Air Quality after the Fire

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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 the language, ideas, expressions, or writings of another.

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Abstract

The problem that was researched in this applied research project is that the Noblesville Fire Department is possibly allowing our members to be exposed to harmful airborne products after a fire. The purpose of this research was to collect and analyze data on air quality, after a fire, to determine what level of protection is necessary for use after the fire is out. This research utilized the evaluative research method. The research questions asked were the following: Why study the air quality, what is in the air after a fire, what are the risks associated with the products found, and what would be the cultural response to having to wear respiratory protection during times that typically didn't require respiratory protection?

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Introduction

The human respiratory tract is one of only a few direct routes into the human body. Humans inhale and exhale massive volumes of air each day, but natural protective measures, such as mucus, render the air relatively clean for use by the human body. There are, however, some vapors, gases and particulate matter that are not filtered and, if inhaled, can cause both acute and chronic health issues. Firefighters, as a matter of the job, routinely enter environments that can contain many of the aforementioned vapors, gases, and particulate matter. If a firefighter were to enter an atmosphere that was thought to be void of harmful airborne products without respiratory protection, the consequences could be severe if that atmosphere was, in fact, contaminated.

The problem is that the Noblesville Fire Department (NFD) does not know what particulate matter or gases are inspired by our members after the order to remove air packs is given, thus allowing the potential for our members to be exposed to harmful airborne products. The purpose of this research is to collect and analyze data on air quality, specifically after a fire, to determine what level of protection is necessary for members operating at a fire incident after Self Contained Breathing Apparatus (SCBA) removal.

Evaluative research was used to formulate a basis for analysis and a correct course of action, if necessary. The research questions included the following:

a) Why study the air quality inside of structures from the point of SCBA removal to the fire suppression crews departure from the scene?

b) What particulate matter or gas is in the air from the point of SCBA removal until fire suppression crews depart the scene?

c) Given the particulate matter or gas present, what are the potential health risks to personnel who inhale these products?

d) Given the particulate matter or gas present, what level of respiratory protection is most appropriate for the protection of our members?

e) Given the appropriate respiratory protection, what would the response be from the members of the NFD to having to wear respiratory protection during times that they historically did not?

Background and Significance

Smoke and other unburned products of combustion have always been and probably always will be a great obstacle to firefighters. A chronological perspective reveals that firefighters have been devising means of self-respiratory protection since the days of the bucket brigades. In fact, "…folklore relates that early American firefighters grew long beards which were dipped in a pale[sic] of water and subsequently clenched between the firefighter's teeth in an effort to filter the smoke" (Hashagen, 1997, ¶ 2). Ultimately, Scott Aviation developed the "AirPac" in late 1945 (Hashagen, 1997). Arguably the "AirPac" appears to be the most closely related prototype to the models currently in use.

Numerous efforts to develop better respiratory protection over the years have gradually proved to be a successful venture. As with most new technology, respiratory protection transformed from the prototypes of the early development stages into the products that are available today. The transformation deals strictly with the technological aspect of change and the subsequent equipment available to firefighters. Changing the culture of the fire service to incorporate SCBA's has proven to be almost as challenging.

On May 17, 1971, the National Fire Protection Association (NFPA) approved the first document to address firefighter respiratory protection. This document was known as NFPA 19B, *Standard on Respiratory Protective Equipment for Firefighters.* A reflection of the prevailing attitude at NFD, and it seems many other departments, during the time of transition from pre-SCBA usage to SCBA usage had to undergo serious cultural scrutiny. I spoke with NFD Fire Chief Gilliam about the cultural aspect of SCBA's and their usage at NFD during that transitional period. Chief K. L. Gilliam (personal communication, January 22, 2008) said:

> The prevailing attitude in the early 1970's to the late 1980's was that SCBA's had value, but they took way too long to put on. Our firefighters felt that they could have extinguished the fire in the time that it took to put on the SCBA. SCBA's, in those years, were viewed as tools for defensive or well involved fires and for search, if one [a search] were to be conducted. I would speculate that SCBA's were only used roughly 10% of the time.

While the resistance to SCBA usage could have been specific to only NFD, research indicates that the problem exists throughout the fire service, even today. A quick search of the website firefighterclosecalls.com in the Close Calls section revealed no less than 4 SCBA- related close calls for firefighters in 2007. Three of the four close calls were related to failure to wear an SCBA, while the fourth person had the SCBA on but was not breathing air. Circumstances and reasoning vary from case to case, but the real message is that firefighters are still placing their respiratory systems in jeopardy.

