency power to operate the elevator in the case of main power failure is also specified. Water intrusion into the hoistway can short out safety components such as switches that prevent the doors from opening unless there is a car present, and even the safety brake; so water protection or waterproof components are needed.

Within the United States, any use of the elevator for fire service access or for rescue of people with disabilities is done under manual control of a firefighter in each car under Phase 2 recall. The elevator industry cannot guarantee that its automatic controls will react appropriately to all hazards that might occur and cannot assure safe operation. Thus, the trained operator must be able to recognize hazardous conditions and cease operations. This represents a resource allocation problem for most fire departments that simply cannot assign a firefighter to every car. Further, the susceptibility of safety controls to failure from water results in a requirement for an automatic shutdown of elevator power before activation of fire sprinklers in the machine room or hoistway. This would result in any operating elevator cars to suddenly come to a halt.

SOLUTIONS FOR RELIABLE EMERGENCY ELEVATORS

The first solution is to eliminate the susceptibility to water by using waterproof components and eliminating the requirement to shut down power. Next is to eliminate the need for firefighters to operate each car.

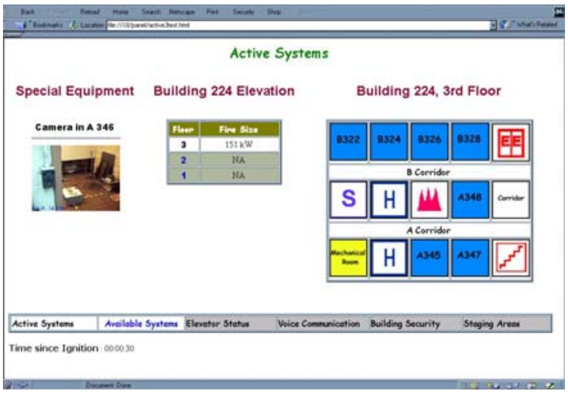

Figure 3 - NIST prototype fire service interface

Here we propose operating the elevators under ***remote manual control***. The elevator industry would identify every parameter critical to the safe operation of the elevator and these would be monitored and displayed in real time on the ***standard fire service interface***[7] recently implemented in the National Fire Alarm Code[8] (NFPA 72). This interface was developed as a tool for incident management that can collect information from its own sensors and other building systems (through a common communication protocol such as BACnet) and display the information in a format common to all manufacturers' systems. The interface further supports specific control functions so that the operator could manually initiate recall if any monitored parameters exceed the allowable operating envelope (Fig 3).

Because continuous monitoring of the system is crucial to safe and reliable operation, we propose incorporating a triple redundant communication pathway. The fire alarm system is currently required to incorporate two redundant communication trunks usually run up the two stairways. Either trunk is sufficient for the full system operation and two-way communication to the entire building. While these trunks are "remote" it is possible that a single event could sever both trunks, rendering the portion of the system above the breaks inoperable. We propose providing a wireless link between the bottom (generally the fire command center) and the top of the system as a third, independent pathway. This would maintain full operation of the system should both trunks fail. This would add little cost, ensure high reliability, and can be done with current technology.

One outstanding reliability question involves the provision of emergency power to the elevators. Most tall buildings have triple redundant power systems with generators on site. The problem is that the power is generated at the base of the building and the hoisting and controllers are at the top. How do we provide a reliable transmission path between the two? It may be possible to use a battery/inverter system in the machine room with sufficient capacity to move the cars safely to the bottom. Similar systems powered from small batteries are used in seismic areas to move cars a single floor.

DEVELOPMENT OF OPERATING PROCEDURES

Prior research and recent advances can address all of the technology issues identified as critical to the safe and reliable operation of elevators during fires. The remaining piece is the development of operating procedures for access, egress, and rescue of the disabled that are sensitive to the human factors issues and to the need for these activities to occur simultaneously in tall buildings. Thus the systems must be designed and used such that they do not interfere with all these uses.

Firefighter Lifts

Many US fire departments have adopted operating procedures for fires in tall buildings that incorporate elevator access that are similar to those described in a draft CEN/ISO standard[9] for firefighter lifts. The primary differences relate to the fact that most firefighter lifts are dedicated to this use and thus are immediately available to the fire service on their arrival. In the US firefighters use the passenger elevators that are either still operating or are waiting at the ground floor in Phase 1 recall.

