

**OPTIMAL STAFFING LEVELS FOR FIREFIGHTER EFFECTIVENESS AND
MITIGATION OF FIREFIGHTER INJURIES**

EXECUTIVE DEVELOPMENT

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ABSTRACT

Martinsville Fire Department provides fire protection and EMS first response to Martinsville, Virginia, a city of 16,000 residents. The problem was that as call volume increased, MFD frequently responded to fire calls with a number of firefighters perceived to be below the optimal level for performance of duties and mitigation of firefighter injuries. The purpose of this research project was to identify the optimal staffing level for fire ground operations in order to effectively and safely perform firefighting duties.

The evaluative research method was used and answered the following questions:

1. During fire ground operations, what laws and/or standards govern numbers of firefighters required to perform fire ground duties?
2. How do staffing levels of MFD compare to other fire departments?
3. At what numerical threshold do firefighter injuries increase during fire ground operations?
4. What is the effectiveness of three, four, and five-person engine companies during firefighting operations?
5. What do past-reports show to be the frequency of MFD being on another call when receiving a structure fire call?

Research was conducted with a literature review, personal interviews, and with a survey instrument. It was learned that this agency responded to structure fire calls with less than optimal numbers of firefighters and with fewer firefighters as compared to other agencies. Recommendations include hiring one additional firefighter per shift, establishing an automatic aid agreement with Henry County, and implementing an aggressive volunteer recruitment campaign.

INTRODUCTION

Each year, twice as many firefighters are injured as civilians (National Fire Data Center, 1996). In 1994, the Martinsville Fire Department (MFD) responded to 425 calls per year, and in 1999, the same department answered 1,966 calls (Brock, 2000). Since the increase in call volume, staffing levels have not increased. The problem is as call volume increases, MFD frequently responds to fire calls with a number of firefighters that is perceived to be below the optimal level for performance of duties and mitigation of firefighter injuries.

The purpose of this research project was to identify the optimal staffing level for fire ground operations in order to effectively and safely perform firefighting duties. Fire suppression operations have three basic functions: 1) rescue; 2) work involving the ladder, forcible entry, and ventilation; and 3) the application of water through hand lines (International City Management Association, 1988). Due to present personnel staffing, MFD fears that these objectives cannot safely be met. The evaluative research method was utilized to answer the following research questions:

1. During fire ground operations, what laws and/or standards govern numbers of firefighters required to perform fire ground duties?
2. How do staffing levels of MFD compare to other fire departments?
3. At what numerical threshold do firefighter injuries increase during fire ground operations?
4. What is the effectiveness of three, four, and five-person engine companies during firefighting operations?

5. What do past-reports show to be the frequency of MFD being on another call when receiving a structure fire call?

BACKGROUND AND SIGNIFICANCE

MFD covers 12 square miles, 16,000 citizens, has 28 career personnel, twelve volunteers and two stations. The department is composed of three divisions that include suppression, emergency medical services (EMS), and prevention. Four personnel of the career staff perform administrative duties and are not assigned to engine companies. Eight firefighters are assigned per shift, with a minimum of six personnel per day. When fully staffed, six firefighters are assigned to the main station, and two firefighters are assigned to the second station. At less than full staffing, firefighters at the main-station are reduced, with four or five personnel on duty while two firefighters remain at the second station. Volunteer firefighters may respond to the scene of a call or may ride the apparatus responding from the station. Volunteers are in no way obligated to specific duty rosters.

On November 1, 1995, MFD became licensed by the Commonwealth of Virginia as an advanced life support, first response agency. The program was initiated following the conclusion of a comprehensive study by an independent consultant. The study suggested implementation of an EMS program through the fire department to provide patient care due to increased response times and unpredictable responses by the local rescue squad. Firefighters are cross-trained in both fire and EMS. Personnel are certified at various levels from first responder to paramedic. Patients are transported to the hospital by local, volunteer rescue squad ambulances. In 1999, during 50% of the

rescue squad's calls, the ambulance arrived with a one-person crew (Hopkins, 2000). This equates to an average of 50 calls per month in the City of Martinsville, and this figure has escalated as compared to 1995 when the EMS first responder program was initiated. Prior to the EMS program, MFD responded to 425 calls per year. Since implementing EMS first response, MFD responds to nearly 2,000 calls per year. This represents an increase in call volume greater than 400%.

When only one crewmember responds with an ambulance, a firefighter is forced to ride with the patient to the hospital as the attendant-in-charge of care. This leaves the department understaffed while the firefighter is acting as an emergency medical technician. When a fire call is received and first responders are answering EMS calls, only four to six firefighters are available for fire response. Occasionally, fire engines leave the station with only one or two firefighters. In the case of only four firefighters responding, the incident commander is forced to serve in the standby mode to back-up firefighters that are performing an interior attack. This sacrifice is necessary due to a new regulation by the Occupational Safety and Health Administration (OSHA) called 2-in/2out. When the incident commander serves as a back-up member, it is anticipated that one day, the same person may have to abandon scene-management duties to rescue interior firefighters. Additionally, MFD fears that continued, upward trends in call volume will lead to firefighter injuries due to being understaffed. The problem and potential, future increases in call volume is related to legal implications and labor relations, and these areas were studied in the Executive Development Course. MFD is genuinely concerned about studying minimum staffing levels and identifying any relationships between sub-minimal staffing levels and firefighter effectiveness.