The great irony with this situation is obvious, but important to note. The firefighters of the 19th and early 20th century went to great lengths, trying anything to help them operate in smoke-filled environments. Their efforts were to our benefit in that new technology now allows us to operate with an uncompromised respiratory system far longer than our forefathers could. Unfortunately, some firefighters still try to fight fire without the use of an SCBA.

The problem, it seems, is that the smoke and other unburned products of combustion are fast becoming, if they are not already, more dangerous than the fire that spawned them. Historically, if all units marked “in service” from a fire and left the scene relatively unscathed, the efforts of those units was a “success.” That is still true today; however, there is more to the “success” equation. The relative “success” should not be judged only in the acute sense, but should also be judged over the long term or chronic sense.

It may take years to realize the damage that inhaled unburned products of combustion have caused. Death, as most people know, does not always appear during an incident, or even shortly after an incident for that matter. There is the issue of chronic illness that can result from the inspiration of unburned products of combustion. Certainly the acute or immediate health issue or death captures headlines, as it should. What of those who die a slow death from cancer? The questions about that type of death are many, but the one question that is often impossible to determine is what caused the cancer?

Firefighters are developing certain types of malignancies at an alarming rate. LeMasters et al. (2006) conducted a meta-analysis of cancer risk among firefighters and found significantly increased cancer probabilities for certain types of cancer such as; multiple myeloma, non-Hodgkin’s lymphoma, prostate, and testis.

A quick review of NFD retirees over the past 25 years revealed a cancer rate of seven percent. The number of retirees, however, is very small and creates a very narrow sample for evaluation. The NFD currently follows a respiratory protection standard operating guideline (SOG) for use during specific periods of an incident. This policy relies on a measure of CO, oxygen and lower explosive limit monitoring to determine if the tested environment is tenable. This policy does allow for gaps or potential gaps in respiratory protection and possibly exposure to a variety of harmful airborne products.

The Noblesville Fire Department consists of 120 sworn firefighters operating from six stations. The 2005 census report for the City of Noblesville indicated a population of 39,000 living in the city with another 10,000 to 15,000 in the township. The NFD has experienced a fire/EMS run increase of roughly eight percent per year since 2004. The City of Noblesville is growing at a very rapid pace, and therefore, so is the NFD. Speculation indicates a continuation of this growth pattern. Deductively it stands to reason that the NFD should anticipate an increase in the run load, including fires, for the foreseeable future. This data should cause concern about the exposure potential to our firefighters in the years ahead.

The United States Fire Administration (USFA) has identified five operational objectives. This research is aimed at the operational objective of reducing the loss of life from fire of firefighters. A linkage may be drawn connecting increased firefighter cancer rates with the respiratory protection practices employed at fire scenes by firefighters. Further, this research applies to the National Fire Academy’s (NFA) Executive Analysis of Fire Service Operations in Emergency Management (EAFSOEM) curriculum concept of ensuring the safety of personnel in the Incident Command module. There is a quality-of-life issue that does or should exist after a fire service career that must be considered. The conscientious leader should recognize this quality-of-life issue and embrace any initiative aimed at meeting this end.

Literature Review

This literature review was based on data obtained from the National Institute of Standards and Technology (NIST), Bureau of Alcohol, Tobacco, and Firearms (ATF), the International

Association of Firefighters (IAFF), the National Institute for Occupational Safety and Health (NIOSH), the National Fire Academy (NFA) Learning Resource Center (LRC), journals, magazines, and the internet. A search of the United States Fire Administration (USFA) website revealed a Topical Fire Report Series (TFRS) for Fire Department Fire Run Profile for 2004. This 2004 report indicated that nearly "95% of fire runs to structure fires are to buildings and that 62% of those buildings are used for residential purposes" (USFA, December 2007, p. 2).

The NFPA estimated the number of firefighters in 2006 at 1,140,900 (NFPA, November, 2007). Of those, 316,950 or 28% are career firefighters. The remaining 823, 950 or 72% were volunteers (NFPA, 2007, November). These firefighters responded to 1,642,500 fires during 2006. Of those fires 511,000 were structure fires (NFPA, 2007, August). The number of fires obviously varies from year-to-year, but the fluctuation is generally not substantial. In 2007, the NFD responded to 53 structural fires (NFD, 2007). The total number of firefighting personnel in 2007 at the NFD was 120 individuals.

