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Occupant Behavior in Building Fires

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Occupant Behavior in Building Fires

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OCCUPANT SAFETY IN BUILDING FIRES

Arthur I. Rubin and Arthur Cohen

Fire safety in buildings is important in building design and the formulation of codes and standards. However, an examination of the information concerning the needs of occupants in fire emergencies (as opposed to ensuring a degree of structural integrity for the building) indicates that the scientific information base is woefully inadequate. The increasing prominence of high rise buildings having many occupants intensifies the need for better information about the behavior of occupants during fire emergencies. Fire researchers have indicated that it is often not feasible to evacuate buildings because of time constraints. Instead, designers use techniques such as safe areas within buildings and requiring people to respond differentially, based on their particular location. This approach emphasizes communications and warning systems to transmit messages. These systems such as loud noises or blinking lights should be designed to "take advantage" of the usual responses made by people. Occupants can actively be a part of the fire warning and fighting system instead of being unwilling victims. This possibility is pursued and a human factors approach is taken to suggest some means of better understanding the capabilities of occupants.

Key Words: Disaster research; high rise building fires; occupant safety.

1. INTRODUCTION

A fire breaks out in a building!

How do the occupants typically find out about it?

What is their reaction to the fire emergency?

How do they usually escape?

Are present fire safety systems in buildings responsive to the occupants' needs?

The present project was initiated to address these questions and provide information in an appropriate format which can be used by those concerned with fire safety in buildings. It was anticipated that a questionnaire could be developed and administered to a large sample of people who had experienced fire emergencies. The questionnaire items (questions) would be selected on the basis of their adequacy in past surveys concerned with occupant fire safety in buildings. The research investigation was expected to focus primarily on the compilation, analysis and evaluation of "relevant" data with a view toward improving current fire safety systems. We assumed that much of the preliminary work concerned with defining the problem was already accomplished and the findings were available.

Discussions conducted with members of the staff of the National Bureau of Standards and others familiar with fire research activities indicated that the assumptions made concerning the availability of useful data were seriously in error. The major point made was that the behavioral data of interest was probably not available and would have to be collected rather than found. It would therefore be necessary to develop a research program instead of relying on a literature search in order to obtain the required information. During the course of the investigation, it became apparent that the staff experts were correct in their evaluation of the "state-of-the-art" and of the necessity to develop appropriate methods of collecting a meaningful data base. The goals of the program were considerably modified to meet these more limited objectives. The focus of interest was multiple occupancy dwellings in general, with emphasis on high rise buildings. Single family dwellings were not considered because they appear to present a different set of fire safety problems warranting separate treatment.

It is important to note at the outset that fire research associated with the behavior of people during emergencies poses a dilemma for the researcher. It is not feasible (or desirable) to artificially establish an experimental situation where subjects are in any real danger. The data must therefore be developed as real situations arise with the researcher having virtually no control over the "experiment" being conducted. The best that can be done is to make careful and systematic observations and measurements of events judged to be critical.

2. GENERAL BACKGROUND

The fire problem is one of significant magnitude and many conflicting facets. Although this study does not purport to investigate the entire range of problems, the following comments from Ahern and Morgan (1) and America Burning (2) provide an indication of the study's scope and ramifications:

- More than 12,000 persons have been killed in fires in each of the past six years in the U.S. (1). Only motor vehicle accidents and falls rank higher among the causes of accidental death (2).

- In the United States, the death rate attributed to fires on a per capita basis is twice that of Canada, four times that of the United Kingdom, and 6 1/2 times that of Japan (1).

- As a nation, the United States spent about $5.5 billion in 1971 on fire-related activities: $2.7 billion on fire protection, $2.8 billion due to property losses (1).

- In America Burning (2) one finds that the United States leads all the major industrialized nations in per capita deaths as well as property loss from fire. The total cost of destructive fire is estimated to be $11.0 billion per year. Both of these estimates are thought to be conservative by some experts.

There are many fire-related problems which become increasingly critical in high-rise buildings: distance to exists, safe areas within the building, fire control and extinguishment, detection and alarm, etc. These factors raise a number of questions. Is total evacuation within reasonable time limits possible in a high-rise building? How does one deal with disabled occupants? Are exits appropriately designed? Are conventional fire alarm systems adequate for high-rise buildings?

As a result of the fire problem, more governmental and public attention is being given to try to control, and perhaps reduce, the needless personal suffering and human loss from fire. There is some evidence that efforts designed to improve the existing situation during the past several years have been somewhat effective although in the case of high rise buildings the problems remain severe. In the words of Ahern and Morgan (1)[1] of the National Fire Protection Association (NFPA) "No single organization or group of organizations has been responsible for the gains. A large part of the credit must go to property owners and managers, from corporate heads to small homeowners, who have had the interest and taken the initiative to do something about fire protection and prevention in areas under their authority."

Aside from organizations, other contributing factors have an impact on fire protection. There are new methods and materials available to the architects and builders who are responsible for building construction. These have resulted in improvements in some instances while adding to the problem in other cases, especially with respect to smoke generation associated with some products. Finally, there have been some improvements in fire department apparatus, although serious deficiencies exist in the ability to fight high rise fires.

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[1] Figures in parentheses indicate the literature references at the end of this paper.

The Federal Government has played an important role in the changing of popular attitudes toward fire safety. The Fire Research and Safety Act, the Flammable Fabrics Act, the Occupational Safety and Health Act, and other legislative and administrative activities have brought the forces of government to bear on the problem at an unprecedented level. The National Commission on Fire Prevention and Control, appointed by President Nixon in November 1970, under the leadership of Professor Richard Bland of Pennsylvania State University, has reported to the President in May of 1973. This report illustrates the more significant fire problems and recommends ways to mitigate needless personal suffering and loss from fire. For example, the Bland report recommends that there should be annual home inspections conducted by every fire department in the country; home fire protection should be upgraded by encouraging homeowners to install early warning fire detection and alarm systems in their homes. Congress should encourage these activities by allowing the Internal Revenue Service to grant tax rebates for homeowners who install such devices and the report suggests the need to lower fire insurance rates by insurance companies in compliance with homeowner initiatives in this area. In addition, the Report recommends a concerted fire prevention education program in the schools as well as in the home.

Local paid and volunteer fire fighting organizations are the ones in the forefront during actual emergencies having the major responsibility for the day-to-day protection of the safety of the citizens. Their activities have also included a major role in educating the public-at-large concerning proper actions in both preventing and combating fires. At the local level, model code groups have been active in the development and enforcement of building codes and regulations.

The National Fire Protection Association (NFPA) has been instrumental in promoting fire safety activities in many ways over the past 75 years. They have considerable expertise in both the day-to-day fire fighting activities as well as the highly technical aspects of the fire mitigation and have often served as a catalyst toward promoting fire safety improvements by initiatives to governmental and other organizations.

Finally, laboratories of industry, government and universities have been increasing their basic and applied research programs, although not sufficiently enough, to mount a truly effective attack on fire-related problems.

As practiced today, fire safety is more of an art than a science. The evolution of building codes is a testimony to this evaluation. Our present-day code regulations were largely formulated during an age of less sophisticated technology and building design. Many of the codes can be directly traced to the interests of insurance companies whose main concern is property protection. Mr. G. Robert Fox, AIA, of Smith, Hinchman and Grylus indicates that "... code theory is often derived from presumptive kinds of reasoning, not facts." (12). He points out that there is considerable evidence indicating that smoke is more of a threat to health and safety than fire, but few building codes deal with problems of smoke development and propagation. The greatest irony in this situation is that considerable information exists concerning the smoke producing properties of interior material finishes.

As in the development of building codes generally, those regulations pertaining to fire safety have evolved based largely on past experience. Typically, as noted by Mr. A. F. Sampson, Administrator of GSA, revised sections of fire codes address shortcomings on the previous codes which were implicated in fire disasters (23). When building construction techniques and design features are somewhat uniform and do not constitute major breaks with the past this "add-on" system of safety regulation appears quite reasonable to the authors of this technical note. The design criteria and building code provisions in current use are largely materials oriented. Specifications are written in prescriptive terms using "proven and well established" building practices in meeting safety and durability requirements. This empirical approach, with all of its inherent limitations, has had fairly general acceptance, primarily because it is virtually the only one used.

