Is It Safe To Take Your Mask Off?

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A completed research project submitted to the Ohio Fire Executive Program

23 April 2010

CERTIFIACION STATEMENT

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ABSTRACT

This research was evaluating the effectiveness of Perrysburg Township Fire/EMS's policy of allowing its members to remove their air-packs during the overhaul phase of fire ground operations once the carbon monoxide level is below 35ppm. Specifically, this study looked to see how the levels of carbon monoxide within the structure compared with the firefighters' carboxyhemoglobin levels. The study also looked at whether or not the levels of carbon monoxide within the structure were indicative of the levels of other fire gases in the structure. Finally, the study looked for any signs or symptoms of exposure in the firefighters' operating within the structure during overhaul. The literature shows that the toxic byproducts of combustion are a real threat to today's firefighters. There is also some literature that found no correlation between levels of carbon monoxide within the structure and other fire gases. This study has evaluated the levels of several toxic by-products of combustion to include: carbon monoxide, hydrogen cyanide, phosgene, sulfur dioxide, and acid gas. It also evaluated the levels of carbon monoxide within the firefighter's blood stream following operations within the structure without an air-pack. Results of this study indicated that carbon monoxide levels of less than 8ppm were associated with undetectable levels of hydrogen cyanide, phosgene, sulfur dioxide and acid gas. In addition, firefighters did not experience any signs or symptoms of exposure at these carbon monoxide levels. Several shortcoming of this study were noted to include: sample size, the use of positive pressure ventilation while data was collected, equipment limitations, distractions to the researcher, and this researchers position within the organization where the data was being collected may have influenced the results. The final recommendation to the department was to change the current policy of the department and mandate that all firefighters wear air-packs while conducting overhaul in order to prevent exposure to the toxic byproducts of combustion.

TABLE OF CONTENTS

INTRODUCTION

Statement of the Problem

Fire departments throughout the country use a variety of methods to determine when it is safe for their personnel to remove their self-contained breathing apparatuses at a fire scene. These range from the complete absence of any policy and procedure, where it is left up to the individual to determine whether or not they need an air pack, to not allowing the firefighter to remove their air-pack at all when operating at a fire scene. The debate has always raged around the need for respiratory protection versus the increased fatigue that the device places on the rescuer.

The Perrysburg Township Fire Department attempts to address both of these view points by using a carbon monoxide level of less than 35ppm as an indication that it is safe for the firefighters to remove their air packs. The theory is that if carbon monoxide levels are at a safe level than all of the toxic byproducts of combustion must also be at a safe level. This then allows our firefighter to work at the fire scene without the added burden of an air pack. However, this may or may not be an acceptable practice since there are a multitude of harmful gases present in the post-fire environment. The problem this study will address is whether the policy of allowing personnel to remove their SCBA on the carbon monoxide level has reached 35ppm is an effective guideline for protecting the safety of fire ground personnel in the post fire environment.

This study evaluated the effectiveness of the Perrysburg Township Fire Department's overhaul policy by determining whether or not the level of carbon monoxide measured at a fire scene was a valid indicator that other toxic byproducts of combustion were no longer present in harmful quantities.

Without appropriate respiratory protection in the presence of the toxic byproducts of combustion the effects on the firefighter can be many. Initially the firefighter may experience the acute effects which are defined as occurring within twenty-four hours of exposure. During this time the firefighter may experience irritation to the eyes, throat, mouth, and/or nasal mucosa. In addition they may experience unexplained weakness, headache, tachypnea, tachycardia, and/or dizziness. Often times these signs and symptoms may be missed or attributed to simple fatigue from fighting the fire. In a worst case scenario the firefighter may experience: chest pain, dyspnea, syncope, cardiac dysrhythmias, bronchoconstriction, pulmonary edema, hallucinations, syncope, and/or death. Long term or chronic health effects are much more difficult to identify and etiology is even more difficult to pinpoint. Some of these chronic effects include: cancers, cardiac dysrhythmias, sudden cardiac death, heart attacks, and lung disease to name just a few.