LITERATURE REVIEW

Research was conducted at the National Fire Academy's Learning Resource Center in Emmitsburg, Maryland. Additionally, fire service standards, laws, publications, emergency service magazines, books, executive fire officer research papers, and personal interviews were researched and examined. The goal of the research was to identify current sources that directly relate to the problem. In at least one case, a source from 1988 was utilized due to no evidence of the given material being obsolete.

Research Question #1– During fire ground operations, what laws and/or standards govern numbers of firefighters required to perform fire ground duties?

The National Fire Protection Association (NFPA) publishes standards for fire departments to use as a guide. Although they are not required to follow, the publications often become the way of conducting business in the fire service. The NFPA Index was examined for standard(s) of recommended numbers of firefighters when performing fire ground operations.

Per *NFPA 1500, Standard on Fire Department Occupational Safety and Health Program* (1997), fire departments have the responsibility to set policies with the minimum number of firefighters. The standard further states:

“The fire department shall prepare and maintain written policies and standard operating procedures that document the organization structure, membership, roles and responsibilities, expected functions, and training requirements including the following: 1) the minimum number of members who are required to perform each function or evolution and the manner in which the function is to be performed,

and 2) the number and types of apparatus and the number of personnel that will be dispatched to different types of incidents.” (Section 2-1.2)

Safety risk mitigation is the responsibility of the fire department. It shall be the responsibility of the fire department to research, develop, implement, and enforce an occupational safety and health program that recognizes and reduces the inherent risks involved in the operation of a fire department (NFPA 1500, 1997).

The fire department shall be responsible for compliance with all applicable laws and legal requirements with respect to member safety and health (NFPA 1500, 1997). In the event of a firefighter injury or death, the fire department is the agent responsible for demonstrating compliance with such issues. It is vital for fire departments to be cognizant of safety and health issues in order to facilitate adherence to any such standards.

Since fire departments are required to develop procedures for defining the number of members to perform each function, NFPA 1500 (1997) adds that the fire department shall provide an adequate number of personnel to safely conduct emergency scene operations. Additionally per the standard, operations shall be limited to those that can be safely performed by the personnel available at the scene.

Two subsections of NFPA 1500 (1997) were located that actually define the minimum number of personnel that are required at certain types of incidents.

“In the initial stages of an incident where only one team is operating in the hazardous area at a working structural fire, a minimum of four individuals is required, consisting of two individuals working as a team in the hazard area and two individuals present outside this hazard area for assistance or rescue at an

emergency operation where entry into the danger area is required.” (Section 6-4.4)

“One standby member shall be permitted to perform other duties outside of the hazardous area, such as the apparatus operator, incident commander, technician, or aide, provided constant communication is maintained between the standby member and members of the team. The assignment of any personnel, including the incident commander, the safety officer, or operators of the fire apparatus, shall not be permitted as standby personnel if by abandoning their critical task(s) to assist, or if necessary, perform rescue, they clearly jeopardize the safety and health of any firefighter working at the incident.” (Section 6-4.4.2)

As the apparatus operator, incident commander, or safety officer at the scene of a fire, deciding whether to abandon a task is subjective. It is difficult to include such decision-making criteria in a department’s standard operating procedures. This most likely would leave the decision to the particular fire member, thus subjecting the person to potential litigation or hesitation in making or implementing the decision.

A section of NFPA 1500 (1997) stated:

“At an emergency incident, the incident commander shall have the responsibility to develop an effective incident organization by managing resources, maintaining an effective span of control, and maintaining direct supervision over the entire incident, and designate supervisors in charge of specific areas or functions.”

(Section 6-1.5)

This standard, coupled with the previous standards, places conflicting areas of responsibility on the incident commander in that the person would be charged with the

responsibility of managing the incident and potentially serving as a rescue team member in the event of a rescue situation. Ceasing to manage the incident may potentially endanger other scene personnel. Not providing a rescue may result in a firefighter injury or death.

The standby members shall be responsible for maintaining a constant awareness of the number and identity of members operating in the hazardous area including their location, function, and time of entry (NFPA 1500, 1997). This standard further complicates the issue of giving additional responsibility to the incident commander. In the event the incident commander is serving as one of the rescue team members, this places an extra burden on the officer.

Not every state of the country complies with the regulations set by the Occupational Safety and Health Administration (OSHA). However, Virginia is one state that enforces the regulations set by OSHA. Regulations of the same agency were examined that affect numbers of firefighters required for certain fire ground duties.

Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA (1998) were examined. The standard is required of certain industries and employers, including fire departments with career employees. Although designed as a respiratory protection standard, the same includes requirements for firefighters working as teams in certain conditions. Specific numbers of fire personnel are required when performing duties in interior structural firefighting. In the report, OSHA concluded that “compliance with the final rule will assist employers in protecting the health of employees exposed to certain elements” (p.1152).

Paragraphs (g)(3) and (g)(4) of the standard describe procedures for immediately dangerous to life or health (IDLH) atmospheres. Included in IDLH atmospheres are structure fires. The same paragraphs contain a requirement dealing with standby personnel outside the IDLH atmosphere and also require communication between standby personnel and firefighters wearing respiratory protection inside the burning-structure. In NFPA 1500, communication was also required between standby personnel and inside personnel performing firefighting duties.

Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA (1998) states:

“The need for standby personnel when workers use respirators in IDLH atmospheres is clear. The margin for error in IDLH atmospheres is slight or nonexistent because an equipment malfunction or employee mistake can, without warning, expose the employee to an atmosphere incapable of supporting human life.” (p.1242)

OSHA concluded that, for interior structural fire fighting, a buddy system for workers inside the IDLH atmosphere and at least two standby personnel outside the atmosphere are necessary (Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA, 1998). In the same section, OSHA goes on to require that two firefighters must remain outside as a standby team for the two firefighters that work inside a burning structure. This ruling is known as 2-in / 2-out.

Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA (1998) points out that psychological stress is caused by the firefighter’s need to focus on the protection of lives and property, as well as the need to focus on personal

safety. As stated in NFPA 1500, the incident commander or apparatus operator may serve as part of the two-out team. If so, additional elements of psychological stress is placed on the firefighter as is, let alone if the same person serves in dual roles.

Per *NFPA 1404, Standard for a Fire Department Self-Contained Breathing Apparatus Program* (1996), members using self-contained breathing apparatus shall operate in teams of two or more.

Marenette (1998) said that the OSHA 2-in/2-out rule bars fire departments from interior operations at a structure fire if rescue is not an issue and the minimum number of personnel are not present to protect each other.

After examining standards and regulations such as those from NFPA and OSHA, there is in fact, a minimum number of firefighters that must be present in certain circumstances. Per NFPA 1500 (1997), the standard is set of at least four firefighters; two firefighters are to be inside and two firefighters outside in the standby mode. OSHA mandates that at least four firefighters must be present during structural fire fighting; this regulation identifies that there must be two firefighters outside while two personnel are inside the structure.

Research Question #2 - How do staffing levels of MFD compare to other Fire Departments?

Per an article in *Fire-Rescue News* (February, 1998), a majority of progressive paid and volunteer departments nationwide have exceeded this new rule (2-in/2-out) for years. During some structure fires, MFD barely complies with this regulation, let alone exceeding the requirement.

Bruno (1998) said that many fire departments already are operating with variations of the 2-in/2-out procedure. Bruno goes on to say that at some calls, there may be more than one standby crew. Only at full staffing could the MFD utilize more than one back-up crew. In such case, MFD could only be committed to one other call at the same time.

A personnel survey was distributed in 1999 to other Virginia Fire Departments. Eight fire departments responded to the survey. According to survey results, (Appendix A), of the eight fire departments responding, one other department, Waynesboro, had fewer on-duty personnel than that of MFD. Waynesboro operates daily with seven firefighters. The other seven departments operate with 11 to 56 firefighters per shift. These agencies have more human resources available to adhere to NFPA standards and OSHA regulations. Of the departments surveyed, Martinsville has the lowest number of minimum firefighters responding to calls; Martinsville has a minimum number of six. Other departments vary by minimum number. Danville responds with 13 firefighters while Lynchburg has a minimum staffing level of 17 firefighters.

Research Question #3 - At what numerical threshold do firefighter injuries increase during fire ground operations?

Substantial efforts over the years have been made to identify if lower staffing is associated with increased numbers of injuries. In 1995, Russell noted the following:

Historically, the fire service has been regarded as having an increased risk for injury. The fire service is at very high risk for musculoskeletal injuries, and it is one of the most hazardous industries in the country, with work related injury rates

reported to be 4.3 times greater than private industry and work lost hours 8.5 times greater than the private sector. (Russell, 1995, p.8)

The issue over minimum staffing has become one of the most controversial subjects in the history of the fire service (Clark, 1994). The topic continues to impact labor relations, especially in recent years. This subject has polarized groups representing firefighters and fire chiefs, paid firefighters and volunteers, and firefighters and city managers (Erwin, 1993; Butters, 1992; Whitehead, 1992).

In the past, staffing levels have been viewed as a matter of efficiency, as opposed to firefighter safety (O'Hagen, 1984, 1994). Only recently, has firefighter safety been linked to staffing (Varone, 1994). In 1954, the 11th edition of the NFPA Handbook (NFPA FPHB) cited the National Board of Fire Underwriters recommendation for minimum staffing of seven members on engines in high value districts, and five members on engines in other districts (NFPA, 1954). By 1969, the NFPA recommended the minimum staffing level reduced to four members per engine (NFPA FPHB, 1969). O'Hagan (1994) said a staffing study conducted by the Dallas Fire Department in 1984 measured the time necessary for three, four, and five-person crews to accomplish specific tasks during a fire ground simulation. The results of the Dallas Study indicate that staffing below four personnel can overtax the operating forces and lead to higher losses of property or life. This does not suggest that assignments were not carried out acceptably by the three-person crew, nor does it ignore the demonstrated ability of the three-person crew in controlling the test fires.

