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HUMAN FACTORS CONSIDERATIONS FOR THE POTENTIAL USE OF ELEVATORS FOR FIRE EVACUATION OF FAA AIR TRAFFIC CONTROL TOWERS

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I. INTRODUCTION

A. Purpose of this study. This study is part of a wider investigation of the feasibility of using elevators for emergency egress in Federal Aviation Administration (FAA) air traffic control towers. This study is also part of an ongoing effort to examine those factors that will allow the design, installation and maintenance of elevators that can be safely used to evacuate occupants during fire emergencies from all types of occupancies. Elevator use for emergency egress is a complicated topic, and the specific issues that must be dealt with vary considerably depending on the specific application. This is especially true where human factors are concerned, because the characteristics of the individual building occupants vary so widely. Organizational attributes differ also. The focus of this report, human factors considerations for using elevators for evacuating aviation control towers, is narrow. In order to be safe for fire evacuation, elevators must be protected from fire, heat, smoke, water, loss of electric power, and loss of elevator machine room cooling. These engineering issues and an overview of human considerations about elevator fire evacuation are presented by Klote, Levin and Groner (1994).

B. Related study. A more broad-ranging report was written by the present authors titled Human Factors Consideration in the Potential for Using Elevators in Building Emergency Evacuation Plans (NIST-GCR-92-615). This study presented a detailed discussion of many issues of concern in elevator evacuation, and did not focus on any particular type of occupancy or building. The study presented herein examines the same issues as they pertain to aviation control towers.

C. Visits to towers. The authors visited several air traffic control towers. As discussed in the next section of this report, the towers are very unusual buildings. For this reason, it was imperative to conduct on-site examinations of a representative sample of towers. In all, 13 towers were visited by one or more members of the project team. These towers were selected to provide examples of all the principal architectural designs used by the Federal Aviation Administration, as well as some "non-standard" types which are not replicated elsewhere. The project team was comprised of the two authors of this report, both human factors specialists, and the scientist/engineer from the National Institute of Standards and Technology, Dr. John Klote, who is the project director for this and the other studies related to fire safety and elevator use.

The visits included a tour of each facility and interviews with a manager and at least two air traffic controllers. In most towers we also interviewed FAA employees concerned with maintaining the building and the equipment. These brief interviews (typically around 15 minutes) were required to solicit opinions about the willingness of building occupants to use elevators in the event of a fire emergency, as well as various other topics. Air traffic controllers will evacuate only after alerting the pilots they are directing and, normally, they will evacuate only after arranging for other controllers to assume their more critical functions. During the interviews we attempted to learn how long the controllers might take before they would leave the cab so we might better understand the potential queuing at the elevators and possible effects on the fire safety plan of any possible substantial delays in actually evacuating.

Table 1. FAA Air Traffic Control Towers Visited

Location	Design	Visitors	Date
Scottsdale, SDL	Leo Daly Low	Klote, Levin & Groner	Nov 16
Andrews AFB, ADW	Pei	Klote, Levin & Groner	Jan 31
Washington/Dulles, IAD	non-standard	Klote, Levin & Groner	Jan 31
Detroit/Metro-Wayne, DTW	Leo Daly Major	Klote, Levin & Groner	Feb 1
Baltimore/Wash, BWI	non-standard	Klote & Levin	Feb 3
Metro Oakland, OAK	non-standard	Groner	Feb 7
Bates Field (Mobile), MOB	Lart	Klote & Levin	Feb 8
Sarasota/Bradenton, SRQ	Mock	Klote & Levin	Feb 9
Ontario Int'l, ONT	Goleman Rolf	Groner	Feb 15
Van Nuys, VNY	Type O	Groner	Feb 16
Philadelphia, PHL	Welton Becket	Klote & Levin	Feb 22
Atlantic City, ACY	Goleman Rolf	Klote & Levin	Feb 23
Tetersboro, TEB	AVCO	Klote & Levin	Feb 24

D. Importance of a systems approach to the evaluation of safe elevator use. Human behavior can not be "engineered-out" of any system designed to protect people from fires. Even the most reliable hardware system, for example, fire sprinklers, inevitably depends on people to maintain them and to avoid compromising their integrity. Similarly, the behavior of people always depends on the settings in which they are located, including the fire protection features and physical layout of buildings. This essential truth, the mutual dependence of human behavior and building features, was repeatedly illustrated during our visits to the towers.

This study specifically involves an application of the Life Safety Systems approach. Essentially, this heuristic approach uses the concept of life safety strategies (the basic plans that people follow during emergencies) as a means of integrating all the various components, human actions and hardware, that comprise an elevator evacuation system. For a detailed explanation of this approach, see Groner and Levin, 1992.

E. Distinctiveness of air traffic control towers. Consistent with the life safety systems approach, the design of any elevator evacuation system must be tailored to the specific application. This is especially true for air traffic control towers, in as much as they are very distinctive from other occupancies.

Air traffic control towers are tall and narrow. They are tall because the "cab" needs to be high enough that the air traffic controllers can view any portion of the airport or the air space where there might be airplanes with which they are in communication. Narrow towers are less expensive to build, are less likely to contain extraneous activities (that could lead to a fire requiring an evacuation) and are unlikely to obstruct the controllers' view of the runways. The limited area on each floor discourages installing two stairways and precludes installing two stairways that are remote from the standpoint of providing independent access to the exit stairways. (Once in the stairways the routes could be adequately independent.)

