SURVIVAL BREATHING TECHNIQUES FOR USERS OF SELF-CONTAINED BREATHING APPARATUS IN THE MONTGOMERY COUNTY FIRE AND RESCUE SERVICE

Executive Analysis of Fire Service Operations in Emergency Management

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Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used language, idea, expressions, or writing of another.

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Abstract

The Montgomery County Fire and Rescue Service (MCFRS) provided emergency service that required its personnel to use respiratory protection specifically self-contained breathing apparatus. In the course of its mission, the MCFRS supported safe operations and strives to reduce civilian and firefighter injuries and deaths. Although the MCFRS has not experienced a line of duty death in the last three decades, the risk of firefighter death due to fire still exists.

The purpose of this research was to provide the MCFRS with a survival breathing technique for firefighters in a mayday situation during structural fires. Action research was employed to improve the performance of an existing problem. Thus the problem statement was expressed as: the MCFRS has not successfully identified a universal survival breathing technique for those that must use SCBA.

This applied research addressed the following questions:

1. What were the existing survival breathing techniques for users of self-contained breathing apparatus and similar breathing apparatus?
2. How effective were existing survival breathing techniques?
3. What were the physiological factors involved with physical exertion and the use of self-contained breathing apparatus?
4. What role did breathing air duration play in documented line of duty deaths in the United States?
5. During a mayday event, what limitations were presented to rapid intervention teams due to self-contained breathing apparatus duration?

Information and data was collected through a literature review, personal communications, and a performance test. The result yielded several survival breathing methods that failed to
provide firefighters with an adequate means of survival. However, skip breathing was identified as the only method that did not expose the user to a contaminated atmosphere and did not require a second SCBA.

The researcher recommended that the MCFRS adopt skip breathing as a survival breathing technique in its indoctrination and in-service training.
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Introduction

Suffocation is defined by the Merriam-Webster dictionary as dying from the inability to breathe. When a firefighter depletes their air supply in self-contained breathing apparatus (SCBA), a consequence is suffocation. The United States Fire Administration (USFA) stated that 30 percent of all firefighter line of duty deaths (using SCBA) occurred when firefighter’s air supply was depleted (USFA, 2002). It is not clear if those deaths could have been avoided if the firefighters involved were trained on survival breathing techniques specifically to conserve one’s air supply. It is also not clear if the firefighters involved were trained on survival breathing. Weather or not survival breathing techniques could have affected the outcome of the aforementioned line of duty deaths is a matter of conjecture and speculation. However, it may be reasonable to conclude that survivability may have been increased if survival breathing was employed.

As of 2005, the Montgomery County Fire and Rescue Service (MCFRS) did not have a curriculum in its firefighter indoctrination program to teach specific SCBA survival breathing techniques. For purposes of this research, the problem statement is further refined as: the MCFRS has not successfully identified a universal survival breathing technique for those that must use SCBA in Montgomery County, Maryland. Thus, the purpose of this applied research project is to identify survival breathing techniques for firefighters utilizing SCBA during a mayday situation in the MCFRS. While this problem statement and purpose may be applied to other fire departments or the American fire service as a whole, the limits of the applied research project remained within the confines of the MCFRS. The research method employed in this applied research project was action research because the result will improve the performance of
an existing problem (National Fire Academy, 2003). Thus based on the problem and purpose statements, the researcher developed the following research questions:

1. What are the existing survival breathing techniques for users of self-contained breathing apparatus and similar breathing apparatus?
2. How effective are existing survival breathing techniques?
3. What are the physiological factors involved with physical exertion and the use of self-contained breathing apparatus?
4. What role does breathing air duration play in documented line of duty deaths in the United States?
5. During a mayday event, what limitations are presented to rapid intervention teams due to self-contained breathing apparatus duration?

Background and Significance

Montgomery County is an adjacent suburb northwest of Washington, D.C. Montgomery County’s size is 497 square miles of a combination of urban, suburban, rural, and protected areas. The Montgomery County Fire and Rescue Service (MCFRS) provides emergency services for the County’s 913,881 residents (US Census Bureau, 2004). The MCFRS is a metropolitan size fire and rescue service according to the International Association of Fire Chiefs (IAFC) and National Fire Protection Association (NFPA) metropolitan department criteria (400,000 population served or 400 career firefighters). Additionally, the MCFRS is a combination department with career and volunteer response personnel. The MCFRS provides fire suppression, rescue, and emergency medical services with a workforce that is trained to deliver all three disciplines.
Organizationally, the MCFRS has placed emphasis on firefighter safety by adding uniformed officers to operate the MCFRS Safety Section and by participating in national efforts to reduce firefighter line of duty deaths such as the National Near-Miss Reporting System and the National Stand Down for Firefighter Safety (conducted on June 21, 2005). Locally, the MCFRS has dedicated resources for firefighter safety for example by fully implementing the IAFF/IAFC Wellness-Fitness Initiative (with the Candidate Physical Ability Test) and providing additional driver training to all MCFRS members to reduce the number of vehicle collisions.