However, the building industry today is somewhat different from what it has been in the past. Although many builders appear to be following a "business as usual" approach, there is considerable impetus to speed up the construction process to meet the demand for more and better homes. As a result of HUD's Operation BREAKTHROUGH and similar programs, a variety of innovations have been introduced. These innovations encompass materials, components, building subsystems and housing construction technology in general. In some ways, they can be considered revolutionary in their impact on fire safety research and applications. For example, the slowly accruing empirical data base associated with fire safety may become rapidly obsolete when innovative buildings are under evaluation, because many major design parameters will differ from those traditionally employed. If it is not possible to rely on past experience, innovative design solutions should be evaluated from the standpoint of fire safety of the occupants.

2.1. Performance Approach

The rate of application of building-related innovations, coupled with the need for more and better housing, has resulted in a sense of frustration among those concerned with applying these new technologies to building problems. The institutions and processes associated with building construction activities appear to be designed to resist change. The traditional methods of designing and testing building components and materials make use of time consuming, parametric, trial and error procedures. After these tests have demonstrated the feasibility of an innovation, building code modifications are often necessary, before builders can apply this new technique. These modifications further lengthen the time span between the development of an innovation and its ultimate large-scale use. As a result of this traditional procedure, many domestic and foreign organizations concerned with buildings have become dissatisfied with the "status-quo" and have taken a new look at the methods currently used by building designers. This reexamination has resulted in the use of the concept of performance, based upon the requirements of the users. Since ultimately the function of buildings is to serve their occupants, performance requirements must be defined in terms of user needs and wants.

As generally used by building research organizations in the United States and abroad, the performance concept begins with a performance statement which has three essential parts requirement, criterion and test. A requirement is a qualitative statement which identifies a human need. The criterion is a quantitative description of a requirement. It provides specific levels for attaining compliance with the intent of the requirement. The test indicates a method to assess the degree of compliance with the criterion. The methods include analysis, physical measurement, and expert judgment. The primary purposes of the performance approach are to point the way for the development of new products and techniques, and to promote impartiality to the acceptance of innovations. It was formulated particularly to overcome the constraints inherent in the prescriptive approach which largely stifles innovative solutions.

Inherent in the performance approach is the use of a systems orientation to the solution of problems. This situation is especially true when we consider the life safety system of a building where the primary requirement is the adequacy of all subsystems in minimizing injury and death due to a fire emergency. The performance approach for BREAKTHROUGH housing recognized this problem and imposed performance requirements for all of the following fire safety characteristics: detection, alarm, exiting, design of passageways, and control of materials.

Mr. H. Finger, a former Assistant Secretary for Research and Technology for HUD, at a symposium dealing with the performance concept in buildings (17) pinpointed several specific problems associated with fire safety of occupants. He noted that the standard ASTM #119 fire test (Fire Test of Building Construction and Materials) makes no provision for measuring the amount of smoke and toxic gases associated with the materials used in construction. As long as traditional materials are used, the test is valid, but with the introduction of new materials such as fiberglass-reinforced polyester, new problems arise but the traditional test method remains in use despite its evident shortcomings. This discrepancy becomes especially significant when we consider that innovation is now being encouraged in the use of chemical and plastic construction materials and that smoke and toxic gases have always been a major source of injury and death in fires. Mr. Finger also indicated that generally, fire alarms have not been particularly effective because the incidence of drills and false alarms encourages a feeling of safety rather than danger among occupants. He then

questioned the adequacy of a bell alarm system as compared with other possible approaches-visual signals, voice communication. He concluded that more knowledge was needed in the design of warning systems.

Mr. A. F. Sampson, Commissioner, GSA, in a talk recently made at the International Conference on Fire Safety in High-Rise Buildings dealt with the design, use and management of buildings as they relate to fire safety:

> "As all of you know, the present system of codes, standards, and criteria have been developed over the years and certainly contain many sound requirements. However, we can all agree that the present concept of unitized performance requirements (i.e., a door, a beam, the width of a corridor) fitting together by a series of go/no-go acceptance requirements involved both safety inadequacies and elements of overdesign. We fall down because we usually do not have a total safety system for the total building. Analysis or attack on this problem is difficult because of the lack of an identified goal (a way of identifying a level of safety in a building) and a way of measuring this goal. In many instances present fire safety concepts and requirements are grossly conceived and grossly applied in a manner that provides an overall, though undefined, degree of safety in a typical building. This results in a situation where it is virtually impossible to evaluate the potential of a specific element or the impact of a proposed change. This inability to evaluate the potential of change is a major factor in both the present problem and in the frequent charges that fire safety professionals are reluctant to accept new design concepts and materials and are an obstruction to progress. Building design, use and operational concepts must change rapidly and dramatically to be responsive to current requirements. Still another major impediment is the well known time consuming process required to changed any code -- and fire regulations are not an exception.
>
> This presents a dilemma. Most current fire safety requirements are based on experience and since building concepts are rapidly changing, much of this experience is of questionable value. Fire safety planning must have a better base on which we can predict the success of a design or the potential risk in an existing building, and from this evaluation, develop the appropriate actions to achieve the desired level of safety. The answer to this dilemma rests in the development of sound basic concepts and fundamentals that will allow the analytical measurement of the level of safety and comparative evaluation of alternatives. This will provide truly realistic evaluation of alternatives. This will provide truly realistic inputs to the ultimate problem solution."(20).

Unfortunately these and other user requirements are often described by qualitative statements of the attributes desired from buildings. In order for the performance approach to work, these qualitative statements must be translated into quantitatively defined scientific engineering statements which fulfill the meaning and intent of the human needs.

3. STUDY OBJECTIVES AND METHOD OF APPROACH

The objectives of the present program are both long and short range in nature. The long term objectives of the work are to provide fire safety criteria in performance terms based upon a scientifically defensible quantitative data base describing user requirements. However, it is recognized that this goal is very ambitious and that a great many intermediate steps are required. Perhaps the first step in this process is to better understand the many problems associated with the response of people to fire emergencies. The process of upgrading our current data base is a lengthy one and in the meanwhile, there are fire emergencies occurring daily and it is necessary to devise interim solutions. As the first study of a research program, one of the primary objectives was to better understand the problems and then suggest techniques of coping with them.

In determining the "state-of-the-art" in the problem area, a number of standard approaches were employed. A literature search of both technical and non-technical publications was made. Interviews were conducted with researchers as well as administrators who are experts in fire safety. Correspondence was also initiated with several foreign researchers who are pursuing similar goals.

4. LITERATURE REVIEW

The information compiled during the literature survey presents a mixture of findings. However, since the major study objective was defined in very general terms, and we consider this work to be largely that of trying to first define the problem, this result is not very surprising. The source material examined ranged from "popular" accounts of fire emergency behavior, stress behavior in laboratory investigations, disaster studies, to theoretical work designed to improve existing communications capabilities in fire fighting activities. Because of the diversity of source material, it is difficult to identify common themes which can be employed to coherently organize this section of the report. Consequently, several topics have been identified as being of particular relevance and will be treated separately. Whenever interrelationships can be identified, they will be explored in some detail.

4.1. Popular Accounts of Fire Emergencies

A major source of information was thought to be anecdotal and narrative accounts of fires appearing in the popular press, magazines and other publications. Fires are an everyday occurrence in most communities and receive extensive treatment in the news media for several reasons. They often are spectacular visually and therefore lend themselves readily to photographs and television coverage. Fear of fire seems to be a universal phenomenon and when combined with the perceived vulnerability of most homes to fire, it can be readily anticipated that accounts of fires create strong empathic reactions among viewers and readers. In other words, they are newsworthy events from several standpoints.

There is no disagreement about the availability of information from the news media. The major problems are the technical adequacy of the information for research purposes and the anticipated payoff for a determined effort to explore these sources. The sheer mass of available information poses a formidable obstacle because its form does not lend itself readily to compilation. Rather, in most instances it is a case history of a single event, resulting from an interview designed by a reporter seeking a "good story". Simple, straightforward and objective accounts of behavior (which might prove useful to researchers) are likely to be considered not newsworthy and would therefore not appear in print. Investigators concerned with fire safety have been very reluctant to use newspaper accounts (6, 22) in their studies. Interviews conducted with disaster study researchers have resulted in similar conclusions about the adequacy of the press information for research purposes. Their primary caution is concerned with the major sources of bias inherent in collecting information for the mass media: the selection of content as well as format, and the inability to draw conclusions about the representativeness of the available sample of behavior.