The unusual geometry of air traffic control towers has created a unique emergency egress problem. Most current air traffic control towers contain both a single stairs and a single elevator serving the upper portion of the tower. The elevator is used to avoid using a long stairway to travel to and from a location below the work site in the cab. (The elevator does not serve the cab itself. The cab can be reached only by a single stairway.) The stairs are needed for emergency egress and as a backup when the elevator is not in operation due to routine maintenance or unanticipated problems.

This unusual configuration has created an interesting problem as regards emergency egress. The presently installed elevators in the towers, as well as current elevators in other buildings, are unacceptable as a means of leaving the building in a fire emergency. The towers are left, therefore, with only a single means of emergency egress. Having only one means of egress, some towers currently fail to meet a safety specification in a code used by the Federal government as described below.[1]

The Life Safety Code, a model code whose development is administered by the National Fire Protection Association, is used by the Federal Occupational Safety and Health Administration to determine whether Federal agencies meet minimum levels of safety for their employees. Section 5.4 of the Code requires that there be at least two means of egress from any story of most buildings, and specifically disqualifies elevators as a means of egress.

F. Relationship of occupancy loads to Code requirements. The low occupancy loads in most towers help them to meet Code requirements. Section 30-2.4 of the 1991 and 1994 editions of the Life Safety Code provides an exception to the two means of egress requirement for certain "towers." Among other requirements, the exception to the two means of egress requirement can be used when the tower is occupied by fewer than 25 persons. (In earlier editions, the exception applied when each of the floors are occupied by fewer than 25 persons.) Most of the towers we visited easily fall below this occupancy limit.

However a few of the towers we studied had more than 24 occupants at some time during a typical day. These towers are older nonstandard designs where the tower is not devoted exclusively to air

[1] Although the towers fail to meet a specification in the Life Safety Code, this does not mean that the towers fail to meet the requirements of the Code. The Life Safety Code permits the use of alternate means of achieving the desired level of safety. It is beyond the scope of this report to address whether current air traffic control towers meet or fail to meet the requirements of the Code.

traffic control from the cab. In one of these towers, the TRACON[2] and administrative offices are located in the tower. In another, the local port authority maintains administrative offices within the tower and there is a public bar/lounge in the tower as well. This latter tower is scheduled to be replaced in a few years. Further, it is our understanding that the newer standard designs for towers largely restrict such extraneous functions in the towers. Nonetheless, some of the towers that we visited did not meet all the specifications in the Life Safety Code. This study is dire at studying the possibility of qualifying the elevator as a second means of egress, both for the purpose of satisfying Code requirements, and as an enhancement to the overall safety of tower occupants.

As stated above, the Life Safety Code [Section 30-2.3, Exception No. 3(b)] has an exception that allows only one means of egress in towers occupied by fewer than 25 persons. This exception applies only when all the people in the tower are "able-bodied". Despite the ambiguity inherent in the choice of wording, the intent is to preclude the presence of people who cannot descend stairs, and, therefore, who would not have any safe means of egress that they could use without assistance in the event of a fire emergency.[3] Currently, towers are occupied only by persons who are able to use stairs. A potential benefit to qualifying elevators as a second means of egress is that a wider range of persons could work in the tower without violating this important exception in the Code.

Historically, only people with normal mobility have been hired and trained as air traffic controllers. The problems that people with disabilities would have in satisfactorily performing the tasks of the job are beyond the scope of this study. However, this policy is being reevaluated within FAA.

The current absence of persons with such mobility-impairments is especially important because much of the impetus towards using elevators for emergency egress in other occupancies has come from the problems of evacuating people with disabilities during fires. However, the ability to safely evacuate towers using elevators would remove one barrier to the presence of people with mobility disabilities in the towers. Procedural changes, related to fire safety, that would be necessitated by their presence are explored later in the section covering life safety strategies.

G. Tower visitors. For the most part, visitors are not found in aviation control towers. In particular, security is provided to prevent unauthorized persons from entering FAA controlled portions of the tower. (In one tower a security person, who was not a FAA employee, was in the tower observing the loading of a plane as part of his security function. Also, the authors of this report were "visitors" when we conducted our study.) In one of the older non-standard towers, a bar/lounge area was located in the tower. However, access to this area was provided by a dedicated

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[2]TRACON contains a group of air traffic controller controlling airspace that is not controlled by controllers in the cab of the tower.

[3] Apart from Life Safety Code requirements, persons with stair-use related disabilities are prevented from working in the cabs of towers because, to date, the only access to the cab is via stairs. The elevators in control towers travel only to a level below the cab. A typical elevator going to the cab might block the required views of runways or planes in the air and would use a large percentage of the floor space in the cab. See Klote, Levin, and Groner (1994) for discussion of possible elevators that might serve the cab.

elevator. The FAA elevator did not serve this floor. As we discussed in our prior reports (Groner and Levin, 1992; and Levin and Groner, 1992) special measures need to be taken to assist visitors in following the procedures designed to enable safe use of elevators, especially when those visitors are not accompanied by permanent building occupants. However, the absence of unaccompanied visitors greatly simplifies the organizational aspects of evacuating by elevators.