Although the MCFRS has not experience a line of duty death due to a structural fire in the last three decades, the hazards of structure fires exist within Montgomery County. Hence, the potential for a line of duty death during structural fire still exists. The MCFRS Guiding Principles (MCFRS, 2005) state that the MCFRS would promote the highest standards of safety and welfare. The MCFRS provides comprehensive fire and rescue services that require SCBA or supplied air breathing systems to include the following operations: structural firefighting, confined space rescue, and underwater rescue. The MCFRS regulates its SCBA use by means of a departmental policy and adherence to state and federal regulations. MCFRS currently uses the Scott Fifty 4.5 Airpaks as its primary SCBA.

In relation to the National Fire Academy course, Executive Analysis of Fire Service Operations in Emergency Management, this applied research project focuses on reducing pre-event risk. Specifically, increased survivability of firefighters reduces the risk of death to the affected firefighters and those who are charged to rescue downed firefighters. This applied research project is directly related to the USFA’s operational objectives, specifically the reduction of loss of firefighter lives due to fire.
Literature Review

The researcher reviewed literature using resources from the National Fire Academy’s (NFA) Learning Resource Center, the Montgomery County Fire and Rescue Training Academy, George Mason University, the Fairfax County Public Library, and the Internet.

The literature review was used to examine the research question: the role of breathing air duration and line of duty deaths, limitations placed on rapid intervention teams due to SCBA, and the physical and physiological factors involved with SCBA use. The researcher discovered that breathing air supply was a factor in line of duty deaths due to fire. Reviews of the National Institute for Occupational Safety and Health (NIOSH) reports yielded statements that deceased firefighter’s SCBA air supply was depleted in 15 NIOSH reports. Of those reports, three reports (NIOSH, 1997a; NIOSH, 1998b; and NIOSH, 2003) indicated that firefighters had become trapped by various causes (ceiling collapse, floor collapse, etc.) and were not able to escape to a non-contaminated atmosphere. Subsequently, those firefighters died due to asphyxiation when their SCBA air supply depleted.

Five NIOSH reports (NIOSH, 1997b; NIOSH 1998a; NIOSH, 1999b, NIOSH, 2001b, and NIOSH, 2004) indicated that firefighters did not leave the fire structure for non-specified reasons. When those firefighters were found by either rescue or recovery crews, their SCBA air supply was depleted and the firefighter was found dead. Three of these fatalities (NIOSH, 1997b; NIOSH 1998c; and NIOSH, 2004) stated that the victims had removed their facepiece and died due to either asphyxiation or carbon monoxide poisoning.

The effects of carbon monoxide poisoning has an adverse affect on one ability to think rationally and their decision making ability. The Texas Department of Insurance (2001) noted that fire victims with elevated levels of carbon monoxide affected an individual’s ability to think
clearly and to make rational decisions. Clinically, carbon monoxide poisoning presents the following symptoms: dizziness, impaired judgment, confusion, hallucinations, agitation, visual changes, and memory problems (Cole, 2003).

In the Houston Four Leaf Towers fire, the victim called for help at 0509 hours. At 0512 hours, the victim made his last call for help and indicated that his air supply was low. Subsequently, a rescue team had found the victim at 0530 hours with his air supply depleted and his facepiece off. The victim was removed to from the burning structure at 0536 hours (Texas Department of Insurance [TDI], 2001). TDI (2001) noted that the victim’s facepiece was not damaged and with no visible smoke or soot on the inside of the facepiece.

In Phoenix, the Southwest Supermarket Fire claimed the life of one firefighter and presented significant issues for rapid intervention teams. In this incident, firefighters responded to an operational supermarket with an interior fire. The victim was engaged in firefighting activities when he notified his supervisor that his SCBA air supply was running low. Due to the complexity of the structure, the victim had become disoriented and separated from his crew. The victim had requested help using his portable radio at 1726 hours. Rapid intervention teams were assigned at 1727 hours and proceeded with search and rescue operations. Another engine company encountered the victim and noted that the victim was out of air and disoriented. The victim was brought to a hoseline for exiting purposes but was unable to follow directions. The victim stood up and disappeared in a different direction. This engine company was low on air supply and exited the structure. A member of the rapid intervention team encountered the victim at 1733 hours. Eventually both firefighters became incapacitated as both had depleted their SCBA air supply. Another engine company encountered both firefighters. One was removed by the crew while the engine supervisor remained with the victim for removal. Efforts to remove
the victim were unsuccessful due to the victim’s physical size; additionally the engine supervisor’s air supply had expired. Another engine company came across both victims and removed the first engine supervisor and the victim. Several other crews were required to move the victim out of the structure at 1819 hours (Phoenix Fire Department, 2002).