"Carbon Monoxide (CO) is the most common cause of poisoning in industrialized countries," (Bledsoe, 2008, p. 6) this fact alone speaks to the deceptive nature of CO. According to Bledsoe, CO is an odorless, colorless, tasteless gas and results from the incomplete combustion of carbon-containing fuels (2008). Firefighters, as a natural part of the profession, are at an increased risk of exposure to CO since their "working environment" often is inside of a structure that has burned. This CO information is provided to students in a student manual for a new initiative that is sponsored by the IAFF to educate firefighters about many of the acute and chronic signs and symptoms of CO poisoning.

H. A. Schaitberger, General President of the IAFF, wrote in a letter to all IAFF local Presidents (personal communication, November 2007), "We believe that many of the cardiac arrests firefighters are experiencing may well be attributable to CO exposure." Mr. Schaitberger made a very interesting statement when one considers that the leading cause of death among firefighters is cardiac arrests. In fact, a total of 49 (46.2%) of the firefighter line-of-duty-deaths that occurred in 2006 were ruled to be cardiac arrest (USFA, 2007, July). In a NIOSH Alert, NIOSH recommends, among other things, that "fire departments control exposure to CO and other fire contaminants with proper fire scene management and respiratory protection" (NIOSH, 2007, introduction section, ¶ 4).

The smoke from residential fires can contain an infinite number of products. These products are not only based on the fuel source, or what was burning, but also on fire conditions (NIOSH, 2007). CO is only one by-product of the combustion process. Hydrogen cyanide, for example, is also frequently detected in structure fires as, is a plethora of other particulate matter and gases (NIOSH, 2007). According to Michael Lee (2007), there is a strong possibility that cyanide poisoning is responsible for some portion of the cardiac arrests experienced by firefighters. As is evident, much time and effort has been spent studying the effects of these products on the cardiovascular system.

In April 2003, NIST sponsored Smoke Component Yields from Room-scale Fire Tests (Gann, Averill, Johnsson, Nyden, & Peacock, 2003). While the structure of the NIST tests was not an exact match to the testing conducted as a part of this research, the results do add credibility to some of the research questions contained herein. Gann et al. conducted measurements of CO, Carbon Dioxide (CO2), Oxygen (O2), Hydrogen Cyanide (HCN), Hydrogen Chloride (HCl), Hydrogen Fluoride (HF), Hydrogen Bromide (HBr), Nitric Oxide (NO), Nitrogen Dioxide (NO2), Formaldehyde (H2CO), and Acrolein (C3H4O).

The purpose of the NIST testing was to "…establish a technically sound basis for assessing the accuracy of the bench-scale device(s) that will be generating smoke yield data for fire hazard and risk evaluation" (Gann et al., 2003, p. xi). This testing measured pre-flashover and post-flashover levels of the aforementioned compounds in a controlled setting using a sofa, a particleboard bookcase, a polyvinyl chloride sheet, and a household electric cable. The results indicated the yields of CO2, CO, HCl, HCN, and carbonaceous soot were determinable and measurable, while NO2, formaldehyde, and acrolein were not found above the detection limits. The review of this literature and confirmation of the presence of toxic particulates served to add direction and credence to the need for further testing of an atmosphere after a fire.

An earlier study that was requested by the ATF and conducted by a branch of NIOSH occurred in 1997. This study, hereinafter referred to as the "ATF study," is a very close match to the study that was conducted for this research. "A fire scene usually happens in three distinct phases; suppression, overhaul, and investigation" (Kinnes & Hine, 1997, p. 2). The ATF study focus was specifically directed to the timeframe of the investigation. The catalyst for the ATF study was a concern by ATF special agents and fire investigators in Northern Virginia about potential respiratory health effects from conducting fire scene examinations and the adequacy of their respiratory protection (Kinnes & Hine, 1997). The results indicated the presence of various concentrations of the tested analytes. The tested analytes included respirable dust, metals, HCN, inorganic acids, aldehyde, polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC), and elemental carbon (Kinnes & Hine, 1997).

A similar study conducted by Bolstad-Johnson, Burgess, Crutchfield, Storment, Gerkin, and Wilson (2000) focused on firefighter exposures during fire overhaul. Sampling was conducted for aldehydes, benzene, toluene, ethyl benzene, xylene, hydrochloric acid, polynuclear aromatic hydrocarbons (PNA), respirable dust, HCN, CO, NO2, sulfur dioxide(SO2), asbestos, metals, and total dust (Bolstad et al., 2000).