H. Single tenant. For the most part, the towers were the exclusive domain of the FAA. The presence of a single "tenant" greatly simplifies the management of evacuations and the training of occupants. One of the visited towers was a notable exception. This tower included numerous administrative offices and equipment rooms used by the local port authority. As such, planning, coordinating, and executing an emergency evacuation would be more difficult. For example, the port authority maintained the facility. The FAA representatives interviewed by the visiting project team member were unfamiliar with the fire alarm system. They did not know where the annunciator was located, and they were uncertain as to who they needed to contact in the port authority. When asked about the alarm system, the facilities manager said that he too was unfamiliar with the system, and we were unable to contact the port authority employee with the needed information. This type of coordination problem was not evident in towers under the exclusive control of a single "tenant", i.e. the FAA.

II. DEVELOPING AND INSTALLING THE EMERGENCY PLAN

A. Life safety strategies. A building emergency system based on the life safety systems approach is based on a set of strategies, all with the objective of keeping building occupants away from smoke and fire conditions. The set of strategies--called life safety strategies--is the starting point. Systems components are discussed in relation to their contributions to completing a strategy.

We sometimes refer to a "set of strategies," because there may be a separate strategy for each floor or group of floors and there may be backup strategies.

A "life safety strategy" has been defined as "a general plan for protecting building occupants from being exposed to the flames and smoke of a fire." (Groner, 1985). A strategy can be expressed as a short statement that describes the fundamental actions that building occupants follow in a fire emergency. A few examples are: "Everyone in the building leaves using the nearest exit," and "The alarm alerts building occupants that they may need to evacuate. Floor wardens are notified when their respective floors should evacuate, and which stairway should be used." (The above three paragraphs are taken from Groner and Levin, 1992.)

Life Safety Strategies are heuristic devices that integrate all the disparate components of an elevator evacuation system. Using the elevator to evacuate aviation control towers is fairly straightforward, without the complexities of evacuating large numbers of people on many floors from other occupancies such as high rise office buildings. In these more complex settings, different strategies are needed depending on such factors as occupants' location in the building relative to the fire. However, if a tower were to have a fire safe elevator, the following basic life safety strategy would seem appropriate for ambulatory occupants:

> Use stairs to leave tower. If stairs unavailable, then use elevator.

As discussed earlier, the installation of elevators that can be used safely during fire emergencies would remove one impediment to the presence of persons who cannot use stairs. For such mobility-impaired occupants, the following strategy would be more appropriate:

> Use elevator to leave the tower. If elevator is unavailable, then summon assistance to descend stairs.

These two strategies then become the basis for developing the entire elevator evacuation system. The components directly concerning fire protection engineering are discussed in the companion report (Klote, Levin and Groner, 1994.) This report focuses specifically on the organizational and human factors that will determine whether these basic strategies can be successfully implemented during an emergency.

B. Suggestions for the "written" plan. Written plans are generally created to serve two, often incompatible, goals. First, they provide information to building occupants about the appropriate procedures to be followed during an emergency, what we call an "action document." Second, they provide evidence to organizational and regulatory authorities that an appropriate plan has in fact been developed--what we call a "compliance document." The two goals tend to be incompatible: the first goal encourages brevity, clarity, and the absence of information that is non-essential to the reader; the second emphasizes comprehensiveness to ensure that all the elements of the plan have been incorporated. A possible resolution of this conflict might be to prepare two documents, one directed at each goal.

During our visits we collected the portions of tower emergency plans that concerned fire evacuations. For the most part, these plans were principally intended to serve as compliance documents. Fire emergency procedures were a small portion of a larger document concerned with all types of emergencies. The fire emergency portions were typically brief, reflecting the relatively straightforward nature of such an emergency in these facilities.

In general, we recommend that separate action documents be developed for different occupant groups to better avoid the common problem of masking critical information by including information that is irrelevant to the actions. If there are different plans for different parts of the building, it is anticipated that there will be significant overlap in the contents. The availability of word processors and inexpensive high quality printers help to make this approach feasible.

The same action document, with some minor variations, can probably be used for all tower occupants, because all will be using the same life safety strategy. Moreover, the plans for tower personnel can be so simple that the entire action document for fire emergencies can possibly fit on a single page of large print. This document should clearly state the life safety strategy (e.g., "If there is evidence of an actual fire, use stairs to leave tower. If stairs are unavailable, then use elevator.") Specific actions that are needed to implement the strategy should also be addressed, (e.g., how to investigate an alarm, where to report a fire, and the details of transferring control of the airspace). The contents of the plan may vary depending on the jobs of the building occupants. For example, the action document for those maintaining the electronic equipment would not need to include procedures for transferring control of planes to a different tower or to the TRACON.

A common problem with all types of occupancies is that the action documents, if they exist at all, are not immediately available to building occupants. They may have been distributed, but people may not remember where they put them. Access to the action document should be immediate, and its location should be obvious. For example, posting the action plan by a fire alarm annunciator seems appropriate for many of the towers that we visited.

C. Criticality of occupant knowledge about life safety systems. As a general rule, during an emergency, people will pursue a course of action that they believe is most likely to provide safety. A building may have fire protection features that support a certain life safety strategy, but if the building occupants are unaware of those features, they may be unwilling to follow the strategy. The use of elevators during fire emergencies is an excellent example of this problem. Later in this report, we discuss the reluctance of interviewed air traffic controllers to use elevators during an emergency. Without a fairly detailed understanding of the hardware features used to protect the elevators, we believe that many tower occupants may not follow the recommended strategy. Instead, they may endanger themselves needlessly by using stairs that have a dangerous amount of smoke, or by simply remaining in the tower hoping that the fire can be controlled and that they will be rescued.