In the aftermath of the Southwest Supermarket Fire, the Phoenix Fire Department (PFD) published lessons learned from this firefighter fatality. The PFD stated that the window of survivability is directly related to a firefighter’s SCBA air supply especially for those waiting for rescue. Air equals time. The PFD listed self-survival as one of the critical skills for lost firefighters. Additionally, the PFD stated that the SCBA is the most important piece of safety equipment for firefighters and is often the difference between life and death. With regard to buddy breathing systems, the PFD addressed the technology associated with this method to maintain a firefighters protective envelope and not remove one’s facepiece (Phoenix Fire Department, 2002).

Breathing air limitations have limited rapid intervention teams and their efforts during rescues. In two NIOSH reports (NIOSH, 1999a and NIOSH, 1999c), the rapid intervention teams had to abandon their rescue efforts due to depleted SCBA air supply. Subsequently, the victims in both of these incidents perished due to asphyxiation. Rapid intervention team SCBA limitations also existed in three other incidents (NIOSH, 1998a; NIOSH, 2000a; and NIOSH, 2000b).

Alternative SCBA survival methods have been employed without success. In NIOSH (1998a and 2001a) reports, the victims had depleted their SCBA air supply and had attempted to filter contaminated air by removing their air hose (connected to the low pressure regulator or facepiece) and placing the open end in their turnout coat. The theory was to attempt to filter
breathing air to a limited degree and escape the contaminated atmosphere. In both instances, the victims perished due to asphyxiation and smoke inhalation. A variation of this technique requires a firefighter to filter contaminated air by removing their SCBA facepiece and protective hood. The hood is turned around and replaced on the firefighters head to filter the contaminated air (NIOSH, 2000a). In this instance, the firefighter did not survive and suffered from acute carbon monoxide poisoning.

Rapid intervention teams were meant to remove firefighters in distress from hazardous environments and conditions. However, the process of rescuing a downed firefighter from a structure fire is not fast. Morris (2004) cited two unrelated studies conducted by the PFD and the Seattle Fire Department. The purpose of each study was to determine the effectiveness of rapid intervention teams. The results from Seattle were that 11 personnel could effectively rescue one firefighter in 20 minutes. Similarly, the PFD study required 12 personnel to rescue on firefighter in 21 minutes. Morris (2004) stated that this period is a long period especially if the victim has depleted their air supply.

Kreis (2003) examined time from another approach. The effective time that a firefighter can work using SCBA in a contaminated environment is between 16.6 to 18.5 minutes. Additionally, Kreis (2003) cited a study where rescue teams averaged 2.47 minutes to get ready. The time for rescue teams make entry from the point where a mayday is declared was 2.55 minutes. The time for the rescue team to reach a downed firefighter from entry averaged 5.33 minutes. Finally, the time to extricate a downed firefighter out of a commercial structure averaged 21.8 minutes. Conversely, Kreis (2003) cited a National Institute of Standards and Technology (NIST) study where one cannot operate on top or inside a structure on fire between 16 to 18 minutes from the point of ignition. Additionally, Kreis (2003) states that 20 percent of
firefighters on rapid intervention teams will require rescue assistance for themselves when fully engaged in rescue.

The literature review discovered journal articles and teaching curriculum regarding SCBA survival. Buddy breathing is the process where one firefighter has depleted their SCBA air supply and another firefighter with an adequate SCBA air supply will share to rescue the firefighter in distress (Pindelski, 2002). The logistics to accomplish this task can be broken into two categories. First, some SCBA manufacturers had designed an emergency breathing support system (EBSS). EBSS facilitate supplying a SCBA operator without compromising the facepiece seal. Pindelski (2002) stated that two firefighters may utilized the EBSS system to share one SCBA air supply for escape purposes. However, NIOSH, OSHA, and SCBA manufacturers do not recommend or approve the practice of buddy breathing. The second category involved methods where the SCBA facepiece seal is broken to engage in buddy breathing. This includes sharing one facepiece among at least two firefighters and using a tube to transfer air from one facepiece to another. This method was utilized in two documented incidents without success (NIOSH, 2000b and NIOSH, 2000c).

Pindelski (2002 and 2003) outlines two SCBA survival methods that involve potentially exposing the firefighter to a contaminated environment. The first method involves having the firefighter disconnecting their regulator from their SCBA and connected to a new SCBA. The second method involves having the firefighter breathe directly from the SCBA cylinder. The air would be directed into the SCBA’s low-pressure hose or the facepiece opening. Similarly, Sendelbach (2005) recommended that firefighters should remove either their low pressure hose or regulator and cover the vulnerable opening with their gloved hand if their SCBA air supply was depleted.
Human physiology has an effect on air consumption. Firefighters consume SCBA air at different rates based on physical condition, training, work performed, and mental state (Pindelski, 2002 and White and Levy, 2000). Regarding physical condition, Sendelbach (2005) stated that a firefighter in poor physical condition will expend their SCBA air supply faster than firefighters in optimal physical condition. Sendelbach (2005) also purported that firefighters with larger physical frames tended to consume air at a higher rate than firefighters with a smaller build. Morris (2004), White and Levy (2000), and Pindelski (2002) agree that a 30 minute SCBA air cylinder will practically last approximately 20 minutes.