The publications of the NFPA, O'Hagan, and Varone show that earlier research on staffing levels was directed toward fire ground operational efficiency, and not toward

firefighter safety. Whitehead (1992) wrote that firefighter safety was indeed directly associated with minimum staffing. He cited numerous sources of statistics and unpublished research that showed firefighter injuries increased dramatically when staffing dropped below four firefighters per apparatus (Varone, 1994). Similarly, Stapleton (1992) wrote about staffing problems in the Boston Fire Department. He felt that the subsequent effort to reduce staffing on apparatus was purely economic. In addition, Stapleton wrote:

By the start of the 1960s, the seven and six member companies were reduced to five and four at the start of the 1980s; all companies, ladder and engine, had only four personnel responding per unit. At one point in 1981, the administration reduced staffing to three members, but there were so many additional injuries that this truly unsafe policy was reversed in a short time period. (Stapleton, 1992, p.3)

The Whitehead (1992) and Stapleton (1992) research provided supporting documentation that staffing apparatus below four-person crews leads to an increase in injuries to personnel. In addition, editions of NFPA 1500 recommended that the minimum staffing level was four firefighters responding on apparatus and at least four firefighters be assembled on scene before interior firefighting operations could be initiated at working structure fires. The publication of NFPA 1500 is the first apparent document that a staffing standard was based upon firefighter safety (Varone, 1994).

In contrast, a noted increase in injuries was documented when too many firefighters were assigned to an engine company. The United States Fire Administration (USFA) provided computer data from the National Fire Incident Reporting System (NFIRS) pertaining to the number of firefighters on incident scenes, as well as the

number of injuries. The data from a five-year period showed that nearly six firefighters on an engine had a higher rate of injuries than just over five persons per engine (USFA, June 8, 2000). Appendix B shows provisional data from NFIRS extracts, in which all types of incidents and injuries were reported. Approximately one-third of all fire departments, representing nearly one-half of the nation's population, reports data to the system.

Research Question #4 - What is the effectiveness of three, four, and five-person engine companies during firefighting operations?

One study was conducted to evaluate the effectiveness of crew size. Another study was performed to illustrate the rate of fire spread with various size engine companies. These studies are examined next.

Webb (1994) states the Dallas Fire Department performed a study after a demand to reduce staffing. The study, Impact of Crew Size of First Alarm Assignment on Fire Attack in a Residential Structure, was conducted. Firefighters were evaluated in three settings that included fire in a single-family residence, fire in a two-story apartment, and fire in a high-rise. Thirteen firefighting tasks were performed in the study with crew effectiveness expressed as a percentage. Table 1, below, depicts the results of the Dallas Fire Department Study.

"Page Not Available. Please visit the Learning Resource Center on the Web at <http://www.lrc.fema.gov> to learn how to obtain this report in its entirety through Interlibrary Loan."

on the scene. The situations given for MFD assumes that no volunteer firefighters respond; often no volunteers respond to structure fire calls. It must be understood that Dallas Fire Department's Study of efficiency ratings for first responding, four-person engine companies is the situation MFD is in on most days. MFD, with only four total firefighters, are often on scene alone, with no immediate, additional assistance responding.

The Dallas Fire Department Study analyzed three, four, and five person engine companies. As noted in the paragraph above, often MFD has only four firefighters present. Additionally, when at less than full staffing, the Incident Commander serves as a firefighter, especially since OSHA's 2-in/2-out was initiated. This study illustrates the vital importance of having additional personnel on the scene of various types of structure fires.

Another study was conducted by Ohio State University for the Columbus, Ohio Fire Department (Webb, 1994). In the study 404 structure fires were analyzed to show firefighter injuries and the rate of fire spread with various numbers of staffing. This study took a different approach as compared to the Dallas Study. Ohio State University's Study broke the research down to residential fires and incidents with large fire risk. Staffing levels of 15 and 23 firefighters were used. The study results are shown in Table 2.

Table 2

Rate of Firefighter Injuries and Fire Spread (per 10 Fires)

	Firefighter Injuries	Number of Fires Which Spread Beyond 25 Square Feet
Residential Fires		
Less Than 15 Firefighters	2.2	3.6
15 or More Firefighters	1.5	2.9
Variance	46.7%	24.1%
Large Fire Risk		
Less than 23 Firefighters	5.9	3.4
23 or More Firefighters	3.4	2.9
Variance	73.5%	17.2%

Source: Webb, J., EFO #26602

The Ohio State University Study uses 15 and 23 firefighter parameters. MFD employs only 28 career firefighters. Only on large-scale fires does MFD ever get 15 firefighters, only after mandatory recall of off-duty personnel or mutual aid response from the neighboring county. However, the study demonstrates that firefighter injuries increase by 46.7% when staffing levels drop below 15 firefighters for residential fires while firefighter injuries increase by 73.5% at large fire risks.

After further examination, the Ohio State University shows that the number of fires that spread beyond 25 square feet in size increase as staffing levels diminish.

Specifically, at residential structure fires, there is a 24.1% negative variance when less than 15 firefighters respond. But, at large fire risks, when there are less than 23 firefighters, there is a 17.2% negative variance as a result of reduced staffing.

A summary of the two studies is offered. First, the Dallas Fire Department Study depicts that five firefighters are optimal and more efficient at performing typical fire suppression efforts. When four-person and three-person engine companies act, efficiency is reduced at performing the same duties. Second, the Ohio State University Study reveals that there are more firefighter injuries with reduced staffing levels, and fires are likely to spread more than 25 feet with reduced staffing levels.

Research Question #5 - What do past-reports show to be the frequency of MFD being on another call when receiving a structure fire call?