D. Training. To assure that the emergency plan is followed properly in a fire emergency, it is important to inform the building occupants about the plan and the total fire safety system. The occupants need to receive training. We do not envision formal training classes with large groups of students. The training can be less formal and more individualized. For example, individual air traffic controllers could view instructional videos during non peak hours. Reading of the emergency plan would convey considerable information. Simulated fire drills would make the plan more understandable and help the participants remember the plan. Small groups could discuss what constitutes a fire that warrants an emergency evacuation.

Topics that should be covered include:

Characteristics of the new elevators that make them safe to use when there is a fire. Occupants need to understand that the presence of some smoke does not disallow elevator use or stair use. Some entry of smoke into the elevator lobbies or stairways is likely as occupants open and close doors, but a very limited amount of smoke will neither endanger occupants nor interfere with the operation of the elevator.

Fire safety features of the building that make it unlikely that there will be a fire that becomes dangerous enough to require an evacuation. The training should include encouragement not to violate these fire safety features.

Fire safety features that make it likely that, in the event of an evacuation, there will be a safe path to both the stairs and the elevator.

Characteristics of the stairs that make it unlikely that they will be blocked.

Characteristics of fire and fire growth. When people who are investigating smoke alarms or smoke odor discover a fire, they should be able to ascertain to some degree the extent to which the fire is an immediate threat.

Procedures for safely investigating potential fires. Controllers need to know how to investigate locations where opening a door or using the elevator could endanger themselves or allow fire or smoke to spread to other locations. (For example, anyone investigating ambiguous signs of a fire should know to make sure the edge and knob of a door is cool before it is opened. Only if the door is cool should it be opened, and then, if the door opens toward the person, a shoulder should be braced against the door while it is opened just a little.)

Procedures for transferring control of aircraft to other air traffic controllers.

Assignment of responsibility for calling the fire department and upon their arrival informing them of the location of the fire.

Procedures for determining the location of all building occupants during the evacuation and determining when all occupants have evacuated. Procedures for meeting the fire department upon their arrival and informing them of the need for rescue.

Training in the use and limitations of portable fire extinguishers.

E. <u>Need for elevators and other building equipment to be highly reliable</u>. Air traffic control towers normally have only one elevator. In the elevator industry it is well known that buildings with only one elevator suffer from a high level of complaints due to "out-of-service" conditions.

People become annoyed when they cannot use the elevator and must climb the stairs, especially when the climb is long such as in an air traffic control tower.

Our interviews with air traffic controllers clearly demonstrated that the perceived reliability of elevators has a strong effect on the controllers' expressed willingness to use them during an emergency. In a few of the visited towers, we heard comments that there had been frequent problems with the elevators. For example, one tower was visited on a Monday morning, and the elevator had been repaired just prior to the visit after having been inoperable since Friday. In a second tower the elevator was not operating smoothly (i.e., there was a very noticeable vibration) even though repairs had been completed several hours earlier. In the towers where we heard complaints about reliability problems, we noted that tower occupants were much more emphatic in expressing their reservations about using elevators during an emergency. Many of these controllers continued to lack confidence even after we described the types of features that could make elevators relatively fire-safe. In the other towers, controllers also expressed hesitation, but in a milder fashion. Most of these controllers seemed more willing to revise their views after our discussion of the safeguards that would be designed into fire-safe elevators. It follows that it is important to have elevators with a minimum of down time. Scheduled preventative maintenance should be well publicized in advance so that the down time is not interpreted as a sign of an unreliable elevator.

It is reasonable to generalize that good general maintenance of the building will encourage people to trust a fire safe elevator system to provide a safe means of emergency egress. Similarly, occupants of a poorly maintained building are likely to hesitate using an elevator when their safety depends upon its reliability, even if the elevator itself has been generally reliable. Generalizing further, it is likely that the attention given to preparing and distributing fire safety plans and the effort given to explaining the fire safety features of the building to the occupants are likely to increase the occupants' confidence in the elevator. As one General Services Administration official said to the authors during a related study, "We have to earn their trust."

III. FACTORS AFFECTING ACCEPTANCE OF AND COMPLIANCE WITH THE EMERGENCY PLAN

A. Recognition that current elevators should not be used in case of fire. For over twenty years the general public has been warned that they should not use elevators for evacuation in fire emergencies. Fire safety experts have been consistent in their universal agreement with this policy. Most buildings with elevators have signs to that effect near each elevator on each floor that is not at grade level. The average building occupant is well aware that he or she should not use the elevator if there is a fire in the building. All the FAA employees we interviewed knew they were not to use elevators during a fire.

Actually the generally accepted strategy is a little more complicated. Many experts recommend that ...e occupants can and should use an elevator after the fire department has determined that the ...vator can be used safely. This would be a reasonable way of evacuating an occupant who has ... disability that would make it impossible or very difficult for the occupant to use the stairs.