A component of SCBA survival is a firefighter’s breathing. White and Levy (2000) outline four methods to control breathing: in through the nose and out through the mouth, in through the mouth and out through the nose, the five second count method, and skip breathing. In the first method, the firefighter breathes in through he nose and out through the mouth. White and Levy (2000) outlines that the firefighter’s breath should be held for three to four seconds to maximize oxygen to carbon monoxide exchange. Likewise, the five second count method entails inhaling for five seconds, holding one’s breath for five seconds, exhaling for five seconds, holding again for five seconds, and then repeating the cycle. Sendelbach (2005) suggests that this method is best when engaged in strenuous work. However, Pindelski (2002) states that a firefighter should not hold their breath in an attempt to conserve air. The reasoning is that when the human body releases adrenaline, the body consumes oxygen at a higher rate. Thus, holding one breath may cause elevated levels of carbon monoxide and subsequent unconsciousness. Pindelski (2002) and Sendelbach (2005) also stated that breathing in through the mouth does not conserve air since breathing in through the mouth increases the body’s respiratory rate while preventing the body to utilize all of the available oxygen before exhaling.
Skip breathing is a method to conserve air once a firefighter becomes trapped or lost. Different authors have cited separate extensions of air supply using skip breathing. Pindelski (2002) cited that a firefighter may extend a 30 minute SCBA air cylinder to over an hour while White and Levy (2000) and Sendelback (2005) cited a 30 minute SCBA air cylinder may extended to two hours. Regardless of the theoretical extension, Pindelski (2002), Sendelbach (2005), Hall and Adams (1998), and Cook (2005) stated that skip breathing is a last resort method and should not be engaged to perform additional work. The method is preferred to provide a rapid intervention team additional time to rescue the firefighter in distress.

Skip breathing is performed by a single firefighter. The first step is to inhale and hold their breath until normal exhalation. When the firefighter feels the need to exhale, the firefighter takes and additional breath and then slowly exhales. The process is repeated until the firefighter is rescued (Pindelski, 2002; Sendelbach, 2005; Hall and Adams, 1998; and Cook, 2005). One of the potential dangers of skip breathing is carbon monoxide retention. Campbell (1996) stated that convulsions and hypoxia due to carbon monoxide retention were primary concerns to SCUBA (self contained underwater breathing apparatus) divers due to skip breathing.

Austin (1997) described anecdotal evidence of decreased SCBA performance from firefighters and carbon monoxide poisoning among SCUBA divers. Austin (1997) demonstrated that carbon monoxide contamination ranged from 6 to 17 percent with SCBA cylinders contaminated with 250 parts per million of carbon monoxide.

Regarding the physical and psychological factors in SCBA use, researchers have cited factors that effect SCBA air supply. Louhevaara (1985) noted the physical restraints of SCBA harnesses prevent the free motion of the thorax thus affecting regulated breathing, ventilation, and oxygen exchange. The problem is compounded as physical exertion increases. However,
Manning (1983) cited that firefighters attain a high level of physical exertion quickly and maintain that level as long as they are engaged in firefighting activities. What Manning (1983) suggests as significant is that firefighters have the same level of physical activity (85 to 100 percent of their maximum output) regardless of the weight of SCBA. However, Morgan (1983) purports that SCBA weight nor breathing resistance affects firefighter’s performance. Regarding physical fitness Williford (1999) stated that the best indicator of physical fitness, as it relates to firefighting, was a one and half mile run and pull ups. As the performance of both exercises increased the firefighter’s efficiency in firefighting tasks increased. Regarding psychological factors, Morgan (1983) supports the notion that those with certain psychological conditions affects performance although little research has been conducted to examine the human component (psychological) of respirator use.

Another component of SCBA survival is developing confidence. Sendelbach (2005) theorized that firefighters that are well trained and comfortable with using their SCBA tend to control their breathing rates and overall air consumption more efficiently. Under various programs in the United States, firefighters are subjected to task related exercises such as confined mazes, self-escape methods, and basic fire suppression. These exercises were performed while the firefighters utilized SCBA. The Mississippi State Fire Academy conducts a class known as Smoke Divers. This program is conducted over 40 hours and includes many exercises utilizing SCBA. The objective is to teach firefighters to conserve air while working under stressful conditions (Rosenham, 1991). Another class titled Smoke Divers is conducted by the Florida Fire College and used various firefighter task related exercises to acclimate students to SCBA use under stress (Whalen, 1991). Similar classes were conducted before Smoke Divers with the objective to build confidence which would theoretically transfer to the firefighter during
a real incident (Granruth, 1982). More recently, STAR (Survival Techniques and Rescue) conducted by the Broward Fire Academy consists of 40 hours of training in task related activities utilizing SCBA. The notion of SCBA familiarity is supported by Donovan (1999) who tested exercise performance between two groups: firefighters and civilians. In these experiments, Donovan (1999) concluded that firefighters used significantly less air and the rate of breathlessness was lower than the civilian group. The study also stated that increased breathing frequency and not tidal volume may help reduce breathlessness during exercise.