The personal drama inherent in a major fire also lends itself to extended narrative treatment, in the form of both non-fiction and fictional accounts of disasters. The account of the Coconut Grove fire (4) is an especially compelling example of this type of treatment. The author expended considerable effort in detailing many of the factors associated with the fire and describing the activities of many of these who experienced the fire. However, despite this evidently exhaustive description of the fire, the book is not useful as a scientific source document. Although many individual and group behaviors are treated in some detail, it is almost impossible to attribute any causal links between environmental (fire related) events and individual or group behavior. The inferences made by Benzaquin are based primarily on a single fire. They are reasonable, but not researchable in any meaningful way since it is extremely difficult to translate the individual circumstances described into generalizable and testable hypotheses.

4.2. Non-Behavioral Information

The study of fire research programs was limited to those which focused primarily on the behavior of people in fire emergency situations. Obviously, this undertaking is enormous in itself. Only a cursory examination was made of some general reports which summarized the current status of the "fire problem". The objective was to determine the scope of the problem by obtaining relevant statistics and to develop an insight into the type of data available and its applicability for use in designing programs which are directed toward studying human behavior.

The Federal Fire Council produces a summary of federal fire losses annually, which indicates the number of fires, dollar losses, injuries and deaths in fires associated with Federal Government property. The 1967 Annual Report (11) also provides case history studies of major fires and treats in some detail the causes and progress of the fires.

The most recent Directory of Fire Research (21) presents a comprehensive overview of fire research activities in the United States. An index of the subjects included in the volume is revealing. It demonstrates the lack of attention to the human behavioral component of the problem. It is as follows:

- Chemical aspects of fire
- Combustion engineering
- Detection of fires (primarily hardware)
- Fire damage and salvage
- Instrumentation and fire equipment
- Meteorological
- Model studies and scaling laws
- Operations research and mathematical methods
- Physical aspects of fires
- Physiological and psychological aspects of fires - (of 34 studies none mention problems of building occupants)
- Prevention of fires
- Propagation of fires
- Suppression of fires

4.3. Behavioral Research

The material previously covered in this report can best be described as being only tangentially related to human behavior in fire emergencies. However, it is hoped that this information proves useful in providing a perspective for those few studies which have been directed toward understanding human behavior in fire emergency situations.

Behavioral responses to fires has been treated in considerable depth by two researchers, Dr. J. L. Bryan of the University of Maryland, Mr. J. L. Pauls of the Building Use Section from the National Research Council of Canada. Their work serves as a major basis for the following discussion.

Dr. Bryan has focused his attention on panic behavior (6 and 7), but in contrast to the Disaster Studies of panic (see Sec. 5.6), he has concentrated on fire emergencies. Therefore the research is covered in this section. Bryan claims panic is manifested in two different ways -- the individual response of a person during a threat, or a reaction by a group of people causing a crowd panic response. He notes that the two extreme behavioral responses of individuals are a withdrawal reaction and a hyperactive reaction which might be a prerequisite to running from danger.

Dr. Bryan conducted a study in the aftermath of the Arundel Park Hall fire (6), during which he interviewed surviving victims of the fire. He was concerned with the effectiveness of the illumination and markings of exits in the building in leading people to safety. Approximately 86% of the people interviewed did not notice whether exit lights were present and in working condition. Especially interesting is the fact that eight professional firemen and policemen were present, and they were unable to recall whether they noticed these lights.

In a study performed for Dr. Bryan by W. L. Cannon (8), an interview was conducted in a department store to determine the effectiveness of exit markings. The primary purpose of the investigation was to determine the degree of public awareness of exit locations and of the sensitivity to danger of fires in department stores. Almost 92% of the shoppers interviewed were not at all concerned about the possibility of a fire.

Darley and Latane (10) have developed an experimental situation where an emergency situation is simulated. While subjects are involved in completing a questionnaire, smoke is introduced into the test room. If a subject leaves the room and reports the smoke, the experiment is terminated. The authors were primarily interested in determining the effects of social pressure on the responses of a subject to the simulated emergency. Their results were quite dramatic. They found that subjects alone in a room reported the smoke 75% of the time. When two passive individuals were in the room with the subject, only 10% of the subjects reported the presence of smoke. The authors of the study suggest that the smoke represented an ambiguous threat cue. Under these circumstances, the behavior of an individual is readily influenced by others around him. Therefore, when the other occupants of the room do not respond to the smoke, the subject will tend to interpret the smoke as being nonthreatening and will ignore its possible danger.

Galbreath (13) made a survey of ten office buildings at least seven stories in height in order to determine how long it would take occupants to evacuate the buildings in a fire emergency. (Data were collected during a series of fire drills.) His study was performed in the context of evaluating the adequacy of some of the fire safety requirements of the National Building Code of Canada. His major experimental interests concerned the number of occupants as well as the exit and the stair widths in the buildings. He found that the drop in travel rate with increasing density in the stairwell posed a major problem during evacuation which took as long as 12 minutes in some instances. On the basis of his investigation he concluded that, "it is not realistic to attempt to provide for evacuation of high buildings by stairs in a limited time." He noted that his findings were in close agreement with a similar study performed for the London Transport Board.

J. L. Pauls explored the relationship between behavioral requirements and design solutions in the emergency egress of buildings (22). This study, which is very similar in its primary objective to the present investigation, will serve as the major reference source for the remainder of this report since the treatment of the problem by Mr. Pauls was the most detailed and relevant account found. The major focus of attention was the high-rise office building. The investigator's major concern was to "explore how emergency provisions might be designed if the designer worked logically from clearly stated premises or principles through to design conclusions..... Applying this concept to design of emergency provisions, the designer would have to clarify the behavioral goals relevant to the occupancy and building characteristics. He would also need theoretical knowledge of some form of testing to be able to predict whether an environment would satisfy the behavioral goals."

Mr. Pauls identified three classes of behavioral goals:

1. Traditional Rapid Egress from Buildings. -- Within a few minutes after a fire danger alarm.

2. The "Muster-Station" Concept. -- Occupants assemble at various points in the building before taking further action.

3. Non-Egress. -- Most occupants would suffer only minimal disruption of usual activities because of the localization of emergency condition. For example, when an elevator is temporarily removed from service for inspection or repair purposes.

Mr. Pauls performed a number of investigations during fire drills to determine whether auditory alarm signals should be supplemented by visual signals in facilitating egress from buildings. He administered questionnaires to occupants, made observations of behavior, and varied the lighting conditions by making the lights flicker. Although his findings were indeterminate, the rationale and approach are interesting and will be treated in some detail in the discussion sections of this report (22).

4.4. Other Sources of Information

In an effort to augment the information which was available in the open literature, a number of discussions were conducted with NBS Fire Research personnel and members of the original Disaster Research Group from the National Academy of Sciences (NAS) who were still engaged in similar research activities. As a result of these discussions it became evident that little current research was directed toward the problem of concern. The Disaster Research Center at Ohio State University has assimilated many of the functions performed by the disbanded Disaster Research Group of the NAS, but their interests are primarily concerned with developing improved communications among the organizations concerned with combatting fires. They employ a systems orientation to better understand the necessary interactions of individuals and organizational units (whether government or private) during the many processes associated with fire emergencies (detection, control, evacuation, etc.).

Contact was also made with a number or research organizations in foreign countries. These include:

The Japan Fire Prevention Equipment Inspection Association

Japanese Building Research Institute

National Swedish Institute for Building Research

National Research Council of Canada

Fire Research Station, Herts, United Kingdom

Unfortunately, these contacts were no more fruitful in identifying relevant research than were the discussions. However a number of questionnaires (designed by others) were made available. These provided a starting point for the present study of behavioral responses during fires. The type of study is typified by a report by the Fire Research Station in the United Kingdom (9) which provides summary information on fire deaths in 1971. The data are presented in tabular form and are of the type available from insurance companies and the Federal Fire Council in the United States.