In 1976, Martinsville City Council reduced firefighter staffing by three personnel. This reduction eliminated one firefighter per shift. Since that time, the department has gained an EMS Coordinator, and a secretary's position was upgraded to the position of Fire Prevention Specialist. Both new positions are administrative in nature. The EMS Coordinator was added due to the department's first responder program. The Fire Prevention Specialist assumes clerical responsibilities and fire prevention tasks. Other administrative positions include the Chief and Assistant Chief / Fire Marshal. All four of the administrative staff assists with response to structure fires during daylight hours, Monday-Friday. With reduction of staff and increases in call volume due to EMS response, research was conducted to investigate the frequency of MFD being on another call when receiving a structure fire call.

Departmental monthly reports were researched. The reports were analyzed back to 1996. This period was chosen due to the department commencing EMS response in November 1995. According to Hopkins (2000), annual reports were scanned with the following occurrences. MFD averages 40 structure fires per year. In 1999, the agency received 13 structure fires while firefighters were already responding to other calls. Comparatively, in 1998, there were 13 such occurrences. In 1997, there were 14 such situations while there were 18 in 1996. Mathematically, the table below, Table 3, shows the occurrences.

Martinsville Fire Department – Table 3

Frequency of Receiving a Structure Fire Call When Already Out On Another Call

Year	# Occurrences	% of Average Structure Fires Per Year
1996	18	45%
1997	14	35%
1998	13	32.5%
1999	13	32.5%

The table shows that there is greater than a 30% chance of receiving a structure fire call when firefighters are already answering other calls. When shifts are staffed at less than the minimum-level, and no other calls are being answered, there is already a less than optimal staffing situation. However, with such a high probability of receiving other calls prior to a structure fire call, the personnel shortage worsens. Crews are not afforded

the ability to discontinue a call when the department receives a structure fire call. If the crew is answering an EMS call, firefighters are obligated to continue providing patient care until the patient is turned over to the rescue squad. But, in the background, it was mentioned that MFD provides a firefighter to serve as the attendant-in-charge of patient care on 50% of the calls that MFD answers. Calls cannot be turned down in anticipation of receiving a structure fire call. Appendix C illustrates the probability of multiple calls occurring when a structure fire call is received.

Literature Summary

NFPA 1500 (1997) charges the fire department with the responsibility of complying with all applicable laws and legal requirements with respect to member safety and health. Additionally, departments shall provide an adequate number of personnel to safely conduct emergency scene operations. A minimum number of four firefighters are required while attacking an interior, structure fire. The incident commander or apparatus operator cannot serve as one of the four firefighters if abandoning the task of command or pump operations jeopardizes the safety and health of any firefighter working at the incident.

OSHA's 2-in/2-out Standard (1998) states that two standby personnel shall immediately be available outside a structure where interior firefighting is occurring. The standard does allow the incident commander or apparatus operator to serve as a standby firefighter. However, psychological stress is caused by a firefighter's need to focus on protection of life and property in addition to the need to concentrate on personal safety. At the scene of a structure fire, the incident commander has many responsibilities with scene management despite being overburdened with firefighter duties.

Bruno (1998) stated that many fire departments utilize more than one standby crew at a structure fire. Of all fire departments surveyed, MFD has the lowest minimum number of firefighters responding to calls. Martinsville has minimum, daily staffing of six firefighters, if not already out on another call, while other fire departments have up to 17 firefighters responding to any single incident.

Firefighting is one of the most hazardous industries in the country (Russell, 1995). Whitehead (1992) stated that firefighter safety is directly associated with staffing; firefighter injuries dramatically increase when staffing drops below four firefighters per apparatus. The Dallas Fire Department Study shows that five person engine companies demonstrate a 100% efficiency rating when performing interior line advancement and search and rescue tasks. Efficiency diminishes with fewer personnel.

When structure fire calls are received at MFD, statistics show that in 32.5-45% of the time, crews will already be answering another call, thus reducing available staffing for such scenarios. With the 1976 personnel cuts, MFD has not replaced the three firefighter positions. The Ohio State University Study does show that when staffing levels drop below 15 firefighters at residential fires, firefighter injuries increase by 46.7%.

PROCEDURES

This research project utilized the evaluative research methodology to identify the following criteria: a) the laws and standards that regulate the number of firefighters to perform fire ground duties, b) how staffing levels of MFD compare to other fire departments, c) at what point firefighter injuries increase while performing fire ground operations, d) the effectiveness of three, four, and five-person engine companies, and e) the frequency of crews being out on other calls when a structure fire call is received. The procedures used to gather the noted information included a literature review, personal interviews, gathering statistics from the National Fire Data Center, and a survey instrument.

Literature was reviewed at the National Fire Academy's Learning Resource Center in Emmitsburg, Maryland. Books were examined. Magazine articles and trade journals were researched. Information that pertained to the given research questions was gathered from the sources. Data was organized as to the particular research question that it corresponded to, and the data was reported in the literature review. Upon return from the National Fire Academy, further research continued.

Additional trade journals and fire-related magazine articles were scanned, sorted, analyzed, and presented in the literature review. Such sources were located in the fire station's library and in the author's personal library. Additionally, NFPA standards were examined as well as OSHA regulations. Pertinent data was collated in the literature review, in the section addressing the particular research question.

Personal interviews were conducted. Fire Chief Jerry Brock was interviewed. Brock, a 25-year veteran of the department was chosen to reflect on the changes in call

volume of the department. Assistant Chief Robert Hopkins was interviewed for collection of figures depicting the receipt of emergency calls by the department. Figures were gathered from the National Fire Data Center for illustration of firefighter injuries.