If elevators that are safe to use for evacuation in fire emergencies are installed in aviation control towers, most air traffic controllers, technicians and others in the tower initially will be scared to use the elevators for fire evacuation. For the installation of such elevators to be a success, there is a need for an effective program to reassure the building occupants that the elevator is different from typical elevators, and is safe to use for evacuation in fire emergencies. Years of training not to use elevators during fires is surmountable. People can be taught that during fires they can use those elevators that have been specially designed for such use and to avoid other elevators during fires. But the problem must be addressed with a well designed training effort. See section on training on page 7.

B. Impact of psychological control. People have strong psychological needs to exert some control over their own fate. This is a well known psychological need that was highlighted in an earlier study regarding the potential for using elevators in fire evacuations (Groner and Levin, 1992, p. 31). As anticipated, in the interview sessions the controllers strongly preferred using the stairs to using an elevator during a fire emergency. In addition, they frequently expressed their concern that they would not want to use an elevator during a fire--even as a backup escape route--primarily because they did not want their safety to rely on the reliability of a mechanical system, i.e., an elevator. They were afraid of being trapped between floors.

C. Confidence that fire safe elevator system can be installed and maintained. When we interviewed air traffic controllers and other FAA employees working in the towers, we encountered considerable skepticism about the likelihood that the system would really work as claimed. They expressed concern that the elevator evacuation system would not be maintained sufficiently rigorously for them to entrust their lives to it. They frequently pointed out that the current elevator in their tower is unreliable or in a poor state of repair. See discussion on need for elevators and other equipment to be highly reliable on page 8.

D. Wait for the elevator. Air traffic control towers, in general, have a small number of people in the tower itself. There was an office area associated with each of the towers we studied. From a fire safety standpoint, most of these office areas would be considered as separate buildings--there was a good fire barrier (i.e., a two hour fire wall) between the tower and the office area. (The escape route of at least one tower includes passing through the office area--a consideration that is beyond the scope of this report.) In most facilities, the occupants of the office area would not be competing for the limited capacity of the tower elevator.

There are several factors that would affect the amount of time that tower occupants might be required to wait for an elevator if the stairs cannot be used safely.

> The capacity of the elevator compared to the number of tower occupants. Multiple trips most likely will be required because the single elevator may not have the capacity to hold all occupants of the tower at one time. If TRACON is in the tower, the elevator may need to make several round trips. (Klote, Levin and Groner, 1994, address the issue of minimum elevator capacity.)
>
> Varied arrival times at the elevator lobby. Some occupants would wish to start their descent on the elevator while others are undertaking actions to assure safe airspace during and after tower evacuation.
>
> The travel speed and acceleration of the elevator.
>
> Enroute stops. The elevator may stop at floors other than the one nearest the cab.

E. Down time during scheduled and unplanned maintenance. Many towers operate 24 hours a day. Maintenance of elevators requires taking the elevator temporarily out of service during routine maintenance. Also, unanticipated problems can take the elevator out of service.

If the fire safe elevator is required to meet fire safety requirements (e.g., to provide a required second escape route) a backup procedure might be needed to maintain the required level of safety during down time. Examples are: sounding of the fire alarm might result in "immediate" evacuation rather than investigation of the cause of the alarm; and special efforts to assure that doors to storage areas and equipment rooms are properly closed and stay closed.

If the fire safe elevator is installed to provide a level of safety beyond that required, providing that increased safety for the vast majority of the time should be deemed sufficient and praiseworthy.

F. Individual differences. While nearly all FAA employees interviewed expressed a strong preference for using stairways as the first choice escape route, there were considerable differences among those interviewed on how willingly they would use a fire safe elevator to escape fire and smoke in an FAA tower. A few would use it with little hesitation if the stairway was unavailable. Others would prefer to wait for possible helicopter rescue; to escape onto the catwalk, or to climb down outside ladders, if available. The majority indicated they would use the elevators if it were necessary with little delay but with considerable concern.

G. Awareness of the nature of fire growth and smoke spread. Many of those interviewed indicated they would prefer to use the stairs even if it contained considerable smoke at the time they entered. Only one controller expressed a concern or fear of using a stairway with a modest amount of smoke because he anticipated that the smoke density might rapidly increase over time. A majority were only concerned with the nature of the smoke at the time of entry into the stairway. In planning fire escape routes one should anticipate that the smoke concentration will probably increase with time. The training program should give the employees guidance on this issue.

IV. COORDINATING AND DIRECTING THE EVACUATION

A. Introduction. Large buildings often have a security force that would investigate smoke alarms, call the fire department (or activate a fire brigade), and initiate and direct the building evacuation. A location in the building is designated as the Command Center: it serves as the central point for communications and control during a fire or other emergency. Large and middle sized federal government buildings managed by the Government Services Administration are required to have a formal Occupant Emergency Plan. The plan assigns duties to members of the Occupant Emergency Organization.

For most air traffic control towers, the approach described above is not feasible. The number of building occupants is too small. Nevertheless, all the functions of the command center and the Occupant Emergency Organization must be accomplished, albeit in a more informal manner.

B. Automatic elevator control. While occupants of buildings are warned not to use elevators in fire emergencies, the elevators contain automatic controls to help assure their safe operation in fire emergencies if they are used contrary to these warnings. These automatic controls also help assure rapid availability of the elevators for use by the fire department. In short, once smoke is detected in an elevator lobby or in the elevator shaft, the current elevators return, with any occupants in the elevators, to a floor with easy access to the outside and easy access by the fire department. (If the safety of the primary destination is not assured, an alternate floor is used.) This is called "Phase I Emergency Recall Operation." Firefighters can use a special key to override the automatic shutdown of the elevators and control the elevator using the control panel in the elevator. When firefighters or others operate the elevators after the automatic Phase I Emergency Recall Operation, it is called "Phase II Emergency In-Car Operation." These terms are often simply called Phase I and Phase II.