5. RELATED PROBLEMS

In view of the lack of concrete information on the behavioral aspects relevent to fire emergencies we broadened our survey to include a number of topics that are only indirectly related to fire emergencies. These include work on the general methodology used in disaster situations, studies of stress, panic and threat behavior and finally some studies of specific disaster situations. These topics are discussed in the following sections.

5.1. Stress Research

One can classify human behavior during a fire emergency as a special instance of stress phenomena, which has been a subject receiving considerable attention recently. However, stress is one of those concepts which has been defined in almost as many ways as there are researchers working on the problem. Social scientists have expended major efforts in trying to better understand individual and collective behaviors under stressful conditions; therefore it would be prudent to consider their findings.

Since there are a multiplicity of definitions for stress, it would be useful to consider some of these before pursuing the topic.

Klier, et al. (6), in summarizing much of the available stress research, indicate that "there does appear to be a basic definition of stress in terms of a disturbing condition which impels an individual to restore some sort of desirable balance or equilibrium between himself and the situational environment, either by a general rise in his level of motivation or by changing specific behavior modes so as to make his response more suitable." These authors summarize the definitions of other investigators concerned with the same topic:

H. R. Schaffer indicates that: "A stressful situation may be described as one in which a major disruption of the relation of the organism to its environment has taken place; it is brought about when a highly motivated organism is unable to find an adjustive response to the problem confronting it."

Selye views stress in a physiological context and sees it as a condition whose function is to restore the organism to its normal state of homeostasis. He calls this response the "general adaption syndrome".

Glass and Singer (15) propose the concept of psychological stress which they define as "the threat or anticipation of future harm". This definition is perhaps the most appropriate for the purpose of the present report.

Stress as a research area is almost unique in that it is associated with a range of difficulties that involve not only technical and administrative judgments but moral ones as well. The research possibilities encompass both "well controlled" laboratory investigations and field studies. Since the subject matter of an investigation is behavior under stress, it is necessary either to locate and study a stressful situation or actually produce such a situation experimentally.

Klier, et al. (6), summarizes three experimental methods often employed in stress research, the first two are laboratory methods while the third is a field investigation:

a. Imposed Stress - Experimental subjects are placed into two groups which perform a task under different conditions - stress and non-stress. The performance achieved under the two conditions is then compared. The stress conditions take a variety of forms -- distraction by extraneous stimuli, physical discomfort, working at an accelerated pace, physical or psychological threat.

b. Manifest Anxiety - By means of psychological tests, subjects are divided into two groups -- those who are anxious and those who are not. All subjects then perform a standard task and the performance of the "anxious" subjects is compared with that of the "non-anxious" ones.

c. Field Investigations - The military has sponsored research to define stress in a combat situation. Psychological and physiological measures were taken of soldiers shortly after they were engaged in combat.

The conduct of these field studies poses another problem for the investigator -- a human one, somewhat akin to the moral one noted earlier. The researcher in a dangerous situation is not immune to the threat that the subjects of the study are exposed to. Under these circumstances, how is it possible to maintain objectivity and not be subject to the stress encountered by everyone sharing the experience? How valid are data collected even by highly trained scientists under these conditions?

The laboratory approach also faces criticism. Lazarus, et al. (6) have seriously questioned the validity of experimental situations designed to simulate stress. They argue that one can never be certain that a situation is truly stressful for the subjects because this evaluation is highly subjective. Stress research in most instances has been performed in university or governmental laboratories using rather sophisticated volunteer subjects. Under these circumstances there is likely to be an awareness that a situation which appears to be dangerous is actually simulated, and not real.

5.2. Panic Behavior

Another concept which has received attention from researchers is panic. Although panic is a dramatic term, it is also an ambiguous one. It has been used to describe many different kinds of behavior -- ranging from a wild outburst of flight to paralysis of action. Therefore, its meaning has become vague. Sometimes the word is employed merely as a colorful term to refer to any type of behavior which occurs when people feel especially afraid or worried. A widely used definition of the term panic is as follows:

"... highly emotional behavior which is excited by the presence of an immediate severe threat, and which results in increasing the danger for the self and for others rather than reducing it."(18)

For example, in accordance with this definition, flight is not necessarily panic since flight may result in reducing the danger.

According to Turner and Killian (18), there are four main factors which are characteristic of the panic-producing situation. They are: (1) Partial entrapment -- one or a limited number of escape routes from a perceived threat situation, (2) Perceived threat - physical, psychological, or a combination of both, and usually regarded as being imminent so only escape is possible, (3) Breakdown of the escape route -- route becomes blocked off, jammed, or is overlooked, and (4) Front to rear communication failure -- false assumption that exit is still open, people at the rear of a mass exert strong physical, or psychological pressure to advance toward it causing those at the front to be smothered, crushed, or trampled.

5.3. Threat Behavior

Glass (14) presents another formulation of behavior under emergency conditions. First, he indicates individuals have a present attitude to an emergency. He notes that uncertain threats might be categorized as mild, moderate or severe. A mild threat to one person might be perceived as being severe to another. For example, travelling as a car passenger might constitute a severe threat to someone who has just recovered from injury due to an automobile accident, while for another person, the same experience might hardly constitute any threat at all. A threat might lead to the readiness for flight from the scene or to fight the cause of the threat. Glass indicates that one type of flight reaction is the refusal of many drivers to use seat belts thereby denying that any danger exists. A contingency response is said to be the most effective one in the face of danger. This consists of gathering additional information and preparing for appropriate behavior without indiscriminate worry.

The same author discusses variations in ability and speed of perception, comprehension and action. The most appropriate behavior is characterized by intelligent prompt perception, analysis and reaction. This behavior is typified by those who can utilize available information and act constructively for themselves and others. An estimated 10-25% of individuals have been recorded as acting in this manner in civilian and military situations.

Most people are said to have adequate perception but irresolution in action in emergency situations. Such persons do not know what to do. So their behavior is often described as irresolute, vacillating or suggestible. They are ready to follow others, either productively or destructively. Another smaller group of people do not perceive the situation adequately and are quite helpless. Even when led, they have difficulty responding. The term "shell shock" evolved from this characteristic behavior pattern in military situations.

5.4. Disaster Studies

A group of studies were conducted under the auspices of the Disaster Research Group of the National Academy of Sciences. In all, nineteen studies were completed between 1956 and 1963. They were designed to provide information which could be used for planning purposes in the event of a nuclear attack in order to reduce the number of deaths and injuries. The studies encompassed a broad range of topics ranging from theoretical discussions of stress behavior, to methodological problems in field studies of disasters, to studies of many actual disaster situations. These studies probably constitute the best available source of information concerned with collective behavior during disasters, but unfortunately they barely address the question of how the individual reacts in a disaster.

Before examining the "disaster studies", it might be useful to explore the difference in viewpoint between the psychologist who is primarily concerned with individual behavior and the sociologist who focuses his attention on group behavior.

The study of group behavior, especially as related to disasters comprised a major effort by researchers. Surveys developed for fire emergency purposes have also frequently reflected the viewpoint of the sociologist. In these instances there has been an abundance of data grouped in accordance with various classification schemes, providing a composite overview of data such as fire injuries and deaths. However, limited information is provided in a form where behaviorally related causes can be associated with these casualties. The study of leadership activities in fire disasters has also been of interest to investigators. Other research topics have been an investigation of the roles played by individuals in an organization as well as the characteristics of the organizations themselves. For example, a fire in a department store can be contrasted with a similar fire in an office building occupied by military personnel. In a department store fire it would be difficult to identify anyone "knowledgeable" or "in charge". It is likely that individual actions will be based upon what each person conceives to be in his or her best interests; i.e., basically each person for himself. Some leaders might emerge, but it is difficult to predict in what form or the degree of acceptance by the group. In the other example, that affecting military personnel, the situation is likely to be quite different. Military personnel are trained to carry out commands by people in authority who are in turn trained to deal with emergencies and provide leadership. In this circumstance, it is anticipated that organizing to act appropriately as a group to combat the fire emergency will entail only a minimum effort in contrast to the department store fire where this might be an almost impossible task.

In contrast to the sociologist who is concerned with roles, group characteristics and organizational influences, the psychologist focuses his attention on individual capabilities and limitations.

