

THE STUDY OF OCCUPANT BEHAVIOR DURING THE WORLD TRADE CENTER EVACUATION - PRELIMINARY REPORT OF RESULTS

by

**Rita F. Fahy
Fire Analysis and Research Division
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101**

International Conference on Fire Research and Engineering, September 10-15, 1995. Orlando, FL. Proceedings. Sponsored by National Institute of Standards and Technology (NIST) and Society of Fire Protection Engineers (SFPE). D. Peter Lund and Elizabeth A. Angell, Editors. Society of Fire Protection Engineers, Boston, MA, 1995.

NOTE: This paper is a contribution of the National Institute of Standards and Technology and is not subject to copyright.

THE STUDY OF OCCUPANT BEHAVIOR DURING THE WORLD TRADE CENTER EVACUATION - PRELIMINARY REPORT OF RESULTS

Rita F. Fahy
Fire Analysis and Research Division
National Fire Protection Association
1 Batterymarch Park
Quincy, Massachusetts 02269-9101 U.S.A.

Introduction

On February 26, 1993, shortly after noon, a bomb exploded in a subterranean garage below the World Trade Center plaza in New York City. The explosion and subsequent fire caused extensive structural damage on several basement levels, interfered with the operation of the fire protection and other emergency systems and resulted in the evacuation of over 100,000 occupants of the complex.

The National Fire Protection Association (NFPA) and the National Research Council of Canada (NRC) undertook a research project, funded by the National Institute of Standards and Technology, the General Services Administration, NFPA and NRC, to study the human behavior of building occupants in this incident and to document, to the extent possible, those engineering details such as building design, fire safety features, and smoke spread, that effected behavior.

The purpose of this project was to collect and preserve human behavior data. The information gathered will aid in the understanding of what people do in fires and why and how those actions may conform to or differ from the assumptions used in designing and planning for life safety in such a large building. Results will help in work toward the improvement of fire safety in similar occupancies and to enhance the knowledge needed in the development of emergency evacuation models.

Background

The Port Authority of New York and New Jersey has made a long-standing commitment to fire safety in their management of the complex. Every tenant is required to conduct at least two fire drills a year. Every tenant has a fire warden trained in building evacuation. Any tenant holding space on more than one floor has a fire warden for each floor. In addition to the fire wardens, there are 25 fire safety directors who coordinate the activities of the fire wardens. These directors are in turn supervised by two Port Authority employees. Since there were 1,200 tenants in the complex, surveying only fire wardens gave us a sample covering every occupied floor and was of a manageable size, a total of 1,598 people. Although they represented less than one person in 50 of those in the building, their special training was believed to have given them a context in which to describe what happened that could provide a comprehensive and valid basis of analysis.

This study was based on a design originally developed by Dr. John Bryan of the University of Maryland and in use since Project People in the 1970s. The design has been enhanced and applied by the NFPA in several fire incident studies over the years, in particular the Beverly Hills Supper Club, MGM Grand Hotel and Westchase Hilton Hotel fire investigations. NFPA's most recent previous use of this method involved the Westin Hotel fire in Boston on January 2, 1984.

A total of 419 surveys were returned, 406 of which were usable (25.4%). The respondents ranged in age from 22 through 70 years of age and included 199 women and 197 men. The 406 respondents included 229 occupants of Tower 1, 163 occupants of Tower 2, seven on concourse levels, one each at the Vista Hotel, at 5 World Trade Center and the World Financial Center, and four who did not report their locations. Four of the occupants of Tower 1 and six of the occupants of Tower 2 were at subgrade, concourse or lobby levels in the buildings or in an elevator. Of most interest for this study were the 382 occupants of the two towers (23.9% of surveys sent).

The segment of the population of greatest interest in this study is the subset of the World Trade Center complex population who worked in the twin 110-story towers, that is, those located on Floors 11 and above in Towers 1 and 2. There were 225 such respondents from Tower 1 and 157 from Tower 2. The following analyses include only those 382 occupants and not those survey respondents who were located on the concourse or lobby levels of the two towers or in other buildings on the site. The responses of the remaining 24 participants also included important information that will be analyzed and reported at a later time.

The bomb was placed closer to Tower 1 than Tower 2 and responses to many of the questions seemed to differ between occupants of the two towers. The following analyses describe how questions were answered by the occupants of the two towers and highlight differences that were found to be statistically significant.

Preliminary Results

Occupants were asked how they first became aware that something unusual was occurring. Respondents mentioned the following cues, either singly or in combination, as the indication that something was occurring: hearing or feeling the explosion, loss or flickering of lights or telephones, smoke or dust, sirens and alarms, information from others, and people movement.