Note that if there is no smoke in the elevator lobbies or the elevator shaft, the elevators operate in the normal mode. There is no reason to change this general approach if the elevator is designed for safe use during fire emergencies in air traffic control towers. However, a modification is recommended below.

Some entry of smoke into the elevator lobbies is likely as occupants open and close doors, but this limited amount of smoke will neither endanger occupants nor interfere with the safe operation of the elevator. Therefore, we recommend that the elevator should not automatically switch to Phase I Emergency Recall Operation until detection of a predetermined amount of smoke. The amount of smoke necessary to activate Phase I should be the subject of a separate study: the threshold for a given tower should be a function of the specific fire safety features of that tower. An alternate approach would be to use low threshold heat detectors to initiate Phase I.

C. Operation of the elevator. During the evacuation, the elevator should operate in the non-emergency mode. It should respond to the call buttons and go to the floors selected on the control panel in the elevator. (When the elevator is in an emergency mode, it cannnot be operated by the tower occupants.)

There are two issues associated with the operation of a fire-protected elevator during an evacuation of an aviation control tower. First, should the elevator be routed in any special way after a fire is detected? Should the elevator contain any special emergency operational features for use by tower occupants not in typical elevators in new office buildings? In both instances, we conclude that, in general, special features are probably not necessary. However, the criteria for initiating the Phase I Emergency Recall Operation (i.e., automatically returning the elevator to a preassigned floor) would need to be changed as discussed above. Also, we do suggest below one special control feature that should prove worthwhile.

In our report covering the general issues of using elevators to evacuate a portion of the general population of office buildings (Groner and Levin, 1992), we devised some fairly elaborate sets of strategies that might be appropriate to high rise buildings. These sets of strategies required that elevators be routed to floors on a priority basis based on the location of the fire and the presence of persons waiting to evacuate. However, the problem of evacuating control towers is much simpler. In most towers, there should be little need to prioritize the evacuation of occupants. Occupants needing evacuation generally would be concentrated in only a few locations, and the complete evacuation should require only a few trips over a relatively short period of time.

We do not recommend redesigning the controls inside the elevator to give building occupants, escaping from air traffic control towers, additional control over the elevators in a fire emergency. Additional control, such as that provided fire fighters during Phase II, gives additional safety from hazardous conditions. However, the building fire protection features should prevent occupants from encountering hazardous conditions while in the elevator. During the evacuation, building occupants should have control of the elevator only when the elevator is safe. If the elevator should not continue to operate because of safety concerns, it is designed to relocate automatically and to stay at a designated safe location (i.e., automatically go into Phase I). Further, as explained in the prior paragraph, we do not believe that there is much advantage to providing any special routing capabilities. Moreover, special emergency operational features would add significantly to the difficulty of training tower occupants. Therefore, special routing controls, such as a feature that allows evacuating tower occupants to cancel calls to specific floors, would be of little value.

However, there might be some advantage in providing to occupants of air traffic control towers a few simple operational features that are currently provided to firefighters when they use elevators in fire emergencies. For example, when firefighters operate the elevator in Phase II, continuous pressure must be applied to a button to open the elevator door. In fire emergencies this feature might provide an increase in safety to tower occupants in the highly unlikely event that the other safety features fail to operate as designed. More important, such a feature would provide tower occupants with an added sense of control, thereby encouraging elevator use during a fire emergency.

There might be some advantage for an unoccupied elevator to go to the highest floor so that workers in the cab might have a shorter wait. If this option is installed, it should not override the call buttons on other floors or the control panel in the elevator.

If the elevator goes out of service because of smoke in an elevator lobby or shaft, it is not anticipated that FAA employees would reactivate the elevator with a key. It is anticipated that they would have neither the training nor the information necessary to safely undertake the task.

D. Response to smoke detector and other alarms. Most alarms initiated by smoke detectors are false alarms. The sounding of such an alarm currently does not automatically initiate an evacuation of the tower. We anticipate no change to that practice. Each tower will develop its own procedures for investigating the cause of the alarm and for disseminating the information. The decision to evacuate is a judgement call but usually the need to evacuate will be obvious. However, since fires may look rather innocuous just prior to a rapid growth stage where the fire may rapidly become a raging inferno, some limited training about fire growth is highly recommended for all workers in the towers (for example, a short training film).

E. Decision to use the elevator. It is anticipated that the vast majority of the current workers in the towers would select the stairs as their first choice route for evacuation in a fire emergency. This was hypothesized prior to undertaking this study and was confirmed in the interviews. The decision to use the elevator, as opposed to the stairs, should be an individual decision by each building occupant. Again, some limited training about fire growth, smoke spread, and the toxicity and irritability of smoke should be given so that everyone will be aware of the dangers involved in going into a stairway containing smoke.

There are several circumstances that might lead people in the towers to attempt to use the fire safe elevator in a fire emergency.