Finally, a survey instrument was distributed to various fire departments. The title of the survey was "Personnel Survey". Criteria addressed in the survey included average staffing per engine company, minimum staffing levels, and numbers of apparatus responding to structure fire calls. Although numerous fire department in the Commonwealth of Virginia, surveys were sent to 15 departments. Criteria for selection of the chosen departments included departments of similar size, departments known to provide EMS services in addition to fire services, proximity to Martinsville, and departments known to offer similar services. Eight departments responded to the survey by answering all data elements and returning the given document to the author. Results were tabulated and summarized in a spreadsheet (Appendix A contains the survey, and it contains the results).

The research yielded limitations. With the literature review, sources were quoted from authors in larger size departments and agencies with larger tax bases and population. Also, some literature sources originated from departments that operate with only career personnel; MFD is a combination department, one that functions with paid personnel and volunteers. In the survey, not all departments responded. Only a sample of the population was selected. Of those agencies that responded, some agencies answer more calls per annum than MFD and possess larger budgets for retention of larger labor bases. In the interview process, only two individuals were selected.

During the research, the evaluative research method was used. Elements of the process included a) defining the parameters of the evaluation study. The chosen subject was optimal engine-company staffing for reduction of firefighter injuries. b) identifying specific criteria against items evaluated. Given criteria was the information gathered that answered the particular research questions. c) developing a plan for measuring each evaluative criterion. This was achieved by noting objective answers to each research question. d) Conducting the study. e) Analyzing and evaluating all collected data in order to reach a final evaluative conclusion. As each research question was addressed, data was presented. Afterwards, recommendations could be made based upon specific content.

Definition of Terms

Apparatus Operator – the person charged with the responsibility of driving a fire engine, ladder truck, or other fire utility vehicle. The person may operate the truck's pump, handle radio communications, or perform other support tasks on the fire ground, in the immediate area of the vehicle.

Hazardous area – a location that has the potential of causing an injury or health problem to a firefighter.

High rise – a building or other structure that is six stories or more above grade. In some localities, fire personnel refer to a high rise as a building greater than three stories.

Immediately dangerous to life or health (IDLH) – a term used by OSHA. This is an atmosphere that poses a significant risk to a firefighter's health or safety. In such an environment, a self-contained breathing apparatus is required.

Incident commander – the officer in charge of a fire scene. It is often the senior, ranking fire officer that is present. The person is responsible for the overall scene management and supervision of tactics to handle the emergency.

Self Contained Breathing Apparatus (SCBA)– a device worn by firefighters that provides protection of the respiratory system. Compressed air is stored in a bottle that is secured to the firefighter. Through a tube, the air is delivered to a face-piece that surrounds the firefighter’s face.

RESULTS

Research Question #1 - During fire ground operations, what laws and/or standards govern numbers of firefighters required to perform fire ground duties?

NFPA 1500 (1997) states that a minimum of four firefighters is required while performing interior, structural firefighting operations. While two personnel are inside the structure with suppression efforts, a minimum of two back-up firefighters are required outside, in the stand-by mode. While four firefighters are required, if the apparatus operator or incident commander serves as a stand-by person, the dual roles cannot sacrifice firefighter safety.

Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA, (1998) mandates minimum firefighters at structure fires. In the section, OSHA requires that two firefighters must remain outside as a standby team for the two firefighters that work inside a burning structure. The standard points out that psychological stress is caused by the firefighter’s need to focus on the protection of lives and property, as well as the need to focus on personal safety. As stated in NFPA 1500,

the incident commander or apparatus operator may serve as part of the two-out team. If so, additional elements of psychological stress is placed on the firefighter as is, let alone if the same person serves in dual roles.

Research Question #2 - How do staffing levels of MFD compare to other fire departments?

Of the departments surveyed, Martinsville has the lowest number of minimum firefighters responding to calls; Martinsville has a minimum number of six. Other departments vary by minimum number. Danville responds with 13 firefighters while Lynchburg has a minimum staffing level of 17 firefighters.

Research Question #3 - At what numerical threshold do firefighter injuries increase during fire ground operations?

Editions of NFPA 1500 recommended that the minimum staffing level was four firefighters responding on apparatus and at least four firefighters be assembled on scene before interior firefighting operations could be initiated at working structure fires. Research showed that five firefighters is optimal for injury mitigation. When engine-staffing levels increase to six firefighters or falls to three or four firefighters, injuries increase.

Research Question #4 - What is the effectiveness of three, four, and five-person engine companies during firefighting operations?

The Dallas Fire Department Study shows that the most efficient staffing level of engine companies is five firefighters. At the five-person level, all tasks studied were performed at a 100% efficiency rating. After further analysis, when four firefighters staff engine companies, efficiency diminishes. Procedures such as advancing interior attack lines and searching and rescuing victims, are sacrificed at reduced levels of efficiency. However, when three firefighters staff first responding engine companies, efficiency ratings are reduced even more.

Research Question #5 - What do past-reports show to be the frequency of MFD being on another call when receiving a structure fire call?

When structure fire calls are received by MFD, statistics show that in 32.5-45% of the time, crews will already be answering another call, thus reducing available staffing for such scenarios. With the 1976 personnel cuts, MFD has not replaced the three firefighter positions. The Ohio State University Study does show that when staffing levels drop below 15 firefighters at residential fires, firefighter injuries increase by 46.7%.