Proponents of not wearing self contained breathing apparatus during the entire fire ground operation argue that the extra weight of the pack places an increase strain on the firefighter leading to an increase in myocardial oxygen demand. This increase strain on the heart may then lead to an increase in the incidence of firefighters experiencing chest pain, dysrhythmias, and sudden cardiac death.

The problem this study will address is whether the policy of allowing personnel to remove their SCBA once the carbon monoxide level has reached 35ppm is an effective guideline for protecting the safety of fire ground personnel in the post-fire environment.

Purpose of the Study

The purpose of this study was to determine if the guideline used by the Perrysburg Township Fire Department is an effective means for determining if it is safe for fire ground personnel to remove their air-packs in the post fire environment.

Research Questions

The following questions will be answered by the evaluative research method:

1. *How do carbon monoxide levels obtained with a four gas monitor compare with blood levels of carbon monoxide in firefighters?*

2. *What is the relationship between carbon monoxide levels that are less than the National Institute of Occupational Safety and Health (NIOSH) permissible exposure limit (PEL) and the following gases: Nitrous Gas, Basic Gas, Hydrocyanic Acid, Acid Gas, Phosgene, Carbon Dioxide, Hydrogen Sulfide, Chlorine, and Sulfur Dioxide?*
3. *After removal of the SCBA in an environment where carbon monoxide levels are less than the NIOSH PEL what signs or symptoms of exposure to the byproducts of combustion do firefighters exhibit in the subsequent twenty-four hours?*

BACKGROUND AND SIGNIFICANCE

When the fire service began there were a lot of technological limitations. There was no such thing as an air pack and water was moved with the aid of buckets. The first generation of firefighters had no form of respiratory protection other than the beards on their faces that they claimed provided some filtering of the air that they were breathing.

With the development of the self-contained breathing apparatus (SCBA) firefighters were able to go where they previously could not. Unfortunately, tradition made many firefighters resistant to the change, and many times firefighters were criticized as being weak for wearing their air-packs in all but the worst of conditions. In addition to the change in tradition the SCBA also added an additional weight that the firefighter had to carry. With this added burden many firefighters were quick to shed their air-packs as quickly as possible when operating on the fire ground. Even today this practice continues. One study that looked at the practices of some of the major metropolitan fire departments in the United States found that 70% of firefighters wore their mask less than 100% of the time during the initial fire attack (Jankovic, Jones, Burkhart, & Noonan, 1992). A second study done in Montreal, Canada found that firefighters only wore their air packs for 6 percent of the total time spent on the fire ground, and they never wore them during the overhaul phase of fire ground operations (Austin, Dussault, & Ecobichon, 2001).

Perrysburg Township is no exception to the above short comings in the fire service. When this researcher joined the department it was not uncommon for firefighters to be hacking and coughing as they walked through thick smoke. Today fortunately, that has changed. During the initial stages of fire attack all Perrysburg Township firefighters wear their air packs, or they face disciplinary action. However, there is still a great deal of controversy over whether or not it is safe to remove the air-pack during the overhaul stage of fire ground operations. Overhaul is the portion of the fire ground operations where the fire has been knocked down, and the firefighters are looking for hidden fire and searching for hot spots. In this stage there may not be a lot of visible smoke, so the firefighter is often led to believe that it is safe to remove their air-pack. In addition, this is the stage where fatigue is likely to be setting in, and the increased weight of the air-pack is an unwanted burden so the firefighter is even more motivated to want to remove their SCBA prematurely.

The policy that is followed by Perrysburg Township firefighters is that they are allowed to remove their air packs after it has been documented by a four gas monitor that the carbon monoxide level is less than 35ppm. The Perrysburg Township Fire Department chose a level of 35ppm based on the recommendations of the Occupational Safety and Health Administration (OSHA). OSHA has established that a carbon monoxide level of 35ppm is a safe working level for a period of eight hours. The theory is that if the carbon monoxide reading is at an acceptable level than the other byproducts of combustion must also be at acceptable levels. This sounds like a good practice but in reality it has never been validated by research.

A series of observations has caused the Perrysburg Township Fire Department to reevaluate its policy and to look for research that validates the practice of allowing firefighters to remove their air packs once the carbon monoxide levels have become safe. Two years ago a firefighter was diagnosed with lungs cancer, and a year ago another firefighter was diagnosed with colon cancer. In addition it is not uncommon to notice firefighter coughing and hacking after fire ground operations.