> The path to the stairs might be blocked when the path to the elevator is available. Given the small area of each floor and the high quality walls and doors, this is not likely to occur.
>
> The stairs can become filled with smoke.
>
> The person can have a disability that forces or encourages the choice of using the stairs. While the current FAA policy is not to hire controllers who have disabilities that prevent them from properly performing the normal tasks of controllers, some current or future controllers may have other types of disabilities that make rapidly descending a long stairway a difficult, unpleasant, or dangerous activity, e.g., arthritis of the knee.
>
> The person may prefer to use the elevator rather than the stairs.

Based on our interviews of FAA employees who work in the towers and our observation of the towers and their contents, all of these are unlikely scenarios in a building that meets rigorous fire safety codes. However, fatal fires do occur in buildings where code-required fire protection features are installed--constant vigilance is needed to make sure that the fire safety features are not modified or by-passed and that the building occupants do not perform inappropriate actions. Relaxation of this vigilance is always possible.

F. Control center and communication. For large structures or building complexes, control centers are often dedicated rooms. These rooms usually contain the communications and monitoring equipment needed to coordinate an evacuation and fire control activities. Most new air traffic control towers, and associated buildings for offices and equipment, are independent and separated from other parts of the airport. The number of building occupants is likely to be too small to justify equipping and manning a dedicated control center. (Some existing towers are part of the terminal building. In these instances, it may be desirable to coordinate emergency activities in the tower with activities in the terminal, in which case, a single control center would be preferred.)

Although a dedicated control room is unnecessary, the functions performed at a control center still need to be addressed.

We recommend that fire protection system annunciator panels and communications equipment be placed at a single location that is readily accessible to arriving fire fighters. This location should be exterior to the tower so that it could continue to be used during a serious fire. Appropriate sites are outside the tower near the exit, and in an adjacent support building. (Towers are constructed so that from a fire safety standpoint, the office area adjoining the tower is considered a separate building.)

It is preferable that the selected site have a view of the tower and its exit discharge. The site should be equipped with a fire alarm system annunciator that provides information about alarm, supervisory and trouble signals. The annunciator panel is used by the responding fire department to locate any activated smoke detectors or manual fire alarm boxes. Other annunciator panels or similar equipment that provide information about the status of smoke control and fire sprinkler systems are best placed at the same location, if at that location the status of the system will be frequently checked and auditory signals heard.

In addition to the fire alarm annunciator installed at a site not in the tower, we also recommend that an annunciator be installed in the cab. (We observed such installations in the some of the towers we visited.) Air traffic controllers need to be automatically informed of the location of activated detectors so that they can respond as appropriately and quickly as possible. Such information can be critical when the tower and associated support space is occupied only by air traffic controllers.

Communications between the central control site and locations inside the tower can be critical during a fire incident. Usually, the need for two-way communications can be most easily satisfied by an appropriately designed telephone system with associated emergency procedures. In designing the telephone system it is important that two rather obvious requirements be met. The telephone system should be protected from fire. The alarm system should not sound in a way that it unduly interferes with the use of the phone: for example, the alarm could sound intermittently and still meet the need for the alarm to sound throughout the fire emergency.

The telephone system may be used by the tower occupants for any of the following purposes: 1. to summon assistance; 2. to receive important information or instructions from the control site or other remote location; 3. to report their locations and conditions encountered to emergency personnel; 4. to arrange for other air traffic control facilities to assume control of airspace as an alternative to radio communications; and, 5. to communicate among themselves. The communications system can also be used by emergency personnel to locate and instruct persons occupying the tower.

Emergency phones are generally required in elevators. (Emergency phones often lack handsets, instead using speakers and microphones to allow handsfree operation and communications with more than one person in the elevator.) If the use of elevators is part of the fire emergency plan, emergency phones are also needed in the protected elevator lobbies, since persons may become stuck in the lobbies without access to the elevator car. A direct dialing feature for these emergency phones will help ensure that persons in elevators and elevator lobbies can easily summon assistance. In addition to providing communications with an exterior control site, these emergency phones should directly dial a remote location that is always manned (for example, an airport security station or fire station) when the tower and adjacent support buildings are occupied by only a few controllers.

V. CARRYING OUT THE EVACUATION

A. Information needs of tower occupants. Initially, fire emergencies are often ambiguous events. Rarely do the first signs of trouble clearly indicate that an evacuation is needed. Most smoke detector activations are false alarms in air traffic control towers and in other occupancies. The faint smell of smoke does not necessarily mean a significant fire. Ambiguous signs of a problem are usually investigated before an evacuation is ordered. The sooner that a fire is verified and the tower occupants notified, the more time that they will have to complete the life safety strategy before the fire grows from a threat to a danger. For this reason, it is important that persons in the cab be notified of a potential problem at the earliest possible time, and that the situation be accurately assessed as efficiently, quickly, and safely as possible. Verifying a fire may become less straightforward during periods of light staffing--there may not be sufficient manpower to conduct a rapid search and still maintain control over flight operations from the tower. For example, at one tower, staffing after midnight was one controller at TRACON and one in the cab.

We offer the following recommendations for any tower emergency plan, regardless of whether elevators play a role in the life safety strategy.

> A fire alarm annunciator in the cab is essential to provide controllers with the maximum amount of information at the earliest possible time when there may be a fire. (We did observe annunciators in cabs.)
>
> A policy and procedure is needed for investigating alarms, especially when the rest of the tower is unoccupied and controllers cannot conveniently be made available to investigate.
>
> A policy is needed for actions to undertake during any period when it appears an evacuation may be needed but not yet necessary. This is a period when an orderly transfer of control of airspace might be initiated.