The findings of the literature review influenced this applied research project in answering research questions three, four, and five. Additionally, the literature review provided the basis for the performance test as outlined in the next section. Specifically, the researcher chose to test skip breathing’s effectiveness based on the literature review.

Procedures

This applied research project involved three procedures: a literature review, personal communications, and physical testing. The literature review was conducted using four libraries and the Internet. A Boolean search was conducted on the Internet using a search engine (Google.com). Keywords were used to initiate the search such as SCBA, self contained breathing apparatus, survival, breathing, etc. The search yielded journal articles, training outlines, and references to other journals or books. All material was reviewed for relevance and included in the reference list if the item was cited in this applied research project. Key organizational websites included the NIOSH and the IAFC. Four library sources were employed to include the National Fire Academy’s Learning Resource Center, the Montgomery County Fire
and Rescue Training Academy, the Fairfax County Public Library, and George Mason University.

Personal communications were initiated by utilizing the Training Resources and Data Exchange (TRADE). TRADE is an electronic bulletin board sponsored by the USFA. Subscription members may post an industry question with contact information. Subsequently readers reply with information that may be useful to the originator. Specific to this project, the researcher posted a question regarding formal SCBA survival training. Personal communications were also sent to three SCBA manufacturers: Tyco (manufacturers of Scott SCBA), MSA (Mine Safety Appliances), and Survivair. Each manufacturer was asked to provide a standard or best practice for survival breathing techniques.

Physical testing entailed utilizing a specific SCBA survival technique based on the literature review. Skip breathing received more citations than any other SCBA survival breathing technique. Thus, this technique was tested using recruit firefighters. The rationale for using recruit firefighter was physical conditioning and training familiarity. The specific group of recruits had been in indoctrination training for 20 weeks in which mandatory daily physical training occurred. This was an attempt to remove physical conditioning as a test variable. The second rationale was training. This group had finished their firefighter training and was familiar and conditioned to SCBA use. Since their training was recent, becoming reacquainted (i.e. reacquainting one-self to breathing compressed air) to SCBA breathing may have been eliminated as a test variable.

The test procedure included training and testing. The training included a lecture and practical session on how to execute skip breathing. The researcher used the curriculum outlined by Cook (2005). The test group included eight members. Four members were used as test
subjects while the remaining four were used as attendants. The attendants accompanied the test subject throughout the test to ensure that the test subjects complied with skip breathing instructions and to monitor the subject’s time and physical condition. The test started with each test subject dressed in all MCFRS issued firefighting personal protective equipment. The test subjects were provided SCBA manufactured by Tyco (Scott Fifty 4.5 Airpack). The cylinder pressure was approximately 1100 psi. The test subjects were instructed to walk a designated path (approximately 100 yards back and forth) and to breathe normally. Once the low pressure alarm sounded, the test subjects were instructed to breathe normally and continue to walk the designated path. When the test subject’s air supply was depleted, the test subject was instructed to kneel signifying air depletion. The attendant tracked the time from the point where the low pressure alarm started to the point where the air supply was exhausted. The test subjects were given approximately 30 minutes to rehabilitate and initiate a second test. The second test utilized skip breathing. The second test began as the first test. Once the test subject’s low pressure alarm sounded, the test subjects were instructed to initiate skip breathing while continuing to walk and the attendant started tracking time. Once the test subject’s SCBA air supply was completely depleted, the test subject was again instructed to kneel to signify the air depletion. At that point, the attendant ends recording time.

Physical exertion was added as a test variable in order to simulate breathing under stress. Instructions to the attendants included stopping the test subject and removing their SCBA regulator if the test subject appeared to be in distress to include the following signs: disorientation, hyperventilation, change in face color (pale), and a positive response (from the test subject) when asking if they felt dizzy or faint.
Limitations

Possible limitations include an incomprehensive search of references during the literature review. Although, the researcher used search tools, it is possible that literature exists without being examined. While the list of published resources is significant in breadth, information may exist in colloquial form. Much of this colloquial information relies on personal communications. While the information may prove valuable, the resources to obtain the information were not within the researcher’s capabilities.

Regarding the skip breathing test, possible limitations center on the test variables, bias, and sample size. While the researcher examined some variables, it was not possible to conduct an extensive test to account for every possible variable. One variable that could not be considered was the presence of a psychological or physical condition that would affect the test subject’s performance. Under the auspices of employee confidentiality, psychological and medical information was not obtained. Additionally, bias may have been introduced into the test by depicting skip breathing as a method to conserve breathing air. It is unknown if the results would have been different if the survival aspect was not introduced. Finally, another limitation could be the number of test subjects. While statistical procedures allow for small samples (Salkind, 2003), test reliability increases with a larger sample.