This study has the potential to effect the fire ground operations of the Perrysburg Township fire department along with every other fire department in the country. Should the study findings indicate that once the carbon monoxide level has reached NIOSH's permissible exposure limit (PEL) of 35ppm *that the other studied gases are also below NIOSH's PEL than the practice of removing your SCBA after monitoring would gain some validity. Now should the results of the study indicate that there is no correlation between carbon monoxide levels and the other studied gases then all fire departments will have to closely examine their practices during the overhaul stage of fire ground operations. It is highly likely that if this is the case that Perrysburg Township will mandate that firefighters wear their self contained breathing apparatuses during all phases of fire ground operations.*

LITERATURE REVIEW

The modern day structure fire is not the same as the structure fire from a hundred years ago. There are numerous synthetic products such as: carpet, plastics, foam, fabrics, and pressure treated lumber. These products give off a wide array of gases and generate a higher number of BTU's in comparison to those of a hundred years ago. The byproducts of combustion vary greatly from one structure fire to the next depending on a variety of factors. Some of the factors include: the product(s) involved, the temperature at which the product(s) are being combusted, the amount of oxygen present in the fire, and how completely they are combusted (Brandt-Rauf, Fallon JR, Tarantini, Idema, & Andrews, 1988).

A variety of gases and particulates have been found in the smoke of the modern day structure fire. The combustion of nitrogen, sulfur, and halogens under the proper conditions can result in the formation of hydrogen cyanide, nitrogen oxides, sulfur dioxide, and halogen acids. Incomplete combustion results in the formation of hydrocarbons, aldehydes, and a variety of particulates. Hydrogen chloride, ammonia, hydrogen fluoride, hydrogen bromide, hydrogen cyanide, isocyanates, and acrolein are generated by the combustion of silk, polyvinyl chloride, wool, plastics, and insulation (Brandt-Rauf et al., 1988). During the overhaul stages of fire ground operations Bolstad-Johnson (1988) identified the presence of the following gases: carbon monoxide, formaldehyde, glutaraldehyde, benzene, nitrogen dioxide, sulfur dioxide, and seventeen polynuclear aromatic hydrocarbons. Additional gases that were identified by Burgess (2001) included: acrolein, hydrogen cyanide, acetaldehyde, benzaldehyde, isovaleraldehde, hydrochloric acid, sulfuric acid and various particulates. Acrolein will irritate the mucus membranes of the respiratory tract and the eye. Significant exposure may result in bronchial inflammation and subsequently bronchitis and/or pulmonary edema. Formaldehyde has been identified as a probable carcinogen and will also cause irritation of mucus membranes. Glutaraldehyde is a known sensory irritant. Sulfur dioxide is an irritant to the mucus membranes of the upper respiratory tract and continued exposure results in fatigue, alterations to the sense of smell, cough, and dyspnea (Bolstad-Johnson et al., 2000).

Carbon monoxide is a colorless, odorless, gas that results from the incomplete combustion of hydrocarbons. Every year in the United States 6,000 people die from carbon monoxide poisoning and an additional 40,000 to 50,000 are treated in emergency rooms each year. When carbon monoxide is inhaled it displaces oxygen from the hemoglobin molecule found in red blood cells and binds to the molecule with more than 200 times the affinity of oxygen. Signs and symptoms of carbon monoxide poisoning include: headache, dizziness, confusion, seizures, coma, chest pain, hypotension, tachycardia, and dysrhythmias (Bledsoe, 2007).

Nitrogen Dioxide is produced during the combustion of nitrogen containing products such as polystyrene. Nitrogen dioxide is an irritant gas that has been responsible for multiple fire related deaths in the past. In addition to death exposure to this gas can cause irritation of the eyes, cough, pulmonary edema, lung damage, emphysema, and interstitial fibrosis (Levin & Kuligoski, 2005).