This research was conducted in Phoenix, Arizona and included air monitoring during overhaul in 25 different structures (Bolstad et al., 2000). Testing media varied for the different analytes tested. The results indicated that the following analytes exceeded published ceiling values: acrolein, CO, formaldehyde, glutaraldehyde, benzene, NO2, SO2, and PNAs (Bolstad et al., 2000). The results exceeded ceiling values of different organizations (e.g., NIOSH, OSHA, etc.) to varying degrees and not at every fire. Secondarily, the Bolstad et al. (2000) study concluded that CO should not be used as an indicator gas for other contaminants found in these atmospheres.

The effects of breathing any one of the compounds by itself are, to varying degrees, predictable assuming exposure levels are known. However, determining exposure levels and limiting inclusion of other compounds are virtually impossible in a fire scene setting. A study conducted by LeMasters et al. (2006) broached the subject of firefighter cancer rates, which has shed some light on potential trends within the fire service resulting from possible exposure. The study was a qualitative three-criterion assessment and a quantitative meta-analysis of cancer risk among firefighters. This study rendered potential cancer rate results for firefighters ranging from probable (high likelihood), possible (more than average), to unlikely (equal to general population). The summary of the LeMasters et al. study revealed the following:

Table 1

Summary of Likelihood of Cancer Risk-Firefighters

Cancer Site	**Likelihood of Cancer Risk by Criteria**
Multiple Myeloma	Probable
Non-Hodgkin lymphoma	Probable
Prostate	Probable
Testis	Probable
Skin	Possible
Malignant melanoma	Possible
Brain	Possible
Rectum	Possible
Buccal cavity and pharynx	Possible
Stomach	Possible
Colon	Possible
Leukemia	Possible
Larynx	Unlikely
Bladder	Unlikely
Esophagus	Unlikely
Pancreas	Unlikely
Kidney	Unlikely
Hodgkin's disease	Unlikely
Liver	Unlikely
Lung	Unlikely

This study confirmed previous findings of an elevated metarelative risk for multiple myeloma among firefighters. LeMasters et al. (2006, p. 1200) further concluded that "…firefighter risk for these four cancers may be related to the direct effect associated with exposures to complex mixtures, the routes of delivery to target organs, and the indirect effects associated with modulation of biochemical or physiologic pathways."

A roundtable discussion in the September 2007 issue of *Fire Engineering* centered on the question "SCBA policies define the required use of SCBA's at fires. During the overhaul phase, when, if at all, are your firefighters allowed to remove their SCBA protection?" (Coleman et al., 2007, p. 34). Representatives from 24 different fire departments (22 U.S. cities, 2 international) responded to the question. The summary results indicated that 21 of the respondents do not currently mandate SCBA usage during overhaul, but instead have varying degrees of respiratory protection criteria. Examples of these criteria include Immediately Dangerous to Life and Health (IDLH) restrictions, CO levels, low O2 levels, and lower explosive limits. Three respondents do have SCBA usage requirements in place. Much of the time, the decision concerning the IDLH atmosphere is left to a monitoring instrument and/or the Incident Commander (IC) or Safety Officer. At other times, the decision considers what has burned, visible particulate matter, absence of visible smoke, etc. Most of the responses indicated positive short term results in that no injuries were reported during or after the incident.

In terms of human exposure to the multitude of different compounds in the field, different organizations have studied and published different definitions of values and limits of exposure. Miller (2004), in a hazardous materials book, defines many of these terms. The terms along with the values associated with them are set by different organizations. The three organizations that are used most frequently are NIOSH, OSHA, and the American Conference of Governmental Industrial Hygienists (ACGIH). NIOSH defines an IDLH atmosphere as "an atmospheric concentration of any toxic, corrosive, or asphyxiating substance that poses an immediate threat to life. It can cause irreversible or delayed adverse health effects and interfere with the individual's ability to escape from a dangerous atmosphere" (2004, p. 78). OSHA defines an IDLH atmosphere as "An atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual's ability to escape from a dangerous atmosphere" (2004, p. 78). OSHA has also defined a limit known as a Permissible Exposure Limit (PEL). A PEL, as defined by OSHA, is "the maximum concentration to which the majority of healthy adults can be exposed over a 40-hour workweek without suffering adverse effects" (2004, p. 78). An OSHA PEL (C) is a PEL ceiling limit and this is the maximum concentration that a person can be exposed to at any time, even for an instant (2004, p. 78). The ACGIH has established a Threshold Limit Value (TLV). The TLV, as defined by ACGIH, is an occupational exposure value recommendation which it is believed nearly all workers can be exposed day after day for a working lifetime without ill effect (2004, p. 78). There are a variety of other limits and values, but those referenced constitute the majority of the measures necessary for this research.