Definition of Terms

Buddy breathing: The practice of sharing a common air supply among at least two firefighters.
Emergency breathing support systems (EBSS): An engineered system built into SCBA for the specific purpose of augmenting air supply.
Facepiece: A component of SCBA that encapsulates the face in a non-contaminated environment where air is supplied to the user.

Line of duty death: The death of a firefighter in the act of emergency response.

Low pressure hose: A component of SCBA that carries breathing air from a regulator (reducing air pressure) to the firefighter’s facepiece.

Mayday: The term used by firefighters to signal distress and the need for other rescuers to render aid.

NIOSH: The National Institute for Occupational Safety and Health.

Self contained breathing apparatus (SCBA): Equipment designed to provide the user with a breathing air supply for use in a contaminated environment. SCBA is characterized by being self contained to the user.

Results

What are the existing survival breathing techniques for users of self-contained breathing apparatus and similar breathing apparatus?

Based on the literature review, the researcher identified various survival methods with the following results. NIOSH (1998a) has described an incident where a firefighter under mayday conditions was instructed to remove their low pressure hose and place the hose under their personal protective clothing in order to filter the contaminated air. While this was used as a matter of survival, the victim’s cause of death was smoke and soot inhalation. Thus, it may be concluded that this method was not effective.

Evidence suggests that the practice of removing SCBA low pressure hoses and attempting to filter was not isolated. NIOSH (2001a) indicated that one victim removed their
SCBA low pressure hose and attempted to filter through their personal protective clothing. This incident occurred in Michigan whereas NIOSH (1998a) indicated another incident in West Virginia. In Utah, a firefighter attempted to filter contaminated air after their SCBA air supply was depleted by removing their facepiece and breathing through their protective hood. Thus, it may be inferred that this practice may be either widespread throughout the fire service or a logical solution arrived under duress.

Various forms of buddy breathing were discovered in the literature review. Buddy breathing can be broken into two categories: engineered and ad-hoc. Engineered buddy breathing involves devices built into SCBA for the specific purpose of buddy breathing. Most of these devices are known as emergency breathing support systems (EBSS). Ad-hoc buddy breathing is accomplished by using the SCBA in a manner outside of its design to share breathing air such as placing a victim’s low pressure hose in the supplier’s facepiece or using a hard tube between facepieces (Granruth, 1982). Another form of ad-hoc buddy breathing involves sharing a common facepiece (Pindelski, 2002). Pindelski (2002) indicated that ad-hoc buddy breathing is not recommended or approved by NIOSH, OSHA, or any SCBA manufacturer. However, Pindelski (2002) noted that buddy breathing must only be engaged in extreme circumstances. NIOSH (2000b and 2000c) exposed a flaw of buddy breathing in that once two firefighters initiate buddy breathing, their air supply must accommodate at least two firefighters. Thus, air supply is effectively reduced by at least 50 percent. Regarding the use of an EBSS for buddy breathing, no documented evidence was found demonstrating EBSS effectiveness.
Pindelski (2003) also provided another extreme SCBA survival technique where the victim would breathe directly from an SCBA air cylinder. However, this implies that the victim has an air supply remaining and would be used in the event of a SCBA malfunction.

Perhaps the most documented method of SCBA survival to extend breathing air supply is skip breathing. White and Levy (2000), Pindelski (2002), Cook (2005), Firefighter Close Call.com (2005), and Sendelbach (2005) cited skip breathing’s technique and effectiveness. In this method a firefighter would inhale and hold their breath, another short breath is inhaled and held, and then the firefighter exhales and repeats the process. Various sources cite and extension of air supply for up to twice the SCBA cylinder’s capacity. However, none of the cited sources refer to specific studies. Additionally, skip breathing is used by underwater divers (SCUBA) to conserve their air supply (personal communication with Dan Painter, June 15, 2005). Campbell (1996) noted that convulsions and hypoxia are primary concerns to SCUBA divers practicing skip breathing.

*How effective are existing survival breathing techniques?*

The literature review noted that filtering contaminated air through personal protective clothing was not effective, engineered buddy breathing reduces SCBA air supply, and that ad-hoc buddy breathing is not recommended. Only skip breathing can theoretically extend air supply. Thus, this technique was the subject of the researcher’s test.

The results of the physical test showed an increase in air supply among all four subjects to varying degrees. The increases were as follows from least to greatest percentage increase: one percent, 10 percent, 28 percent, and 32 percent (see Appendix A). Subsequently, the final product of this action research was provided as a teaching curriculum found in Appendix B. The
results noted that difference between normal and skip breathing yielded an increase in skip breathing but not to the extent purported by White and Levy (2000) which suggested a theoretical increase of 150 percent.