In a fire emergency situation, the ability of a person to respond in the correct way depends upon a combination of inherent and learned characteristics. A fire alarm signal must be intense enough to be sensed but not so intense as to cause permanent damage. The signal must be interpreted appropriately or it will not be effective. The individual must have information indicating what should be done in the event of a fire emergency. Alternative courses of action are often open to him and he must exercise judgment as to the particular behavior to pursue. In making this judgment it is often helpful to obtain information from others who might be experts in fire emergency situations -- the best way to accomplish this transfer is by means of verbal communication. In moving from an area affected by fire to a safe area, environmental cues such as signs or lights are relied on. These signals must be sensed despite the presence of fire and smoke. Fire drills are often used to train people to respond appropriately, and therefore in the stress of an actual emergency a person will be more likely to reach safety. In such an emergency it can be anticipated that children, the aged, and the infirm should not be expected to behave in the same way as normal healthy adults; for each group, activities should be consistent with abilities and needs.

Killian (18) notes that when significant psychological and sociological variables are analyzed to determine how they affect behavior during and immediately after a disaster, special methodological difficulties arise. His work is addressed specifically to field studies of disasters and does not deal with laboratory techniques.

The first and most important constraint facing the researcher is his lack of control over the situation that he is studying. The fact that the research is post hoc rather than a result of careful preparation makes the timing of data collection a critical element. The investigator must be on-the-scene as soon as possible if he intends to obtain valid first hand impressions of the occurrences during the disaster. Two factors are often present which tend to seriously impair the validity of findings obtained long after the event. The first is the general tendency of memories of events to become less clear with the passage of time. The other circumstance which tends toward invalidating survey data is the tendency of people experiencing the same major event (disaster) to compare impressions until there is a general concensus as to what "really happened". This process introduces biases because of the dominance of some people and the susceptibility of others to such influence - i.e., reluctance to express a minority viewpoint.

Also, in a post hoc disaster study, the population is not in, and probably will never quite return to, its normal pre-disaster state. Any analysis of the sociological and psychological characteristics of the population before the disaster must be made in retrospect. The fact that those who did not survive cannot tell their stories can create a significant gap in the data on survival behavior.

Any disaster experience leaves the person with emotional scars. Many persons are highly ego-involved in their experience. This involvement raises the question of whether the interview responses of fire victims may be subject to faulty memory, repression, and retrospective distortion and reconstruction.

For these reasons, careful attention must be given to the design of the research, the selection of subjects, the collection of field data, and the data analysis.

Although studies of disasters have been made at various intervals of time afterward, it is generally agreed that it is best for field work to begin as soon after the occurrence as practicable. This means that a specific research design must be hastily conceived, with little knowledge of the significant characteristics of the situation.

However, if valid conclusions are to be produced, the design stage for the research must begin prior to the occurrence of a specific fire which is to be studied. The hastily designed study is not likely to make a significant contribution to the knowledge of disaster phenomena.

If planned field disaster research is to be as sophisticated as laboratory investigations, several flexible research designs must be developed for specific types of disasters. These designs and models should be supplemented by the creation of basic interview and questionnaire schedules and reliable as well as valid questions. In addition, when a permanent staff is available, trained observers with pre-assigned tasks would considerably shorten the required "lead time" in responding to disasters. Since many disasters, of differing types and magnitudes, have already been studied, the research designs and the findings from these past experiences should provide a satisfactory point of departure for this kind of planning. It is desirable to explore other research techniques in addition to the interview and questionnaire schedules. For example, interviewers should undergo considerable personal screening before being selected as researchers to guard against bias and/or training afterward.

In a report entitled "The Occasion Instant", Mack and Baker (3) investigated behaviors exhibited in situations where unanticipated air raid warning signals were sounded. They found that people exhibited "false alarm behavior" in situations where the signals were real ones. They concluded that hearing the warning signal alone is totally inadequate to stimulate people to immediate protective action. Most people sought additional information to validate or refute the interpretation of the original signal. The sources of verification were usually informal and unofficial ones. The authors indicate that interpretations of the signal might be required during the event to guide people in making the appropriate response. They further note that the organizational context is the most important factor in eliciting the correct response. That is, if there is an official directive in a place of business by "the boss" to perform an action, then people act despite their attitudes because of the sanctions that might be applied in the event of not acting appropriately.

In summarizing their findings, they note that a series of factors must be considered in an emergency. The receipt of a warning message is treated in the context of the overall situation that is evaluated by the person. Objective reality is but one factor in this evaluation -- past experience with the same signal must be considered also. The interpretation also depends largely on the observations made of the behavior of others in the environment. The responses of people in positions of authority are another strong determining factor. The type of group present at the onset of the signal is an important factor. Being with one's family adds to the likelihood of taking a signal seriously. The educational status of the person has been found to be relevant also. Those with middle level educations are more likely to respond appropriately than people with low or high level schooling experience. The characteristic of an organization is another important determining factor. Signals received in a large and complex organization are more likely to be believed than those occurring in a smaller institution. Finally, those people who perceive the environment as a threat are more likely to believe a warning signal than others.

Withey (26) provides a theoretical formulation of the characteristics of <u>threat</u> in his evaluation of disaster research:

1. The probability of occurrence of a threatened event. He notes that as a person perceives an increased likelihood of a threat, the attempts to escape the threat will intensify. A threat with a low probability of occurrence will be ignored if a major effort is needed to protect oneself against that event.

2. The imminence and duration of the threat. The more immediate the threat, the more anxiety and stress is likely to be created in the individual -- thereby increasing the probability of inappropriate behavior.

3. The possibility of escape or adaptation to the threat. When escape is perceived as being possible, the behavior tends to become adaptive for the conservation of the organism.

Withey also identifies a number of ways that an individual may attempt to structure and evaluate situational threat cues.

1. Recognition. The individual must become aware of the warning stimulus. The threat cues in a fire are usually continuous in nature with an increasing intensity due to the dynamics of flame, heat and smoke. Two factors tend to obscure these warning signals. First, there is an attempt to pattern and structure cues in familiar terms, thereby discounting the threat. Second, people are less likely to predict unfavorable events than favorable ones. Therefore a harmless plausible explanation is often accepted as the truth in spite of evidence of the contrary.

2. Validation. Validation consists of efforts to verify the information previously received. In most threat situations individuals communicate with neighbors to help assess whether the perceived threat is a valid one.

3. Definition of the situation. The individual attempts to obtain information better describing the magnitude, timing and possible losses threatened by the event. The role concept adopted by the individual is a very important factor. The fire officer in a threat situation with his entire family may react very differently from his expected professional role. In many instances, roles may conflict thereby making it difficult to even define the appropriate one for the situation (e.g., which takes precedence: being a father or a fire official?).

4. Evaluation. Evaluation is the preparation phase for action. It is the step in the decision process where a decision is made to behave in a particular manner. The behavior of others is often a determining factor.

5. Commitment. Commitment is the action taken in response to the threat and results in success or failure in alleviating threat.

6. Reassessment and Overcommitment. After the failure of a previous action to alleviate the threat, more intense effort is often expended. At this stage the individual is most susceptible to nonadaptive behavior. As successive failures are encountered, frustration increases and adaptive behavior is more difficult to achieve.

Much of the disaster study research was performed in the context of the need for improved methods of organization and communication to avert large scale loss of life. The problems primarily addressed were analogous to the "command and control" concerns of the military, which are often those of translating decisions into appropriate actions. A primary goal in these investigations is the proper planning and coordination of activities to minimize losses during fires.

6. PROBLEM LIMITATIONS AND SCOPE

The preceding summary treatment indicating the breadth of the occupant fire safety problem points towards the need to limit the scope of the present investigation. Our expressed goals are the logical criteria to employ in selecting relevant material to be covered. These goals are defined as follows:

1. To better understand individual behavior during a fire emergency in a building.

2. To investigate a limited number of building design features as they relate to occupant safety.

3. To suggest research approaches to better understand the fire safety problem.

4. To suggest possible methods of improving current design methods as they apply to safety.

The particular focus of attention is therefore limited to the responses of the individual to his environment in a building fire emergency and conversely, the relationship of environmental features to this behavior.

Fire safety will now be considered from the two orientations felt as being the most relevant for the present study: The design/management orientation and the psychological orientation.