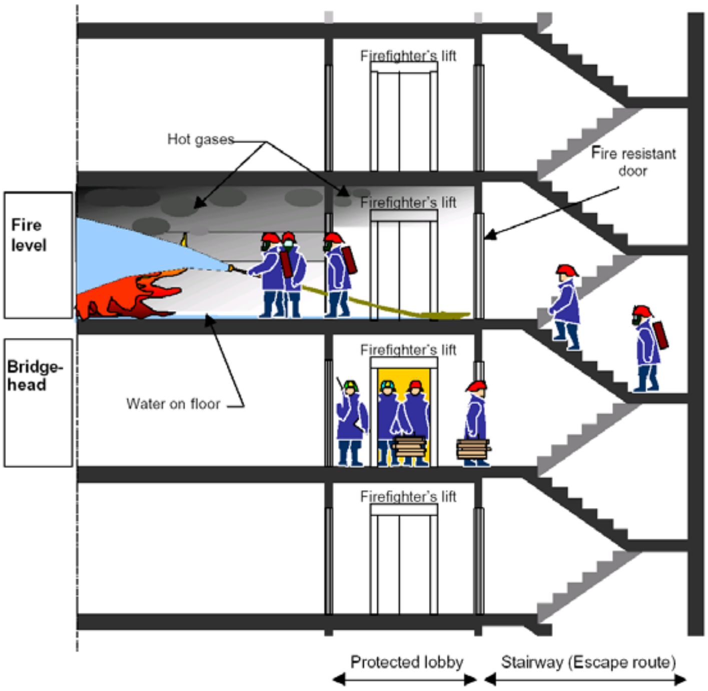

Figure 4 - firefighter lifts carry people and equipment to the floor below the fire with attack staged from the stairs[9]

The procedure is for the firefighters to use the lift to transport people and equipment to the protected lobby 2-3 floors below the fire floor where they stage for their suppression operations. The firefighters then move up the stairway to the fire floor with a standard length of hose (30 m is common in the US and 60 m in Europe), which is connected to the standpipe located in the stairs. This is important because once charged with water the hose becomes very stiff. The hose is usually looped down the stairs and back up so that it can be advanced onto the fire floor more easily. Working from the stairway also provides a protected area to which the firefighters can retreat in case the fire threatens them. The common hose lengths dictate the distribution of firefighter lifts within a building in the same way as the distribution of standpipes. For example, the New York City building regulations require standpipes located so that one is within 40 m (125 feet) – 30 m (100 feet) of hose plus 10 m (25 feet) of water throw from the nozzle of any point on a floor. Figure 4 is an illustration of firefighting procedures utilizing a firefighter lift, taken from the CEN/ISO draft.

This operating procedure highlights the importance and interrelationship of the firefighter lift, protected lobbies, associated stairway and standpipe. These components form a system described in BS5588 as a *firefighting shaft*. The need for an associated stairway impacts on the arrangement of the components and on the designation of multiple cars of an elevator group as firefighter lifts. It also raises issues of the firefighting lift and stair used for occupant egress.

Egress Assistance for People with Disabilities

Standards for firefighter lifts all include their use by firefighters to provide evacuation assistance for people with disabilities. Even in the US where there are no firefighter lift standards the building codes require *accessible elevators* (part of an accessible means of egress) that are used by the fire service to evacuate people with disabilities. The procedures generally are that such occupants proceed to the protected lobby (sometimes called an area of refuge) and request evacuation assistance through a two-way communication system (to the fire command center) provided.

Not covered is any procedure for coordinating the use of the lift for evacuation assistance with that of firefighting. First priority will be given to moving firefighters and equipment to the staging floor to allow the start of suppression operations. Then a firefighter would presumably be assigned to begin to collect waiting occupants in the lift under manual control. Command staff in the fire command center could inform the operator on which floors there are occupants waiting and these could be gathered in some logical order and taken to the ground floor. If there are more occupants than can be assisted in a single trip there is a question about the order in which they are removed. Presumably, this would be done for the floors nearest the fire first, then above the fire and finally below the fire. Because these people are required to wait it is especially important to provide this two-way communication system to the lobby (Fig 5) so that they can be reassured that assistance is coming. The real-time monitoring system described earlier would assure conditions in the occupied lobbies remain tenable.