*What are the physiological factors involved with physical exertion and the use of self-contained breathing apparatus?*

The literature review cited researchers and their work concerning the physical and psychological factors involved with SCBA air supply. Physical fitness was shown to have a correlation with SCBA air supply efficiency. As fitness level increased (indicated by a one and a half mile run and pull ups), the efficiency of SCBA use increased. Manning (1983) noted that firefighters attain a high level of physical activity when engaged in firefighting regardless if they are using SCBA or not. Other physical factors included the restrictions that are applied to the SCBA user due to restriction to inhale. This restriction is caused by the SCBA harnesses and decreases SCBA efficiency (Louhevaara, 1985).

Regarding SCBA familiarity, the literature review revealed training programs that focus on increasing firefighters familiarity with SCBA under the theory that familiarity will decrease anxiety. Donovan (1999) supports this theory and states that firefighters use less air and their breathlessness is lower than civilian who were not familiar with SCBA.

The literature review described the effects of carbon monoxide which impairs one’s ability to accomplish cognitive tasks (Phoenix Fire Department, 2001). Austin (1997) suggests that SCBA and SCUBA air cylinders may become contaminated with carbon monoxide during the filling process.
What role does breathing air duration play in documented line of duty deaths in the United States?

NIOSH provides many examples in the literature review (15 references) where the investigation report specifies that the victim’s air supply had depleted. Of the 15 references, five reports indicated that the victim(s) were trapped in the structure. The remaining 10 references cite victims that have expended their air supply and were not able to escape the structure due to either disorientation or symptoms of carbon monoxide poisoning. During the literature review, colloquial accounts of line-of-duty deaths were obtained. However to maintain the integrity of the literature review, only refereed reports by an independent source or published reports made by the affected jurisdiction were reviewed.

The literature review provided two other examples where the victim died due to asphyxiation and subsequent smoke or soot inhalation. The Texas Department of Insurance (2001) noted that once the victim was found, he was removed from the building in 23 minutes from his last radio transmission. It is unknown how much air was remaining or whether the victim employed a SCBA survival technique at the last radio transmission. However, rescue teams were hampered by their own SCBA air supplies and the arduous effort of engaging in rapid intervention operations. Whether or not extending the victim’s air supply would have saved the victim, the related factor was that rescue teams were limited by the duration of the victim’s air supply.

Air supply was also a significant factor in the Southwest Supermarket Fire. The Phoenix Fire Department (2001) cited that multiple rescue teams had encountered the victim and that he had exhibited signs of carbon monoxide poisoning (i.e. confusion). Again as in the Four Leaf Towers Fire, the victim’s air supply was a factor in the incident. Specifically, the victim’s air
supply dictated that working time of the rapid intervention teams. Additional factors such as victim size, and building complexity also were major contributors (Phoenix Fire Department [PFD], 2001). However, the victim’s cause of death was asphyxiation.

*During a mayday event, what limitations are presented to rapid intervention teams due to self-contained breathing apparatus duration?*

Contrary to its name rapid intervention was depicted as a slow and arduous process. The literature review yielded five NIOSH reports that indicated that a rapid intervention team was deployed but was not able to recover their victim without the rescue team depleting their own air supply. Similarly, the PFD (2001) cited that rescue efforts were severely limited by the rescue team’s SCBA air supply. In this incident, the time between the victim’s request for help and when the victim was removed was 53 minutes. Thus, air supply is a limiting factor in any rescue effort. This factor is divided between the SCBA air supply of the victim and the rescuer.

The relationship between time and air supply is the critical factor in rescuing downed firefighters. Morris (2004) cited two research studies where the rescue of one firefighter can be up to 21 minutes with 12 personnel. Kreis (2003) further outlined the same research and also stated that at least 20 percent of rescue personnel with declare a mayday during a rapid intervention operation.

**Discussion**

In answering the problem statement: The MCFRS has not identified a universal survival breathing technique for those that must use SCBA, the researcher considered all published techniques to conclude that skip breathing was the only acceptable survival method. Pursuant to
the purpose statement, survival breathing methods would be used in mayday situations, meaning that a firefighter may perish if a survival technique was not employed. Skip breathing provides the firefighter an avenue to conserve or extend their breathing air without compromising the integrity of the SCBA facepiece’s seal on the user. Ad-hoc buddy breathing and filtering breathing air was demonstrated as ineffective techniques in the literature review. While engineered buddy breathing (e.g. EBSS buddy breathing) may be effective, the techniques requires a second firefighter to supply breathing air.

Rapid intervention teams have provided the formal means of rescuing firefighters in mayday situations. However, the name rapid intervention provides an unrealistic expectation that once the rapid intervention team is deployed that a rescue is complete shortly thereafter. To the contrary, the process of rescuing downed firefighters is long and arduous (Morris, 2004). In many instances, rapid intervention teams themselves will become disabled and may require rescue (Kreis, 2003). The literature review did reveal that the effectiveness of rapid intervention teams was correlated to the downed firefighter’s remaining SCBA air supply. In all of the examined NIOSH reports, the cause of death was classified as asphyxiation or smoke inhalation. However, only two reports indicated a secondary cause of death such as traumatic asphyxiation or burns. Thus for the downed firefighter, survivability is linked to remaining SCBA air supply. For rapid intervention teams, the greatest challenge is to rescue (or provide supplemental air) the downed firefighter before their air supply expires.