6.1. Design/Management Problems

The recent conference on fire safety in high-rise buildings (20) resulted in a thorough treatment of the subject. The proceedings of this meeting serves as the basic source for the material presented.

The attendees of the conference operated from a number of assumptions. They indicated that the data compiled by Galbreath (13) and others on the time that it takes to evacuate high-rise buildings makes it imperative that fire safety approaches other than evacuation be carefully considered. One such method is the design of "safe areas" in a building and adequate access routes to these areas. One concept proposed at the meeting was that a high-rise building is best thought of as being a self-sustaining community. To some extent, therefore, those responsible for designing and managing a building constitute an important component in a fire safety "system". The treatment of fire emergencies using a systems approach was emphasized in the conference.

Three basic and available methods for fire limitation were considered:

1. Control over the potential fuel for fire. This method encompasses the direct combustion potential and the potential for the development of smoke and toxic gases. Building codes and construction contracts deal with the building design aspects of the problem, but the behavior of the occupants is not considered. There is little or no control exercised over the characteristics of the furnishings which are brought into the building by the occupants and this often constitutes a major hazard.

2. Compartmentalization of the fire by the structural elements of the building. This isolation of one part of the building from other parts has implications for occupant safety. The individuals who are in a zone of the building affected by fire must have ready and multiple access to safety consistent with the degree of isolation of the fire. Similarly, "safe areas" in the building must be both accessable and safe. The independence of sub-sections of the building from a structural standpoint implies that each of the sub-sections may also constitute separate social communities. During the fire emergency there will be a need for communications systems that, from a central location, can contact each of the many communities. Since total evacuation is no longer considered a feasible approach, general messages by means of alarm signals might not be appropriate. Instead, instructions would be more complex because many messages would have to be sent not just one calling for evacuation of the building. The particular message would depend on the location of the fire zone, the location of the zone contacted, the number and placement of safe-areas in the building and a variety of other safety related factors. Management researchers and many others have expressed the view that communications are not effective if they are only one-way. Therefore, it will also be necessary for occupants to have the capability to contact management, fire fighters, and occupants occupying other locations. Similarly, these other groups would need to contact one another.

Because of the population density in a high-rise building a major concern is the avoidance of panic behavior which could result in many casualties. One of the primary justifications for a comprehensive verbal communications system is to avert panic. It is anticipated that if "fire victims" can maintain close and continuing two-way contact with fire safety experts, calm and rational behavior will be maximized and panic behavior avoided.

Verbal warnings can also be pre-recorded, especially if a zoned warning technique is adopted. This would entail messages such as: "... fire has been reported on the fourteenth floor of the building. Please go to the twelfth floor without delay and await further instructions." The recorded announcements can readily be used in conjunction with either real-time voice communication or traditional alarm signals. It is not surprising therefore that communications requirements were a major topic of discussion at the conference, which covered problems such as: the design of general alarm systems, two way communications systems, characteristics of a centralized control, and communications "command post" for emergencies.

3. The prompt and early extinguishment of fire. This measure was largely considered in terms of automatic systems, but the role of building occupants was also thought to be an important component. Mr. Innamoriti of GSA was especially concerned about the general neglect of the occupant in developing fire fighting plans from a systematic viewpoint. Can we expect occupant participation in fire control? If so, what resources should be made available to make participation maximally effective?

Mr. E. G. Halstead of the NFPA outlined the occupant protection safety requirements in high-rise buildings. He noted that three methods of movement are available -- stairways and elevators for vertical transport and horizontal exits to fire safe areas. Since smoke and fire will eliminate some of the paths to areas of refuge and escape, alternate paths are important. Finding these alternative routes might be quite difficult under some circumstances and might necessitate contact with a communications center in the building (or its equivalent). The inadequacy of elevators for fire emergency evacuation has received considerable attention recently. The Washington Post of December 1, 1972 presented a typical example of the problem in a description of a fire which occurred in a high-rise building in New Orleans. The elevators were brought to the floor where the fire was in progress due to a heat sensing "calling" device. The doors were then kept open by the smoke which triggered the electric eye door opener. The victims were thereby first taken to the fire and then trapped there because of the particular design features incorporated in the elevator.

Mr. Halstead also suggested the need for a "public confidence" system which incorporates many of the communications needs mentioned earlier. He further indicated that a safety and training plan should be prepared for a building and its features would depend somewhat on the occupancy -- whether normal, elderly, sick, disabled, etc. He notes the importance of having a central control point for providing information and reassurance to fire victims. The assumption is that the more that is known by occupants about prevention and control programs available, building design safety features, and alternate escape routes -- the more likely that occupants will act responsibly during emergencies.

Smoke presents a particular problem in high-rise structures because the pressure differentials between the top and bottom of the building lead to "stack effects" (the upward funneling of smoke) during a fire. Consequently, during a fire emergency there are likely to be great concentrations of smoke and noxious fumes in the upper stories of a building. Movement to safety is extremely difficult and time consuming under these circumstances for two reasons. First, fire safety information is usually presented by means of visual cues such as lights and signs. Second, actual movement, whether by stairs or corridors, is also largely dependent upon visual perception. Especially difficult is vertical movement because the stack effects are most prominent in such places as stairwells.

A review of the conference findings on design/management problems indicates that a major area of concern should be the clear delineation of responsibility among those participants directly involved in fire safety activities. Table 1 indicates some of the activities of various responsible people grouped by fire-related functions. In any systems oriented approach to the fire problem it will be necessary to:

-- Define all relevant activities and then

-- Assign people responsibilities for performing those activities

After these activities and responsibilities are better understood, it is anticipated that appropriate fire protection systems will be easier to develop. Only after decisions are made about what should be done and who should bear major responsibilities, does the problem of how to accomplish the objective take on major importance. In the design of "systems" dealing with fire safety activities, a major decision point concerns the manner in which the system is supposed to operate -- manual or automatic, or a combination of the two. Naturally, this determination will be largely dependent on the activities and responsibilities which have been identified previously.

TABLE 1

Activities of Various Responsible
People Grouped by Fire-Related Functions

Fire-Related Functions (activities)	Occupants	Management	Firemen	Designers	Building Code Inspectors	Urban Planners
Prevention	Inspect immediate area	Regular cleanup			Enforce Code Requirements	
Detection				Provide automated alarms		
Alarm	Knock on doors					
Communi-cations			Links to building, police			Specify links between building & fire dept.
Combatting Fires	Use extinguishers	Provide extinguishers		Automated fire fighting (sprinklers)		
Movement to Safety		Improved ladder use	Passage-way design			

6.2. Individual Behavioral Problems - Psychological

The research approach employed in the Disaster Research Group studies is almost universally adopted in fire research investigations. That is, the focus of attention is on "mass" and "group" behavior rather than on individual response. The investigations of panic behavior are another instance of a concern primarily with collective rather than individual behavior. It is interesting that both in their publications and during personal interviews, the researchers responsible for much of the disaster investigations made the point that panic behavior is a rare phenomenon. They were unable to document many instances where behavior in a disaster could reasonably be classified as typifying panic conditions. Instead they emphasized that the behavior of most disaster victims is both reasonable and appropriate. Therefore safety systems that are designed primarily to prevent and reduce panic may not be optimal.

The selection of the level of behavior to be analyzed and quantified has profound consequences in terms of conceptual models needed for both understanding the phenomena and for identifying possible solutions to problems. If the group is the smallest unit examined, then communication and organizational variables are likely to be highlighted. On the other hand, if individual behavior is under study, perceptual responses to visual and auditory signals will receive considerable attention. For any real understanding of the behavior of people in fires, it is likely that both individual and group responses must be considered. Since group responses have received considerable attention, we will consider the individual only. This focus on the individual is not meant to preclude an examination of the social forces acting on the person and the influences of these factors on individual behavior.

The conference on fire safety did not completely neglect problems based on occupant characteristics and behavior. They considered both psychological and physiological data requirements in their deliberations. One such interest area was the tolerance of individuals to heat, fumes and smoke before any serious impairment would result. This information would be very valuable in making meaningful tradeoffs between alternative behaviors in a fire emergency. For example, should "fire victims" expose themselves to relatively known concentrations of smoke rather than risk trying to move through a fire in getting to an exit? Without information about the relative dangers of a given fire or smoke emergency, it is difficult to make informed decisions about rescue -- especially when a large number of possibilities are available.