Identification of respirator types and application for each is prudent for the purposes of this research. Research included a study of recommendations by NIOSH, OSHA, and NFPA. All three of these organizations reference each other throughout most of the literature about respiratory protection. A secondary note of importance to this information is that oxygen content must be adequate for any respirator that does not utilize an outside air source. NIOSH divides respirator types into three separate categories: Particulate respirators, gas/vapor respirators, and combination particulate and gas/vapor respirators (NIOSH, 2004). A step-by-step procedure is provided by NIOSH to assist in respirator type determination. The first step as indicated by NIOSH is to ask "Is the respirator intended for use during fire fighting?" (2004). If the answer is yes, NIOSH requires a full-facepiece, pressure-demand SCBA. Assuming a non-IDLH atmosphere is present then, a hazard ratio is determined by first identifying the contaminant and using the TWA to determine the appropriate protection level. A determination must be made with respect to the physical nature of the contaminant (vapor, gas, particulate), which ultimately allows the user to determine the maximum use concentration (MUC). The MUC is defined as the maximum atmospheric concentration of a hazardous substance from which an employee can be expected to be protected by a class of respirator (NIOSH, 2004, p. 3). NIOSH, through an equation, renders all numbers and equates them to an assigned protection factor (APF), which is "the minimum anticipated protection provided by a properly functioning respirator or class of respirators to a given percentage of properly fitted and trained users" (2004, p. 2). Respirators are grouped into type and given the appropriate APF. An example of a combination gas/vapor and particulate APF chart is located in Appendix A. A NIOSH respirator selection logic sequence lists several steps to assist in respirator selection. The first "step" is to determine if the respirator is to be used for firefighting; if yes, only an SCBA is adequate protection (2004). Step 3 asks whether the respirator intended for entry into unknown or IDLH atmospheres is appropriate, if so, NIOSH only recommends an SCBA or a supplied air respirator (2004).

OSHA Regulation 29CFR1910.134 (2007) reads much the same as NIOSH with minor exceptions. One such exception is listed in the general requirements section and is identified as 29CFR1910.134 (d)(1)(iii). This section states:

> The employer shall identify and evaluate the respiratory hazard(s) in the workplace; this evaluation shall include a reasonable estimate of employee exposures to respiratory hazard(s) and an identification of the contaminant's chemical state and physical form. Where the employer cannot identify or reasonably estimate the employee exposure, the employer shall

consider the atmosphere to be IDLH. (2007, p. 5)

NFPA 1981 (2002), A.1.1.1 proposes that "…there is no way to predetermine hazardous conditions, concentrations of toxic materials, or percentages of oxygen in air in a fire environment, during overhaul operations." There is a recommendation in the same location that "SCBA are required at all times during any fire-fighting, hazardous materials, or overhaul operations" (2002, A.1.1.1). This information is important to consider when implementing a process for identifying the most appropriate respirator for the task.

Procedures

The procedures used for this research were comprised of seven steps. The first involved an in-depth and detailed review of available literature. The LRC at the NFA in Maryland was utilized via the online searchable database. Database searches were conducted using keywords/key phrases such as: Air monitoring, air quality, SCBA usage, respiratory protection, respiratory protection during overhaul, respiratory protection after the fire, respiratory protection during the investigation, toxic environments, by-products of combustion, carbon monoxide and cyanide. Few relevant articles were obtained using this resource. The majority of current research data came from the World Wide Web using the Google search engine.

The results of Step One quickly allowed the author to organize and examine areas of concern or question, such as prior research studies, historical data, known health effects, and current SCBA usage trends. Hence, Step Two was an in-depth analysis of prior research. Much of the analysis studied research that was similar to but not an exact match to this research project. This proved to be of critical importance to the thoroughness of this research project as the discovery of new data and subjects for review quickly guided the author to new areas. As a part of this research, the plan was to conduct actual air sampling studies. The insight gained from the analysis of the research of others, including type of samples, timing of samples, etc., proved to be invaluable in determining the sampling criteria that was ultimately utilized.