There are other information needs specifically related to emergency egress using an elevator. Specifically, occupants must know the exact status of the elevator. If the elevator is unavailable for any reason, then occupants will need to take appropriate action. For example, an occupant following the strategy of: "Use stairs to leave tower. If stairs unavailable, then use elevator," will either need to take refuge (perhaps in the elevator lobby) until he or she can be rescued or attempt to travel down the stairs even though that approach had been initially rejected. In any event, the occupant should know not to wait for an elevator that will not arrive. A possible means for providing this crucial information would be to install signage in the elevator lobby that would indicate the operational status of the elevator. For example, the elevator system might include illuminated messages in the elevator lobbies that read, "elevator in normal service," "elevator out-of-service," or "elevator in emergency service" depending on the operational mode. (Tower occupants would need to be instructed on the meaning of these terms as part of their fire safety training.)

B. Time required to transfer control. To safeguard the safety of the aircraft under their control, air traffic controllers must decide whether and how to transfer control of at least some planes before evacuating the cab. This procedure would increase the time required to complete the life safety strategy. During our interviews, we explored this issue with air traffic controllers by asking them to describe what needed to be done before leaving the cab and how much time it would take.

The responses of controllers varied widely. Their responses differed considerably on the minimum time they needed before they could leave the cab. The shortest time estimate was about 30 seconds. This controller said that a blanket call to all approaching planes was sufficient, that the pilots on short and final approaches would be able to land without further assistance, and that other planes could contact TRACON or a nearby tower. Other controllers anticipated that they would notify the appropriate TRACON that they were evacuating the tower and that their planes needed to be contacted in addition to the blanket call. Some controllers believed that there are situations when it is necessary to contact some aircraft individually to maintain adequate safety prior to evacuation. Some controllers stated that if continued contact needed to be maintained with aircraft, a transceiver in the cab could be taken along and used from the ground outside the tower.

Some of the emergency plans reviewed by the authors covered emergency procedures. However, the procedures were typically very general (e.g., "Notify adjacent facilities of significant service disruptions").[4]

Most estimates of delays were from 1.5 to 5 minutes. One controller pointed out that poor visibility would delay their evacuation somewhat. A few controllers estimated longer delays before they could leave the tower--as long as 10 minutes. However, these controllers were fairly vague about what they would need to do during this extended period of time. They appeared to feel that at least some of the planes would need to be contacted individually and followed until such time as the plane could safely land or control has been successfully passed to another tower or to the associated TRACON. It is beyond our scope of work to determine what needs to be done before leaving the cab in an emergency, and how long it would take. However, if the more lengthy time estimates are accurate, that is, if controllers might delay their evacuations for more than a few minutes, then the potential delay would be significant and conceivably life threatening to the occupants of both the tower and aircraft under its control. In this instance, it would probably be worthwhile to study the situation to determine the minimum actions that need to be taken without endangering aircraft, and how those actions could be completed in as short a time frame as possible by establishing and training controllers in a specific protocol. Based on our discussions with the controllers, we believe that it is unlikely that a long delay time is necessary. If this conclusion is proven to be wrong, then it should be determined if the current code, and the upgrades beyond the code installed by the FAA, provide satisfactory protection for the total evacuation time, including the lengthy delay.

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[4] One controller provided interesting insight into the delay problem and the need for detailed emergency protocols. He was present in a control tower during a strong earthquake. Even without a protocol for handling the emergency, the controllers believed they had handled the emergency efficiently without much difficulty. (Of course, his recall of the event may not necessarily be a precise portrayal of what really happened.) He said that it was fairly obvious how to respond. Only planes on a final approach needed to be immediately handled--they needed to abort their landing pending a check on the condition of the runways. Afterwards, other planes were directed into holding patterns while possible damage to the runways was surveyed. After it was determined that only one runway had sustained damage, the planes were directed to the alternate runways at this airport or to other airports. He felt that the lack of formal protocols for handling working planes did not present much of a hazard. The controllers understood their job well-enough to prioritize their tasks so that only critical tasks received attention in this life threatening situation.

C. <u>Delays in evacuating TRACON</u>. For the towers that housed a TRACON, the controllers estimated that it would definitely take longer to leave these posts than to leave the cab--one controller estimated 10 minutes. Again, this estimate of a ten minute delay warrants study as to its accuracy and how the time delay could be shortened. Conceptually, the effect of the delay on fire safety is the same as in the cab. However, the operations in TRACON are sufficiently different from the operations in the cab that conclusions regarding the cab cannot be generalized to TRACON.

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The Federal Aviation Administration (FAA) is interested in the possibility of using elevators for evacuation of air traffic control towers during fire emergencies. Assuming that the FAA could design, install, and maintain elevators that could safely be used by tower occupants during fire evacuations, it would be important to study a number of human factor considerations This report, which is partly based on interviews of occupants in thirteen FAA towers, discusses these issues. Given the fact that there has been a 20 year campaign to discourage elevator use during fire emergencies, most interviewees indicated a willingness to use such elevators as a backup mode of escape with some reluctance. The controls in the elevator would not need any major modification but a special communication system would be needed. Fire emergency plans and training are important to assure proper use of the proposed system and confidence in the safety it provides.

KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)
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