Another question posed was the willingness of people to use safe areas in a building to sit out fire emergencies, especially when they perceive possible routes out of the building. This situation can be interpreted as one aspect of defining individual responsibility for safety and its relationship to preconceived emergency plans.

Pauls (22) presents a detailed discussion of many of the relevant individual parameters that merit consideration in a fire emergency. One such factor is the awareness that there is an occupant safety problem associated with fires. He noted that interviews with many fire officials confirmed his hypothesis that most people feel completely safe in modern high-rise buildings. He was told that warnings of hazardous conditions are often disregarded or rationalized away because of the feeling that the buildings are invulnerable to fires. The author indicates that this behavior of ignoring danger warnings might be appropriate in new structures which are designed to compartmentalize fires, but could be disastrous in traditional buildings where fire spread is more likely. As noted earlier, even in new construction the hazards associated with smoke have not been sufficiently considered. The attitudes of the occupants are therefore an important factor in designing fire safety systems.

Pauls further notes that an understanding of basic perceptual processes might suggest means of facilitating egress from a building. One such method might employ a phototropic response (a reflex orientation of the eye to an area of higher luminance). Blinking lights which are rather unpleasant could then be used to discourage people from remaining in a particular area. He then notes that stairwells are rather unpleasant places because they are often not well lit, have rough surfaces, and are quite noisy due to the hard surfaces. As a result of these factors, people tend to avoid stairwells and therefore they are relatively unfamiliar to most building occupants. During a fire emergency, therefore, when the stairs must be effectively used, this strangeness will likely have a detrimental

effect on evacuating the building in a timely fashion. If stairways were attractively designed, Pauls suggests that they would be used more frequently and their effectiveness during fire emergency conditions would thereby be improved.

In summary, the most striking feature which resulted from the review of psychological material was the dearth of relevant data. The search for information based on multifamily dwelling fires was almost totally fruitless, and therefore the subject area was expanded to include high-rise buildings. In recent years, high-rise building fires have received considerable attention and much of the present report is based upon this information. The treatment of fire-emergencies in a systems context appears to be a major step in the direction of understanding the problem in all of its complexity. The difficulty from the point of view of the authors of the present report is that the human factor (whether as a "passive" occupant or as an "active" fire fighter) has not received sufficient attention as a systems component. This difficulty will be treated in detail later.

7. RATIONALE FOR A RESEARCH APPROACH

The authors of the present report are in agreement with the basic approach taken by Pauls -- to obtain information about the effect of environmental characteristics on the behavior of individuals in fire emergency situations and then design safety systems based on this information.

However, since there is little consistent and systematic information concerning either the responsibilities or the activities of all those directly involved in fire emergency situations, the occupant is in a precarious situation. Is he to assume an active role in dealing with the emergency or is he to remain basically passive and respond to instructions by experts whether planners, managers or fire fighters? Under what circumstances should be perform an action and if called upon to act, what should he do? In a situation where a person's life is at stake, it appears logical that there must be some degree of self-reliance! Ultimately, the individual may be placed in a situation where he unquestioningly follows instructions or directions established by experts or relies on his own judgment. It is more likely that the response will be based upon a combination of the two -- a personal evaluation of the alternatives provided by the experts. Saving one's own life can be considered the most important decision made by a person -- is it reasonable to expect that this decision will be left to others?

The difficulty for fire fighting organizations to gain access to fires in the upper levels of high-rise buildings seems to emphasize the need for participants to have a clear understanding of what they are expected to do in fire emergencies, and how their actions relate to their own safety as well as to the safety of others. Reliance on organizations set up by building managements overlooks current occupancy behavior in many high-rise buildings. It has often been stated that people dwelling in apartment complexes often tend to avoid personal contact with neighbors and do not socialize closely with other building occupants. Instead, they prefer to remain comparatively anonymous and socialize with people outside of their immediate living surrounds. The occupancy of office buildings is also often a random selection of enterprises which have little in common with one another. Consequently people who are "neighbors" have little in common and, therefore, have little reason to interact. Under these circumstances, it is likely that the organization of these diverse "individuals" for any common purpose such as fire drills would be extremely difficult. When a person has limited association with his neighbors and little knowledge about them, he is likely to demonstrate an attitude of "each man for himself" rather than undertake joint effort with others to fight a common emergency. Since this attitude is quite prevalent, it would appear very important to design fire safety systems suitable to the individual's capabilities rather than assume the availability of a complex safety system requiring a great deal of communication and organized responses by groups of people. This consideration would be especially important for buildings designed for specialized occupancy such as homes for senior citizens and people with physical or mental disabilities. The individually designed safety system would in any case serve as a valuable backup for those people isolated from other individuals and without access to communications.

The design approach of compartmentalization in fighting a fire would be effective in preventing its spread, but what about those people directly affected by the fire and smoke? These "victims" would need passage to safety and would require sensory cues (lights, alarms, etc.) to lead them away from danger to safe areas.

In dealing with the fire safety problem from the vantage point of the individual, the concern is to identify those environmental characteristics which can be used to facilitate egress to safety. Before proposing design solutions, questions must be posed in a manner which can provide action in a useful form. For example:

-- What features of the environment either assist or retard the ability to leave the building?

-- How much illumination is required to safely descend the stairs during a fire?

-- What information is needed before a fire alarm is regarded as a real one rather than a test?

-- What is likely to catch the attention of most people and therefore might be used for an alarm signal?

-- What exit markings are appropriate?

-- How does the presence of smoke affect the ability to respond to visual and/or auditory alarm signals?

-- How do individuals differ in their needs in fire emergency situations -- aged, handicapped, children?

An inspection of the subject matter covered by these questions provides some indication of the range of informational requirements needed. In order to obtain the necessary answers, research which spans both fundamental and applied problems will have to be performed. The basic data requirements will include information concerning the functioning of the sensory processes of vision and audition during emergency situations. The interactions among these sense modalities are especially relevant in the design of complex detection and signalling systems. Another fundamental area not well understood is what constitutes "normal" behavior in an emergency. If we knew <u>how</u> an individual typically responds in an emergency and <u>what</u> he responds to, the design of safety systems could be greatly facilitated. (This statement assumes that most people would respond in a common way and even for those who are atypical, the newly designed safety systems would be no worse than those in use at present.) The applied research calls for a better understanding of the situational requirements typical in fire emergencies, including the social forces that operate on an occupant. It is extremely important to identify the tasks that an occupant <u>can</u> perform and to determine how he can best function as an integral component in the design of a complex fire safety system.

In formulating a systematic program of research in fire safety, an investigator concerned with human responses to emergencies operates under a number of formidable constraints. Unlike the engineer, the social scientist cannot produce destructive experiments at will. Sociologists and psychologists fortunately must stop short of inducing experiences that constitute a real threat to the existence and health of the subjects. Fires do not "stop short." Fires, like other disasters, provide the social scientist with advantages that cannot be duplicated in the study of human behavior under normal circumstances. Ordinarily, the differences one finds among human beings reflect the social differentiation and cultural elaboration which attach to the various statuses and roles in society. Fires and disasters cut across many of these social and cultural distinctions and require victims to make choices under similar conditions. For this reason, such studies provide the social scientist with perhaps his best opportunity to develop generalizations about some of the basic processes of social interaction.

7.1. Human Factors Applications for Fire Safety-Recommendations

Is it necessary to wait for the results of a long range research program before being able to do anything about the fire safety problem?

The answer is NO if one considers the already-available information in this report.

Although the literature review did not point the way to many immediate design solutions, it revealed that a systems oriented approach to the problem has now been adopted by the many groups concerned with fire safety. In a sense, this orientation represents a conceptual and methodological breakthrough because it enables us to tap an information base which has been explored in the context of many complex military and civilian systems. Since a high-rise building has already been likened to a community, it appears that past experience with other complex systems might well provide useful insights. The special concern here, since we are dealing with behavioral problems, is the individual occupant's relationship to the system. This study area has often been termed "human factors."

In the design of command and control systems for military use, the traditional method of attack is to first describe overall system requirements, then subsystem requirements and finally the functions that must be performed to satisfy these requirements. Then, on the basis of the ability of man or machine to best perform a particular function, a system design is established, utilizing the particular capabilities of man or machine, in the most effective manner possible. McCormick (19) provides a summary comparison of the capabilities of man and machine.