Figure 5 - Maintaining communication with waiting occupants is crucial

Occupant Egress Elevators

As mentioned earlier, with only rare exceptions for special cases, elevators are taken out of service in fires and people are advised never to use elevators during fires. This policy does not represent a severe hardship for most buildings and occupants, but poses problems for people with (mobility) disabilities and for tall buildings where stairway egress times can be measured in hours.

Operational procedures for occupant egress elevators raise some interesting issues. First, how can overcrowding be avoided? Elevators have weight switches that disable an elevator that is overcrowded. Without a floor warden or firefighter controlling the loading it is likely that occupants may attempt to overcrowd an elevator during emergency evacuation. Similarly, the elevators are unlikely to be capable of handling a large fraction of the floor load – the system specified for air traffic control towers is designed for elevator evacuation of not more than half the occupants. How will at least half the occupants be encouraged to take the stairs? One possibility is to limit the capacity of the lobbies so the excess is forced into the stairways. Another is the phased direction of the elevators to evacuate floors near the fire first. If occupants have the choice of waiting in the lobby or beginning to move to safety down stairs, what choice will they make?

Egress elevators are most likely to be utilized in tall buildings and here the elevator systems are vertically zoned in 30- to 40-floor sections. How would elevator evacuation be operated with vertically zoned elevators? One example where this is being done is for an 88-story building currently under construction in Melbourne, Australia. In the Eureka Place Tower, elevators in the third of the building containing the fire are taken out of service and occupants all use the stairways to the next (lower) transfer floor where they board express elevators to grade. People with disabilities are assisted by firefighters in their dedicated lifts within the zone of origin. This strategy is similar to the Petronas Towers where occupants above the sky bridge level use stairs to that level, move across to the other tower, and use the elevators to grade.

Coordination of emergency elevator uses

Finally, the complete integration of the elevators into the emergency operational plans in tall buildings presents some coordination issues that will need to be addressed. One example is whether firefighter lifts and egress elevators can share common lobbies (Fig 6). Occupants awaiting egress may interfere with staging of suppression operations. Another is access to stairs and the use of the stairs for mounting the fire attack as discussed previously. A third is the sequence of egress operations. First priority would be given to egress of occupants from a few floors around the fire floor. Next a group of

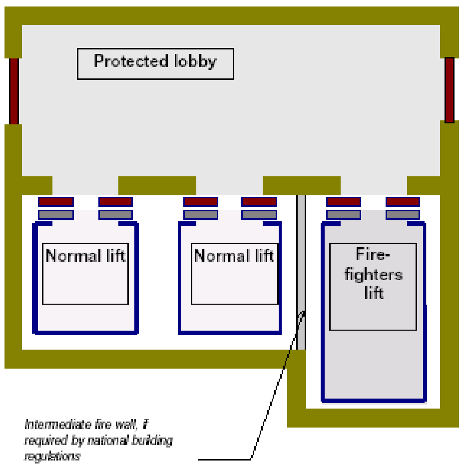

Figure 6 - Will shared lobbies lead to interference between operations and egress?

floors above the first group should be evacuated but if a disabled person enters a lobby on another floor at what point should that person be extracted? These sequencing delays would likely cause people on other floors to use the stairs rather than awaiting the elevators. Should people above the fire take the stairs to a point and then transfer to the elevators while people below the fire should take the stairs all the way? NIST plans to incorporate elevators into evacuation models so that a series of simulations can be conducted to identify the most effective operational procedures. NIST is also working with the US elevator industry to develop control software that can adapt to changing conditions and maintain safe and reliable operation of the elevator system.

Concluding remarks

Operational procedures and sequencing will have an effect on the design and arrangement of the entire egress system and need careful thought. The operational procedures selected must take into account complex human behavioral issues to be successful and also have significant impacts on the design and arrangement of the systems. Thus these issues should be discussed and resolved as a system so that appropriate requirements can be developed for standardization. Finally, there are significant advantages in developing common approaches globally. With the degree to which people travel internationally it is highly advantageous to have consistent emergency procedures so that people know how to react and do not depend on instructions that may not be understood clearly due to language difficulties.

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