DISCUSSION

After analyzing the research, specific findings are linked to each research question. The author's interpretation is then presented. Finally, organizational implications are stated.

Laws and standards exist for governance of minimum firefighters for performance of fire ground duties. Examples include NFPA 1500 and OSHA regulations. NFPA 1500 (1997) suggests that at least four firefighters are present a structure fire; two firefighters should function as stand-by members. Sections 29 CFR Parts 1910 and 1926 of the Respiratory Protection, Final Rule, OSHA (1998), states that a least two firefighters must serve as back-up members at structure fires where interior suppression operations are occurring. These standards are explicit in that a minimum number of four firefighters should be on scene to perform structural attack duties. Marenette (1998) said that the OSHA 2-in/2-out rule bars fire departments from interior operations at a structure fire if rescue is not an issue and the minimum number of personnel are not present to protect each other. Statistics show that MFD had at least a 32.5% chance of being out on another call when a structure fire call is received. Due to an already low staffing level, even fewer firefighters are available to function within the parameters of these standards. Potential departmental implications include withholding suppression efforts until additional personnel arrive at the expense of unnecessary property losses and sacrificing firefighter safety when fire officers serve as firefighters. Regardless, the department is exposed to potential litigation due to personnel issues and/or property loss.

Regarding staffing levels of MFD compared to other localities, an article in Fire-Rescue News (February, 1998), states that a majority of progressive paid and volunteer

departments nationwide have exceeded the 2-in/2-out standard for years. During some structure fires, MFD barely complies with this regulation, let alone exceeding the requirement. Bruno (1998) said that many fire departments already are operating with variations of the 2-in/2-out procedure. Bruno goes on to say that at some calls, there may be more than one standby crew. Only at full staffing could the MFD utilize more than one back-up crew. In such case, MFD could only be committed to one other call at the same time. Of the departments surveyed, Martinsville has the lowest number of minimum firefighters responding to calls; Martinsville has a minimum number of six. Other departments vary by minimum number. Danville responds with 13 firefighters while Lynchburg has a minimum staffing level of 17 firefighters. Due to the low staffing levels, MFD obviously performs with fewer personnel than other departments. Over time, this fact increases the chances of personal injury and unnecessary firefighter fatigue.

Russell (1995) reported that historically the fire service has been regarded as having an increased risk for injury due to occupational conditions present at fire scenes. The results of the Dallas Study indicated that staffing below four personnel overtaxes the operating forces and leads to higher losses of property or life. Whitehead (1992) wrote that firefighter safety was indeed directly associated with minimum staffing. He cited numerous sources of statistics and unpublished research that showed firefighter injuries increased dramatically when staffing dropped below four firefighters per apparatus (Varone, 1994).

The Whitehead (1992) and Stapleton (1992) research provided supporting documentation that staffing apparatus below four-person crews leads to an increase in

injuries to personnel. In addition, editions of NFPA 1500 recommended that the minimum staffing level was four firefighters responding on apparatus and at least four firefighters be assembled on scene before interior firefighting operations could be initiated at working structure fires. In contrast, a noted increase in injuries was documented when too many firefighters were assigned to an engine company. The United States Fire Administration (USFA) provided computer data from the National Fire Incident Reporting System (NFIRS) pertaining to the number of firefighters on incident scenes, as well as the number of injuries. The data from a five-year period showed that nearly six firefighters on an engine had a higher rate of injuries than just over five persons per engine (USFA, June 8, 2000). After analyzing the given evidence, five firefighters on engine companies is the equilibrium level for injury reduction. As already noted, NFPA standards require a minimum of four firefighters. Four firefighters meet fire service standards, but the threshold for injury reduction is five firefighters. With this evidence, the fire department has the obligation to maintain adequate staffing to avoid unnecessary firefighter injuries and potential litigation in the event of a firefighter injury or death.

The firefighter injury reduction threshold has been established; next, efficiency levels of various numbers of staffing levels is examined. Webb (1994) states the Dallas Fire Department performed a study after a demand to reduce staffing. The study shows that the most efficient staffing level of engine companies is five firefighters. At the five-person level, all tasks studied were performed at a 100% efficiency rating. After further analysis, when four firefighters staff engine companies, efficiency diminishes.

Procedures such as advancing interior attack lines and searching and rescuing victims, are

sacrificed at reduced levels of efficiency. However, when three firefighters staff first responding engine companies, efficiency ratings are reduced even more.

Another study was conducted by Ohio State University for the Columbus, Ohio Fire Department (Webb, 1994). In the study 404 structure fires were analyzed to show firefighter injuries and the rate of fire spread with various numbers of staffing. The study shows that the number of fires that spread beyond 25 square feet in size increases as staffing levels diminish. Specifically, at residential structure fires, there is a 24.1% negative variance when less than 15 firefighters respond. But, at large fire risks, when there are less than 23 firefighters, there is a 17.2% negative variance as a result of reduced staffing. Even at full staffing and during weekday hours with administrative staff present, MFD normally would not have 15 firefighters present. These studies suggest that the agency should take steps to increase the number of fire ground members for structure fires. If not, increased fire spread results and firefighter effectiveness is increased.