Of the respondents in Tower 1, 84% reported that the explosion, with or without another cue, was what alerted them, compared to 74% of the respondents in Tower 2. Looking at the responses in another way, 53% of the respondents in Tower 2 reported loss of power (lights, telephone), with or without another cue, as what alerted them, compared to 40% of the occupants of Tower 1. (These responses are not mutually exclusive since the explosion and loss of power were mentioned in combination by many of the respondents -- 35% in Tower 1 and 38% in Tower 2.) Both these differences were found to be significantly different.

Occupants were asked how they realized that what was occurring was a fire or

explosion. Responses were similar to those listed for the previous question, again either singly or in combination, but the predominant responses included the explosion and smoke. Of the respondents in Tower 1, 69% reported that the explosion and smoke were what made them aware that a fire or explosion had occurred, compared to 57% of the respondents in Tower 2. This difference was found to be statistically significant.

Perception Of Seriousness

The occupants of Tower 1 appeared to be more likely to consider the incident very serious than the occupants of Tower 2 and, in fact, this difference was found to be statistically significant. In order to test the hypothesis that differences in the distribution of occupants by age or sex between the two buildings might explain this differences, those distributions were also tested but were not found to be significantly different. In fact, there was no significant difference in perception of seriousness between the different age groups or between men and women. Perception of severity also did not differ significantly by location (floor) within the towers.

Within each tower, responses were checked to see if the perception of severity differed significantly depending on how people became aware of the situation. For Tower 1, respondents' perception of severity did not differ significantly regardless of whether or not it was the explosion or power loss that alerted them to an unusual situation. By contrast, Tower 2 respondents were significantly more likely to believe the situation was extremely serious if they became aware of the situation as a result of the explosion rather than the loss of power.

Attempts To Communicate

Respondents were asked if they called or attempted to call the fire department. Of the 222 respondents from Tower 1 who answered the question, 195 (88%) did not call the fire department and 27 others (12%) called the fire department, the emergency telephone number or 911. Of the 156 respondents in Tower 2 who answered the question, 123 (79%) did not call the fire department and 33 others (21%) called the fire department or the emergency number.

Respondents were asked if they operated or attempted to operate a manual pull station. Of the 222 respondents from Tower 1 who answered the question, 185 (83%) did not and 37 did (17%). Of the 152 respondents from Tower 2 who answered the question, 116 (76%) did not and 36 did (24%).

Respondents were asked if they called or attempted to call the switchboard. Of the 222 respondents from Tower 1 who answered the question, 174 (78%) did not call the switchboard and 48 others (22%) called the switchboard, building services or an emergency number. Of the 156 respondents from Tower 2 who answered the question, 124 (80%) did not call the switchboard and 32 others (20%) called the switchboard, building services or an emergency number.

A higher percentage of respondents from Tower 2 called friends or family than

respondents in Tower 1, possibly a reflection of the less clear fire cues received in that building as well as the long delays in beginning evacuation that occurred in Tower 2. Of the 223 respondents from Tower 1 who answered the question, 138 (61%) did not call friends or family, 78 people (35%) did call and another seven (3%) said they called after they left the building. Of the 78 who made calls, 62 called people outside the building, 11 called people inside the building and three called people in and out of the building.

Of the 156 respondents from Tower 2 who answered the question, 62 (40%) did not call friends or family, 91 people (58%) did call and another three (2%) said they called after they left the building. Of the 91 people who made calls, 79 called people outside the building, four called people inside the building and four called people in and out of the building.

Movement Through Smoke

Respondents were asked if they moved through smoke and if they did, how far did they move, how far could they see and did they turn back. The responses to the distance questions were very subjective and it often was not clear if the respondent was referring to horizontal travel distance on the office floor or vertical distance in the stairs. For the question about how far could they see, the responses often had as much to do with the darkness they faced as with the smoke.

Almost all the respondents in Tower 1 (94%) and over two thirds of the respondents in Tower 2 (70%) reported that they tried to move through smoke. This difference is statistically significant. Almost half of the respondents in each tower who said they moved through smoke said they moved through smoke all the way out of the building. The proportion who did so is probably even higher since those who specified a distance or a number of floors may have been describing their entire travel path out of the building.

Over three quarters of those who moved through smoke turned back. The difference between the two towers was not statistically significant. The most frequent reason given for turning back by those who did so was the smoke. Other reasons given included crowdedness, locked doors, difficulty breathing, not being able to see and being afraid.

The Evacuation

Respondents were asked if they left or attempted to leave without being told to do so. If they did not leave voluntarily, they were asked why not and if they did, they were asked at what time. Two thirds of the respondents in Tower 1 (66%) and almost half of the respondents in Tower 2 (46%) left without being told to do so. An additional 8% in Tower 1 and 11% in Tower 2 attempted to leave. The difference in responses between the two towers is statistically significant.