Hydrogen Cyanide is generated by the combustion of both natural and synthetic substances such as: wool, silk, cotton, paper, plastics, and a variety of other synthetic polymers containing nitrogen and carbon. Signs and symptoms of hydrogen cyanide exposure include: Flushing, anxiety, vertigo, headache, drowsiness, tachypnea, dyspnea, tachycardia, prostration, tremors, dysrhythmias, convulsions, stupor, paralysis, coma, respiratory depression, respiratory arrest, and cardiovascular collapse leading to cardiac arrest (Alcorta, 2004).

The byproducts of combustion can have a myriad of effects on the human body. Burgess et al. (2001) evaluated firefighters before and after overhaul activities in two different groups. The first group wore air-purifying respirators (APR) during the overhaul and the second group did not wear any respiratory protection. Both groups saw a decrease in their forced expiratory volume in one second, but it was more pronounced in the group with no respiratory protection. In addition both groups had an increase in lung permeability at the alveolar-capillary interface. This indicates that an APR may provide firefighters with some degree of protection but it is not complete. These findings were essentially replicated by Large, Owens and Hoffman (2008).

Research and history have shown time and time again that the byproducts of combustion are unusually hazardous and have without question have played a role in the high morbidity and mortality rates within the fire service. Smoke inhalation results 5,000-10,000 death each year in the United States along with an additional 23,000 injuries. Firefighters sustain approximately 5,000 injuries each year due to smoke inhalation (Alcorta, 2004). A poignant example of the lethality of the byproducts of combustion comes from a report done by the New Jersey Department of Health and Senior Services (1997). They reported that in August of 1996 two officers were injured and a deputy chief was critically injured and subsequently died following exposure to the byproducts of combustion while outside a structure fire at a local fast food restaurant. Subsequent investigation revealed that all three officers were exposed to hydrochloric acid, hydrofluoric acid, phosgene, carbonyl fluoride, and chloride gases. All of these gases were produced following a leak and combustion of Freon 22 from an air-conditioning unit on the roof of the restaurant. The medical examiner determined that the deputy chief died from marked tracheobronchial inflammation, alveolar hemorrhage, and pulmonary edema due to smoke inhalation containing phosgene.

In a second case a deputy chief was exposed to smoke while acting as the incident commander at a residential structure fire. Following exposure to the smoke he began to cough. After the incident he developed a persistent cough that lasted for several weeks. He was seen by multiple physicians with no clear etiology defined. He eventually succumbed to his injuries and died over a month after his initial exposure. The coroner ruled the cause of death as progressive respiratory failure and clinical history of adult respiratory distress syndrome due to inhalation injuries as the immediate cause of death (National Institute of Occupational Safety and Health [NIOSH], 2003).

A fire at the Cleveland Clinic in 1929 resulted in 97 deaths during the fire, an additional 26 deaths in the following months, and 92 people who were treated for injuries related to the fire. The majority of these deaths were attributable to nitrogen dioxide exposure. In addition to death exposure to this gas can cause irritation of the eyes, cough, pulmonary edema, lung damage, emphysema, and interstitial fibrosis (Levin & Kuligoski, 2005).

There have been multiple studies that have looked at cancer rates in firefighters. One study reviewed thirty-two different studies evaluating the cancer rates in firefighters. They found that there was a probable risk of firefighters developing multiple myeloma, non-Hodgkin lymphoma, prostate, and testicular cancers secondary to firefighting. They also felt that a phenomenon known as the healthy worker effect may be playing a role in the cancer rates of firefighters. This effect implies that we actually see lower cancer rates in firefighters due to their higher degree of physical fitness and health in comparison to the general population (LeMasters, et al., 2006).

A second study looked at the epidemiological evidence to show a causal association between being a firefighter and developing different types of cancer. Researchers found a higher incidence in three types of cancers in comparison to the general population: multiple myeloma, brain cancer, and malignant melanoma (Howe & Burch, 1990).

The Perrysburg Township Fire Department and a multitude of others have used the measurement of carbon monoxide as a determinant for when it is safe for firefighters to remove their SCBAs and continue fire ground operations. The basic premise of this practice is that if the carbon monoxide level is at an acceptable and safe level other fire gases must also be at an acceptable level. Some departments have used the presence of visible smoke as an indicator of when it is safe for firefighters to remove their SCBAs and continue fire ground operations. Brand-Rauf et al. (1988) found that some of the worst exposures to the byproducts of combustion occurred when the visible smoke levels appeared safe and thus this is not a safe practice.