"Human beings appear to surpass existing machines in their ability to:

1. Detect small amounts of sound or light
2. Receive and organize patterns of light or sound
3. Improvise and use flexible procedures
4. Store large amounts of information for long periods and recall relevant facts at the appropriate time
5. Reason inductively
6. Exercise judgment
7. Develop concepts and create methods

Existing machines appear to surpass humans in their ability to:

1. Respond quickly to control signals
2. Apply great force smoothly and precisely
3. Perform repetitive routine tasks
4. Store information briefly and then erase it completely
5. Perform rapid computations
6. Perform many different functions simultaneously."

It would appear logical in the design of any "safety system", that these factors should be carefully considered. If one were to use this approach, requirements of the occupant must first be defined, since presumably the system is designed to meet these needs. Then the available means of accomplishing these goals would be explored to determine the design tradeoffs which are possible. Naturally, during this process judgments will be made based on an understanding of the assets and liabilities that the human factor brings to a fire emergency.

Perhaps the most important reason to consider the occupant is that, although he can constitute a potential asset in any fire safety system when properly used, he has been largely neglected thus far. The flexibility, adaptability, sensitivity, information processing capability of a human being cannot be duplicated by any combination of automatic devices that could be designed to detect smoke and fire and then fight fire emergencies. With a fully automated system there is an assumption that every possible contingency has been accounted for and that everything will operate reliably during the emergency. Is this a realistic assumption?

Once we consider man as an important system component whether as a detector, a communicator, a fire fighter or in any of the diverse roles that he can play, the fire safety problem attains a new dimension. The choice does not have to be either/or between manual and automated systems. Instead, under many circumstances, man serves as a manual backup system that can be used to either supplement or override an automated one. For example, the heat sensing device at elevator landings has been identified as a major contributor to injuries and death in high-rise building fires. During a fire emergency it would be far better to bypass this automatic system and provide for manual control.

There has already been a demonstrated need for complex communications systems in high-rise buildings because of the difficulty in evacuating them rapidly. Many different types of messages will probably be sent in an emergency situation. Instructions to people directly affected by the fire and smoke are likely to be different than those sent to people in areas remote from the fire. If a master communications concept is employed, people might be asked to first assemble at one location and then receive detailed instructions later. Because of the compartmentalization, a high-rise fire might be seen as several different types of situations which occur simultaneously in the same building -- each one requiring a special response. For example, one "compartment" might be affected by smoke, another by fire, and a third not affected at all. When all of these complexities are taken into account, there appears to be a great need for feedback information by occupants as well as detailed particular instructions for the various groups affected by the emergency. Under all of these circumstances, is it reasonable to expect designers, and building operators to develop fire safety systems which are independent of the occupants and which will safely take every possible contingency into account?

Aside from those systems which are primarily dependent upon an important contribution by man, there are many instances where fully automated systems are logical design solutions, but a manual backup system is also required. When a critical function must be performed (e.g., the activation of a sprinkler system) and its failure could have catastrophic consequences, alternative means of operation are highly desirable.

In reviewing the capabilities of man as compared with that of a machine a major advantage possessed by man is his ability to function effectively under unexpected circumstances and the flexibility of responses that are available to him. Aren't these characteristics critical in getting to safety in a fire emergency situation?

If the occupant is to be an active participant during the various phases of a fire emergency, the fire safety system must be designed in a manner to optimize his contribution toward his own safety. It appears very important to determine how this end can best be accomplished.

8. BIBLIOGRAPHY

1. Ahern, J. J. and Morgan, C. S., "The National Fire Profile", Fire Journal, 66 (March 1972), pp. 7-11.

2. America Burning, The Report of the National Commission on Fire Prevention and Contol, May 4, 1973.

3. Baker, G. W. and Mack, R. W., The Occasion Instant, Disaster Study 15, Washington, D.C.: NAS, 1960.

4. Benzaquin, J., Holocaust, New York: Henry Holt, 1959.

5. Bland, R. E., "The Evaluation Program of the National Commission on Fire Prevention and Control", Fire Journal, 66 (July 1972), pp. 18-20.

6. Bryan, J. L., "A Study of the Survivors Reports on the Panic in the Fire at the Arundel Park Hall in Brooklyn, Maryland, on January 29, 1956." Unpublished Investigation.

7. _____ , "Is Panic Inevitable in Department Store Fires?" Man and Behavior Conference Paper, Ruschikon, Switzerland, 1970.

8. Cannon, W. L., "A Study in the Effectiveness of Exit Markings in Multistoried Department Stores", unpublished study, University of Maryland, 1968.

9. Chandler, S. E. and Woolley, J. E., Fire Deaths in the Third Quarter of 1971, Fire Research Note 902, Borehamwood, Herts, Eng.: Joint Fire Research Organization, 1971.

10. Darley, J. M. and Latane, B., "Group Inhibition of Bystander Intervention in Emergencies", Journal of Personality and Social Psychology, e. 3, 1968.

11. Federal Fire Experience, Annual Report FY 1967, Federal Fire Council, 1969.

12. Fox, G., "Fire Protection Deficiencies in Building Codes From An Architect's Viewpoint", Fire Journal, 66 (May 1972), pp. 666-70.

13. Galbreath, M., A Survey of Exit Facilities in High Office Buildings, Building Research Note 64, Division of Building Research, Ottawa: National Research Council, 1968.

14. Glass, A. J., "Mass Psychology", Workshop on Mass Burns Proceedings, Washington, D.C.: NAS, 1960.

15. Glass D. C. and Singer, J. E., Urban Stress, New York: Academic Press, 1972.

16. HUMRRO Bibliography of Publications, Alexandria, Va.: HUMRRO Publications, 1969.

17. Joint RILEM-ASTM-CIB Symposium Proceedings, Performance Concept in Buildings, NBS Special Publication 361, Vol. 2, Washington, D.C.: NBS, 1972.

18. Killian, Louis M. and Turner, Ralph H., Collective Behavior, Englewood Cliffs, N. J.: Prentice Hall, 1957.

19. McCormick, E. J., Human Engineering, New York: McGraw Hill Book Company, Inc., 1957.

20. National Conference on Fire Safety in High-Rise Buildings, Airlie House, Warrenton, Virginia, GSA-Public Building Service, April 12-16, 1972.

21. National Research Council, Directory of Fire Research in the U.S. 1969-1971, Washington, D.C.: NAS, 1972.

22. Pauls, J., "Responses to Emergencies in Buildings", Diss. Univ. of British Columbia, 1969.

23. Sampson, A. F., "Life Safety Systems for High-Rise Structures" Fire Journal, 65 (July 1971).

24. Second Report of the Operational Research Team on the Capacity of Footways, Research Report No. 95, London: London Transport Board, 1958.

25. Selected Abstracts from the Literature on Stress, Technical Report: NAVTRAD-EVCEN 565-1, Port Washington, N. Y.: U.S. Training Devices Center, 1960.

26. Withey, S. B., "Reaction to Uncertain Threat", Man and Society in Disaster, Ed. C. W. Baker and D. W. Chapman, New York: Basic Books, 1962.

27. Workshop on Mass Burns Proceedings Committee of Fire Research, Washington, D.C.: Dept. of the Army and NAS, 1969.

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Fire safety in buildings is important in building design and the formulation of codes and standards. However, an examination of the information concerning the needs of occupants in fire emergencies (as opposed to ensuring a degree of structural integrity for the building) indicates that the scientific information base is woefully inadequate. The increasing prominence of high rise buildings having many occupants intensifies the need for better information about the behavior of occupants during fire emergencies. Fire researchers have indicated that it is often not feasible to evacuate buildings because of time constraints. Instead, designers use techniques such as safe areas within buildings and requiring people to respond differentially, based on their particular location. This approach emphasizes communications and warning systems to transmit messages. These systems such as loud noises or blinking lights should be designed to "take advantage" of the usual responses made by people. Occupants can actively be a part of the fire warning and fighting system instead of being unwilling victims. This possibility is pursued and a human factors approach is taken to suggest some means of better understanding the capabilities of occupants.

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