Skip breathing provides a firefighter the independent means to extend their air supply in a mayday situation. However, other factors need consideration when examining SCBA air supply consumption. Psychological factors (e.g. claustrophobia) and physical factors (e.g. physical conditioning) can affect one’s air consumption. While these factors may not be easily overcome,
firefighters can increase their consumption rate by becoming acclimated to performing job
related tasks while using SCBA (Whalen, 1991).

The impact of this applied research project on the MCFRS would provide firefighters
with survival techniques in the event of an emergency situation such as becoming trapped in a
contaminated environment. As with any fire department in the United States, a clear
organizational goal is to reduce or eliminate firefighter line of duty deaths. In order to leverage
this preponderance in favor of the MCFRS, many survival tools must be given to operational
personnel including personal protective equipment, prudent operating procedures, and training.
This research addresses a training aspect not currently addressed in the MCFRS indoctrination or
in-service training curriculum.

Recommendations

Based on the information gathered during this applied research project, the MCFRS can
implement a SCBA survival program in both its in-service and indoctrination programs. This
recommendation provides three actions. First is to insert skip breathing as part of indoctrination
curriculums for all personnel required to use SCBA. This will include all firefighters and
hazardous material technicians. This will entail a change in the candidate recruit school
curriculum and the volunteer indoctrination program for structural firefighters. Additionally
civilian and volunteer personnel with specialty response responsibilities (the Urban Search and
Rescue Team, the National Medical Response Team, and the Underwater Rescue and Recovery
Team) should also receive skip breathing training based on the breathing apparatus that they will
use.
The second action involves providing an in-service training program to introduce the principles of skip breathing and provide the environment to practice the cognitive skills. Additionally, this recommendation includes the development of a SCBA specialist school similar to Smoke Divers as described by the Broward Fire Academy (2005) and Whalen (1991). This will provide incumbent personnel an environment to acclimate themselves to the rigors of job related tasks while using SCBA. While it is ideal to have all incumbent personnel attend Smoke Divers, it may not be fiscally possible.

The final action involves continuing the research starting in this applied research project. While the limitations of the research have been outlined, the test experience yielded positive results. Further research could be conducted within the MCFRS by employing the Training Academy and Fire and Rescue Occupational Medical Section’s respective staffs in order to reduce the variables affecting skip breathing. Additionally, the MCFRS has access to potential partnership with the National Institute of Health and the National Institute of Standards and Technologies.

These recommendations seek to maximize the proliferation of skip breathing techniques within the MCFRS and to further study the impact of skip breathing, its variables, and the relationship between extending SCBA air supply and rapid intervention techniques.
References


and Soot Inhalation in Residential Fire - Pennsylvania. Gaithersburg, MD.


the Lives of Three Career Fire Fighters - New York. Gaithersburg, MD.


United States Fire Administration. (2002). Firefighter Fatality Retrospective Study. Emmitsburg, MD.


Appendix A

Table 1

*Results of SCBA physical testing for normal and skip breathing after the virbralert has ceased*

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Age</th>
<th>Time increase from normal breathing to skip breathing</th>
<th>Percentage increase from normal breathing to skip breathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>1:22</td>
<td>10%</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>4:29</td>
<td>32%</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>0:13</td>
<td>1%</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
<td>3:37</td>
<td>28%</td>
</tr>
</tbody>
</table>
Appendix B

Proposed skip breathing curriculum addition to the MCFRS indoctrination and incumbent training for self contained breathing apparatus

(As written by Scott Cook, 2005)

• **Motivation**: The instructor shall explain the necessity to conserve SCBA breathing air especially when faced with a mayday situation. Although the standard operating procedure places a rapid intervention group in place during structural fires, it must be understood that the rapid intervention is not a quick process. Time is consumed to locate, extricate, and remove the victim. Often this is accomplished by many personnel. Thus, if a firefighter has become incapacitated or trapped, the amount of breathing air remaining become the determinant on survival. More breathing air increases the likelihood of survival.

• **Objective**: The student will be able to describe and demonstrate the process of skip breathing using self contained breathing apparatus.

• **Instructional Guide**:

  • SCBA air consumption is individually based and can vary depending on one’s physical fitness and psychological dispositions.
  
  • Buddy breathing is only effective when a partner with an adequate SCBA air supply exists and engineered buddy breathing systems (i.e. EBSS). Buddy breathing requires another firefighter.
  
  • No-effective survival breathing techniques: filtering sir through one’s turnout, sharing a facepiece with non-depleted SCBA, using a hard tube between
facepieces, or any technique requiring exposure to the contaminated environment.

- **Skip Breathing Steps**
  1. Inhale normally.
  2. Hold breath for as long as it usually takes the participant to exhale breath. Do not exhale at this point.
  3. Inhale normally again.
  4. Exhale slowly.
  5. Repeat.