In wildland firefighting, Reinhardt and Ottmar (2004) found a correlation between carbon monoxide levels and levels of acrolein, benzene, formaldehyde, and respirable particulates. This supports the theory of measuring one gas as an indicator of the firefighters' overall exposure risk. However, this does not necessarily correlate with structural firefighting operations.

During the course of overhaul activities at structure fires, Bolstad-Johnson et al. (2000) found no correlation between the levels of carbon monoxide and nitrogen dioxide with other byproducts of combustion. This research clearly brings into question the practice of using carbon monoxide levels and/or nitrogen dioxide levels as an acceptable method of determining whether or not other byproducts of combustion are at safe levels.

In wildland firefighting there has been evidence of a positive correlation between carbon monoxide levels and respirable particulates. Anthony et al. (2007) looked at the overhaul phase of structural firefighting to see if this same correlation existed and none was identified. They recommended the use of carbon monoxide monitoring during structural fire overhaul as a method of keeping firefighters safe, but he also indicates that there is no evidence that it will be of any predictive value in determining the presence or absence of other byproducts of combustion.

PROCEDURES

Data for this research project was collected from the fire ground and subsequently from firefighters at the scene twenty-four hours following four residential and/or commercial structure fires in Perrysburg Township's jurisdiction and surrounding communities. Data were collected only from fire departments that knowingly and willingly agreed to participate. Individual participants will also signed a waiver allowing the use of their unidentified medical information. These data were then examined to determine the answers to the research questions posed at the beginning of this research project. This researcher will begin to collect data at the structure fire scene once the incident commander had declared that the incident was proceeding into the overhaul phase of fire ground operations. Once this occurred, this researcher first obtained a carbon monoxide level in the room of origin using a MSA Orion multigas detector. Once the CO level is at or below 35ppm this researcher obtained gas samples using Drager simultaneous test set 1 and Drager simultaneous test set 2. These are a series of colorimetric tubes that detect and quantify the presence or absence of the following gases: nitrous gas, basic gas, carbon monoxide, hydrocyanic acid, acid gas, phosgene, carbon dioxide, hydrogen sulphide, chlorine, and sulfur dioxide. Those data were then recorded for cumulative evaluation (See Appendix A for a copy of the data collection form).

As the firefighters exited the structure a record their blood carboxyhemoglobin levels were obtained noninvasively with the Masimo Rad-57. This device will measure a firefighter's blood carboxyhemoglobin level within +/- 3% of an arterial blood gas sample. The pump operator will be used as a control since this individual had no role in interior fire ground operations.

Firefighters were also asked a series of questions to detect any signs or symptoms of exposure to the toxic byproducts of combustion. Finally, each firefighter was given a survey to be completed, which again attempted to detect signs and symptoms of potential exposure to the toxic byproducts of combustion twenty-four hours after the event (See Appendix B for a copy of the form used to collect this data).

Once all the data had been collected they were examined in order to determine if the results provided the answers to the research questions proposed in this study. First, we will see how the carbon monoxide levels found on the MSA multigas detector were compared with the blood carboxyhemoglobin level in firefighters after completing overhaul. Secondly, we will see how the carbon monoxide levels found within the fire structure during overhaul were compared with the levels of the following gases: nitrous gas, basic gas, carbon monoxide, hydrocyanic acid, acid gas, phosgene, carbon dioxide, hydrogen sulphide, chlorine, and sulfur dioxide which were obtained with Drager colorimetric tubes. Finally, the firefighters participating at these scenes were examined to see if they exhibited any signs or symptoms of exposure and if such signs were correlated to the presence or absence of combustion byproducts.

RESULTS

The results of this research project came from data collected at four residential structure fires between May 2009 and February 2010 (See appendix C for a description of the fires). All four structures were being actively ventilated with an electric positive pressure fan at the time all data was collected.