The reasons people gave for not leaving voluntarily included 1) waiting for information or instructions, 2) felt it was better to wait or they were told to wait, 3) they didn't know there was a problem, 4) they were making sure others left, 5)

health reasons, 6) too much smoke, 7) waiting for better conditions, and 8) waiting for the fire department as requested.

The times respondents gave for when they left were compared to the times they reported for becoming aware that something had occurred and the times they reported for realizing that what had occurred was a fire or explosion. For Tower 1, the times from awareness of something unusual occurring and time to leave ranged from 0 to 4 hrs 5 min, with a mean time of 15.3 minutes and a median time of 10 minutes. For Tower 2, the times ranged from 0 to 3 hrs 27 min with a mean time of 34.7 minutes and a median time of 15 minutes. This difference was statistically significant. For Tower 1, the time from awareness of a fire or explosion to leaving ranged from 0 to 4 hrs 5 min with a mean time of 11.3 minutes and a median time of 5 minutes. For Tower 2, the times ranged from 0 to 3 hrs 5 min with a mean time of 25.4 minutes and a median of 10 minutes. This difference was also statistically significant.

For those who attempted to leave the building, the differences in times from awareness of something unusual to the time of attempting to leave were statistically significant. For Tower 1, the times ranged from 2 to 30 minutes with a mean time of 8.9 minutes and a median time of 8 minutes. For Tower 2, the time ranged from 10 minutes to 4 hrs 14 minutes, with a mean time of 39.9 minutes and a median time of 25 minutes.

Respondents were asked how long it took them to leave the building. The purpose of the question was to obtain evacuation times that could be used to test or validate evacuation models. Unfortunately, many of the respondents apparently interpreted the question to mean how much time passed between when they started to leave and when they reached the exit, including any time they may have spent resting or waiting in areas of refuge. An attempt was made to count only reported travel times. Over 70% of the respondents in Tower 2 said they left the building in an hour or less, compared to 40% of the respondents in Tower 1. Fifty-two percent of the respondents in Tower 1 reported that it took them one to three hours to leave the building. A significantly higher percentage of respondents in Tower 2 evacuated in less time than respondents from Tower 1 because many delayed their evacuation until told to leave by the fire department, when conditions in the stairs had improved, more lighting was provided and stairway travel was easier and more rapid.

Prior Fire Alarms

Respondents were asked if they were aware of previous fire alarms in the building and if they were, how many had there been in the past year and during those alarms, did they evacuate the building or move to another floor. Many of the respondents who said they had been aware of prior fire alarms in the building specified that the alarms were fire drills. Other who simply checked off "yes" may have meant the same thing. Since occupants' actions should have been the same whether the alarm was due to an actual incident or a drill, those responses can be looked at together.

Most of the respondents in both towers never left the building or the floor when alarms went off or drills were held. Over 90% of the respondents in Tower 2 never evacuated the building and never moved to another floor. In Tower 1, 79% of the respondents never moved to another floor and 88% never evacuated. These results further explain the unfamiliarity with the stairs that many respondents reported, in spite of the fact that most of the occupants who responded to the survey were fire wardens.

Summary

Recent human behavior studies have shown that people will move through smoke, but this incident demonstrated that people will keep moving, even as conditions worsen. Many evacuees believed they were heading straight into the fire, but they kept going down, through increasingly thick smoke.

This incident also demonstrated that, in an emergency, floor wardens need enough information to be able to make safe decisions when the power shuts down and no information is forthcoming from authorities. But training should not be limited to members of the fire safety team. Many fire wardens were not in their areas when the incident occurred. This is always a possibility, due not only to vacations, lunch breaks, and other regular leaves, but also to meetings that take place off-site or in other parts of the building.

All occupants need some level of training or education if they are going to react safely to a fire in a high-rise building. They should understand smoke movement in high-rises, stack effect, and the dangers of falling glass to people below. If fire wardens are properly trained, occupants should look to them in fire emergencies. In some cases, fire wardens reported that they were overruled by their managers, even though the managers may not have had better or additional training.

People should also understand how emergency workers operate. Many who waited for hours on upper floors in Tower 2 complained about the time it took fire fighters to reach them. They need to understand that when power to a building is off, people on upper floors of high-rise buildings who are in no danger can expect fire fighters to take several hours to reach them.

Work on this project continues. There are additional variables that should be analyzed, including respondents' occupations -- a variable found to be significant in some previous human behavior studies. In addition, responses from people on the same floor should be compared, particularly their descriptions of smoke and their perception of severity. Reported delay times require further evaluation, too, so that we can better estimate time before evacuation begins and what variables affect delays in evacuation. This data could have great value for human behavior and evacuation modeling and will be detailed in future reports.

Acknowledgments

This work has been funded in part by the National Institute of Standards and Technology Building and Fire Research Laboratory, Grant No. 60NANB2D1286.