Due to a low number of staffing during normal operations, departmental monthly reports were researched to determine the frequency of the department being out on another call when receiving a structure fire call. According to Hopkins (2000), annual reports were scanned with the following occurrences. MFD averages 40 structure fires per year. In 1999, the agency received 13 structure fires while firefighters were already responding to other calls. Comparatively, in 1998, there were 13 such occurrences. In 1997, there were 14 such situations while there were 18 in 1996. Mathematically, there is between a 32.5% - 45% chance of crews being out on another call when a structure fire call is received.

The department cannot, in advance, determine when calls are received. However, there is a great chance of personnel being reduced even further due to multiple calls at one time. This fact serves as another reminder that staffing levels are of great concern. Potential impact includes overworked firefighters, injuries, morale problems due to workload increases, and diminished public relations due to visible personnel deficiencies.

RECOMMENDATIONS

The problem is as call volume increases, MFD frequently responds to fire calls with a number of firefighters that is perceived to be below the optimal level for performance of duties and mitigation of firefighter injuries. The purpose of this research project was to identify the optimal staffing level for fire ground operations in order to effectively and safely perform firefighting duties. Based upon each research question and the results of the research, recommendations are offered.

Research Question #1 - During fire ground operations, what laws and/or standards govern numbers of firefighters required to perform fire ground duties?

NFPA 1500 and OSHA's 2-in/2-out set the minimum number of firefighters at four while performing interior, structural firefighting operations. While four firefighters are required, if the apparatus operator or incident commander serves as a stand-by person, the dual roles cannot sacrifice firefighter safety. Since MFD's incident commander often serves as a back-up firefighter, it is recommended that this practice cease under normal conditions. One additional firefighter per shift would reduce the potential of a crisis due to the incident commander serving in dual roles.

The incident commander could perform as the incident planner, and firefighting would be left to firefighters. It is therefore recommended that one additional firefighter per shift be hired and placed at the Southside station to increase engine staffing from two firefighters to three personnel. The engine company would be joined at a structure fire by engine companies from headquarters as currently practiced.

Research Question #2 - How do staffing levels of MFD compare to other fire departments?

Of the departments surveyed, Martinsville has the lowest number of minimum firefighters responding to calls; Martinsville has a minimum number of six. Other departments vary by minimum number. Danville responds with 13 firefighters while Lynchburg has a minimum staffing level of 17 firefighters.

Arriving quickly at the scene of a structure fire allows for rapid entry for rescue and suppression efforts. Once initial personnel arrive, additional firefighters can respond for backup, overhaul operations, and other assistance as needed. In addition to hiring one more firefighter per shift, more firefighters are needed to match personnel resources enjoyed by other departments. It is recommended that MFD implement an automatic aid agreement with neighboring Henry County. When any structure fire call is received, county volunteers should be dispatched simultaneously with MFD. Additional firefighters would arrive in time for continued, on scene operations and could provide a moment for rehabilitation of MFD firefighters.

Research Question #3 - At what numerical threshold do firefighter injuries increase during fire ground operations?

It was recommended by two standards that the minimum staffing level was four firefighters responding on apparatus and at least four firefighters be assembled on scene before interior firefighting operations could be initiated at working structure fires. Research showed five firefighters is optimal for injury mitigation and firefighter efficiency. When engine-staffing levels increase to six firefighters or falls to three or four firefighters, injuries increase. Since MFD, on average, has only four firefighters on scene, recommendations to increase staffing as made in research questions one and two would provide the threshold number of firefighters, at least five.

Research Question #4 - What is the effectiveness of three, four, and five-person engine companies during firefighting operations?

A study showed that the most efficient staffing level of engine companies is five firefighters. At the five-person level, all tasks studied were performed at a 100% efficiency rating. After further analysis, when four firefighters staff engine companies, efficiencies diminish. Recommendations to add one firefighter per shift and an automatic alarm initiative would suffice to make fire operations more efficient.

Research Question #5 - What do past-reports show to be the frequency of MFD being on another call when receiving a structure fire call?

Statistics show that in 32.5-45% of the time, crews will already be answering another call when a structure fire call is received, thus reducing available staffing for

such scenarios. With the 1976 personnel cuts, MFD has not replaced the three firefighter positions lost. The above stated recommendations would place an additional firefighter at the station and immediately available for calls. It is further recommended that MFD increase recruitment efforts of volunteer firefighters. By having more volunteers trained and available, additional personnel would help meet the suggested 15-member ratio for structure fires.

Future Implications

With the above-mentioned recommendations, one additional firefighter per shift should immediately be hired and the other two recommendations, an automatic alarm agreement and increased volunteer recruitment, implemented promptly. However, the situation should be closely monitored. The plan should be reevaluated after six months, then annually thereafter. Modifications may have to be made to ensure adherence to fire standards, mandates, and overall efficiency of fire scene operations.

Further research is needed. Laws and standards should be monitored for continued changes. Benchmarking with other similar-sized departments should continue for personnel maximization and economic feasibility. Injury statistics should be monitored to track success of additional staffing or to justify future staffing increases. Studies should be initiated to make sure that MFD personnel are strategically placed at appropriate fire station locations for optimal effectiveness of human resources. And finally, trends should be watched to monitor disposition of multiple calls, especially at peak times.

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Appendices Not Included. Please visit the Learning Resource Center on the Web at <http://www.lrc.fema.gov/> to learn how to obtain this report in its entirety through Interlibrary Loan.