The first question that this researcher attempted to answer was how do the blood levels of carbon monoxide compare with the levels of carbon monoxide within the fire structure. The data collected at these four fires indicated that there was undetectable to very low levels of carbon monoxide within the structure at the time overhaul was commenced. The levels of carbon monoxide within the structure varied between 0ppm and 8ppm just prior to initiating overhaul of the structure. The average reading was 3.25ppm. While overhaul was occurring the carbon monoxide levels varied between 0 and 6ppm with an average of 2.25ppm within the structure. In all cases it was noted that the carbon monoxide levels remained the same or dropped during overhaul. There were no documented cases of an increase in the carbon monoxide levels while overhaul was occurring.

The firefighter's carboxyhemoglobin levels prior to beginning overhaul varied between 0 and 3 percent among all firefighters with an average of 1.14 percent. The incident commander and the pump operator were used as controls whenever possible. The carboxyhemoglobin levels of the controls varied between zero and one percent with an average of 0.60 percent. The carboxyhemoglobin levels of the firefighters actually conducting overhaul varied between zero and two percent with an average of 1.44 percent. According to the Masimo Corporation these are all normal blood carboxyhemoglobin levels. They state that non-smokers should have levels of between zero and four percent. Smokers should have blood levels of between three and five percent (Koster & Rupp, 2005).

Following the completion of overhaul blood levels of the firefighter were re-checked. The controls' blood levels varied between 0 and 1ppm with an average of 0.40ppm. The firefighters' conducting overhaul had blood levels of between 0 and 2ppm with an average of 1.11 percent. These are normal blood levels and indicate that there was no significant exposure to carbon monoxide while overhaul was occurring.

The data indicated that as the levels of carbon monoxide decrease so do the carboxyhemoglobin levels of the firefighters. In addition these data indicate that if the CO level is below 8ppm than firefighter's carboxyhemoglobin levels will remain at safe levels.

The second question that this researcher attempted to answer was how do carbon monoxide levels of less than 35ppm compare to the levels of hydrogen cyanide, phosgene, sulfur dioxide, and acid gas in the post fire environment. In all four residential structure fires there were no detectable quantities of hydrogen cyanide, phosgene, sulfur dioxide, and acid gas found within the structures while overhaul was occurring. This data indicates that when the carbon monoxide levels are at levels of less than 8ppm that these four gases are also at safe levels.

The final question that this researcher attempted to answer was that once carbon monoxide levels have reached safe levels do firefighters exhibit any signs or symptoms of exposure to the toxic byproducts of combustion in the following twenty-four hours. In all cases the firefighters conducting overhaul denied having any signs or symptoms of exposure in the twenty-four hours after a structure fire. However, in two out of the four structure fires this researcher experienced eye irritation while taking gas measurements. In the subsequent twenty-four hours after these data were collected in these same two fires this researcher experienced a sore throat and irritated eyes. This data would indicate that once carbon monoxide levels reach safe levels of less than eight ppm firefighters conducting overhaul will not experience any detectable signs or symptoms of exposure to the toxic by-products of combustion.

DISCUSSION

The data collected during four residential structure fires indicate that if the carbon monoxide levels have dropped below 8ppm than firefighters do not experience any detectable signs and symptoms of exposure. In addition there are no detectable levels of hydrogen cyanide, phosgene, sulfur dioxide, and acid gas in the post fire environment. This however goes against much of the data collected by previous researchers. In wildland firefighting, Reinhardt and Ottmar (2004) did find a correlation between carbon monoxide levels and level of acrolein, benzene, formaldehyde, and respirable particles however this has not been in the case in structural firefighting. Previous researchers have identified detectable levels of: formaldehyde, glutaraldehyde, benzene, nitrogen dioxide, sulfur dioxide, and seventeen polynuclear aromatic hydrocarbons while overhaul was occurring (Bolstad-Johnson, 1988). Other researchers have also found firefighters with signs of exposure to the toxic byproducts of combustion following overhaul (Burgess et al., 2001).

Some limitations to this study that may explain the differences from previous studies are: sample size, the use of positive pressure ventilation while data were collected, equipment limitations, distractions to the researcher, and this researcher's position within the organization where the data were being collected all may have influenced the results. Data was only collected from four residential structure fires and in order for this data to be more meaningful a much larger sample size is needed. It was originally anticipated that data would be collected from ten structure fires but do to time limitations this was not possible.

A sample size of only four structure fires is a limiting factor of this study. Bolstad-Johnson conducted air monitoring at twenty-six structure fires while conducting his research (2000). Reinhardt and Ottmar analyzed air samples over the course of thirty days of wildfire firefighting (2004). These larger samples allow for the establishment of clear trends. The small sample size of this study provides anecdotal evidence. It does not allow this researcher to make a substantiated claim in favor or against wearing a SCBA based on the data collected during this study.

The use of positive pressure electric fans while the data was being collected may have removed many of the toxic by-products of combustion as they were being produced by smoldering fires. This researcher did not find any reference to this tactic being used in any of the previous studies. This is an interesting discovery since there is are a lack of citations about ventilation in past studies in combination with the findings of this study may indicate that positive pressure ventilation leads to a safer post fire environment for the firefighter. In this study positive pressure ventilation was initiated with an electric fan as the attack was commencing in all four cases. It is important to recognize that in all four cases an electric fan was used since gas fans may actually introduce more carbon monoxide into the structure. In all cases positive pressure ventilation continued after the fire was extinguished and crews were conducting overhaul. The exact amount of time each fan ran prior to commencing overhaul or the entire amount of time each fan ran was not recorded. Crews did remove their SCBAs once the post fire environment was deemed safe by measuring the level of carbon monoxide within the structure. As mentioned previously the Perrysburg Township Fire Department uses a level of less than 35 ppm as an indication of when it is safe for fire fighters to take of their masks. In all cases the initial carbon monoxide reading were well below this threshold. The highest reading throughout the study was only 8 ppm. This is an area that is worthy of future research because additional data on the use of positive pressure ventilation while overhaul is occurring may lead to safer tactics for future firefighters.

Equipment limitations were also problematic. The high humidity noted in the post fire environment may have affected the readings of the colorimetric tubes. It was also difficult for the researcher to juggle all of the different tubes, pumps, and meters while overhaul was simultaneously occurring around him. Lighting conditions also made it difficult to read the tubes once measurements were taken. The colorimetric tubes also do not provide an exact reading like digital meters do. It is also possible that there were slight color changes that were in fact positive results but were not detectable by this researcher do to the environment he was working in.

Another problem encountered by this researcher was that he was forced to multi-task at all of these fire scenes. In most cases he was the incident commander who then had to delegate his duties to someone else before being able to conduct the research. In fact there were three or four other fires that could have been used during this study but this researcher was unable to break away from the tasks required by his job in order to conduct this research.

Finally, this researcher's position of Deputy Chief within the organization may have negatively influenced the results of the survey conducted twenty-four hours after the fire event. Subjects in the study may have feared some sort or retribution if they stated they did not wear their SCBA 100% of the time or if they indicated that were having some signs or symptoms of exposure to the toxic byproducts of combustion.

RECOMMENDATIONS

This researcher would make a few recommendations to future researchers. First, in order to obtain a meaningful sample size future researchers should conduct their research within a large metropolitan department where the call volume is high enough to obtain a large sample in a time efficient manner. Secondly, it may be advantageous to conduct the data collection when the researcher can be fully devoted to the task at hand versus being forced to multi-task. More precise data may also be collected by using meters with digital read-outs versus colorimetric tubes. Finally, this researcher believes that conducting future research into the reliability and validity of using positive pressure ventilation as a means of removing the toxic byproducts of combustion may be extremely beneficial to the fire service.

Recommendations to the Perrysburg Township Fire Department based on this research would be to change their current policy to mandate the wearing of an air-pack while overhaul is occurring. Although, the results of this research may indicate that this is not necessary, the flaws in the procedural elements of this study negate the findings. In addition the findings of previous researchers document the presence of multiple toxic byproducts of combustion in the overhaul stage of fire ground operations. Therefore, it is simply not safe for firefighters to operate in this environment without an air-pack on. However, it may be a worthwhile practice to continue positive pressure ventilation while overhaul is occurring to potentially remove some of the byproducts of combustion if an electric positive pressure fan is used. The use of a gas powered electric fan may actually worsen the atmospheric conditions by pushing more carbon monoxide into the structure.

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Appendix A

Fire Data Collection Form

Date: ___________ Location: ___________________ Primary Department: ____________

1. Carbon monoxide level at the start of overhaul:

   _______________ppm _______________hours

2. Carbon monoxide level at the time other gas level are checked:

   _______________ppm _______________hours

3. Hydrogen cyanide level:

   _______________ppm _______________hours

4. Phosgene:

   _______________ppm ________________hours

5. Sulfur dioxide:

   _______________ppm ________________hours

6. Acid gas:

   _______________ppm ________________hours

Data collected by: ______________________________ (Name)

Appendix B

Fire Ground Operations Survey Form

Name: ____________________________ DOB: ________________ Phone: ___________
Location: __________________________ Primary Fire Department: ____________________

Carboxyhemoglobin level prior to starting overhaul: ___________________________________
Carboxyhemoglobin level after completing overhaul: __________________________________

<u>To be completed the day of the fire:</u>

1. What was your role during fire ground operations? Check all that apply:
   - ❑ Fire attack
   - ❑ Ventilation
   - ❑ Salvage and overhaul
   - ❑ Investigation
   - ❑ Incident commander
   - ❑ Safety officer
   - ❑ Pump operator
   - ❑ Other: ____
2. What percentage of the time did you wear your SCBA when you conducted the above activities?
   - ❑ 0-19%
   - ❑ 20-39%
   - ❑ 40-59%
   - ❑ 60-79%
   - ❑ 80-99%
   - ❑ 100%
3. Was this your only structure fire in the past 72 hours?
   - ❑ Yes
   - ❑ No

<u>To be completed 12-24 hours after the fire:</u>

4. In the twelve to twenty-four since the fire have you had any of the following sings of symptoms? Check all that apply:
   - ❑ Headache
   - ❑ Chest pain
   - ❑ Palpitation or irregular heart beat
   - ❑ Difficulty breathing
   - ❑ Nausea
   - ❑ Vomiting
   - ❑ Diarrhea
   - ❑ Dizziness
   - ❑ Sore throat
   - ❑ Watery or irritated eyes
   - ❑ Other: ____
5. What do you attribute these signs and symptoms to? ______________________________

   ____

   Data Collected by: ______________________________________ Date: ____________

Appendix C

The first fire was a bedroom fire in a two story single family dwelling with wood frame construction. The fire was started by a space heater in one of the kid's rooms. The fire had completely involved the room and contents and had vented out the window at the time of arrival. A fast attack on the fire followed by positive pressure ventilation with an electric fan resulted in the fire being brought under control within ten minutes. There was heavy smoke damage throughout the second floor of the structure and the bedroom of origin was a total loss. Positive pressure ventilation continued while crews operated at the scene.

Fire two was a basement fire in a two story single family dwelling with wood frame construction. The fire involved the room and contents of the basement. The extensive amount of storage in the basement made extinguishment difficult. A positive pressure attack utilizing an electric fan was initiated to assist crews in making their decent into the basement. The fire was brought under control in approximately twenty minutes. Damage was limited to the basement of the structure. Positive pressure ventilation continued throughout the entire scene.

The third fire involved an attached garage on a two-story single family dwelling with wood frame construction. At the time of arrival the garage was completely involved and fire had already vented through the roof and was extending into the attic space of the home. After rescuing a subject trapped in the home a line was extended in the house to cut off the fire and a second line was placed on the main body of the fire. Positive pressure ventilation of the house with an electric fan was started in an attempt to keep the smoke and fire out of the house. The fire in the attack space was quickly knocked down and there was no additional fire spread into the structure. The main body of the fire required the application of a master stream for extinguishment. The garage was a total loss and was on the ground by the time operations were complete. The interior of the house had minor smoke damage. Positive pressure ventilation of the home continued while crews operated at the scene.

The fourth fire was a room fire within a one story single family dwelling with wood frame construction. The owners of the home had already moved out so there were no contents within the structure. The fire was quickly extinguished with a single hand line. Positive pressure ventilation with an electric fan was initiated to evacuate the smoke from the building. Damage to the home was minimal. Ventilation was not discontinued until after the crews exited the structure.