The third procedural step in this research included the use of an internal questionnaire which is included as Appendix B. The questionnaire was used to determine: 1) if there is a potential void or lapse in respiratory protection among the members of the NFD sufficient enough to satisfy the first Research Question, which asked why study the air quality inside of structures after the fire is out, and 2) the cultural "mood" of the NFD with respect to respiratory protection usage or lack thereof. The questionnaire was constructed and hand-delivered to 69 members or 73% of the line personnel at the NFD. Questions 1 and 3 were constructed as strictly demographic, while questions 2 and 4 are more historical in that they ask the respondent to relay their past experiences with respiratory protection and their opinion of the need for same. Questions 5 through 10 are labeled as the "opinion element." Questions 5 and 6 ask respondents to voice their opinion for the future, while questions 7 and 8 are searching for current trends. Finally, Questions 9 and 10 are opinion based but are worded in such a manner so as to extrapolate the true cultural tone of the NFD with respect to respiratory protection.

Demographically, the questionnaire captured a representative sample of the NFD population with respect to the tenure dispersal of the NFD +/- 6% deviation. The largest deviations from the NFD tenure population occurred within the tenure ranges of 1-5 years and 16-20 years with the ranges exhibiting a 6% low response and a 6% high response respectively. The rank/position demographic revealed a representation of ranked individuals with dispersal amongst all ranks of +/- 7% deviation. The greatest deviation from all ranks occurred in the rank of firefighter, which revealed a 7% low response. The goal of this researcher was to maintain a standard deviation of <10% deviation across all rank and tenure ranges, and this goal was satisfactorily met. The exact response data is contained within Appendix C with the corresponding dispersal information. There was a 100% return rate on the questionnaires that were delivered.

The fourth step in the research continuum included a study of the historical nature of respiratory protection and fire department responses, both from the perspective of the fire service in the United States and the perspective of the fire service at NFD. Interviews were conducted, both formally and, informally with the subsequent information adding immeasurably to the overall scope of the topic.

The current state of the fire service with respect to respiratory protection was ascertained, to some degree, in this fourth step as well. Standard operating procedures and standard operating guidelines from various departments were studied. These documents certainly aided this researcher’s understanding of current trends at other area departments. Fire department fire responses were studied, as noted in the literature review. Based on that research, it is apparent that the ratio of structure fires to firefighters in the United States (511,000: 1,140,900) is nearly proportional to the number of structure fires to firefighters at the NFD (53: 120). While the degree of proportionality is not 100%, if the cross product multiplication formula is used to compare the ratios, the resulting yield is only slightly disproportionate. This information is helpful when comparing national trends with local trends. It certainly does not mean that all things are equal between NFD and the rest of the U.S.; instead this data simply shows that NFD firefighters should reasonably expect to enter structures that have burned at roughly the same rate as their counterparts throughout the country.

Further study was done to determine the types of fires that fire departments, both nationally and at NFD, have responded to. The data indicated that 62% of the fires that fire departments are responding to are residential fires. A study of the geographic information system (GIS) for the city of Noblesville revealed that roughly 90% of all structures in the city of Noblesville are residential structures. This data provide justification that statistically, fire departments are responding and working in residential structures more so than any other type of structure. All of this information was extremely helpful when constructing the parameters for the air sampling that is described in the next step.

The fifth step in this process was the identification of the different compounds that are actually present in the air after a residential fire. Galson Laboratories an American Industrial Hygiene Association (AIHA) certified Laboratory was consulted for guidance. Financing was secured through the training budget at the NFD. Galson Laboratories were ultimately retained for air sampling services. In conjunction with a laboratory representative, it was determined that air testing would be conducted for the following broad categories: Polynuclear Aromatic Hydrocarbons (PNAH), Aldehydes, Acids, Volatile Organic Compounds (VOCs), CO, CO2, and HCN.

There are three very distinct criteria sections to this air testing process. The first is related to the specifics of the burnt structure. Criteria for a structure to be considered included the following: a) the structure must have been a wood frame residential structure; b) the structure must have been occupied and contain furnishings, floor and window coverings; c) the structure must have suffered damage significant enough to have rendered at least one room at least 75% fire damaged; d) air currents within the structure must have been controllable.

The second criteria section describes the parameters that are established for the actual field testing. The following criteria apply: a) all work within the structure, destructive or otherwise, must cease while testing is in progress; b) artificial air circulation must cease while testing is in progress; c) every effort must be made to establish a sampling site with low air circulation; d) the sampling site should be established as near to the area of fire involvement as possible; e) in the suppression continuum, the fire should be in the post-overhaul, pre-investigation phase; f) testing will commence for a period lasting no less than 10 minutes; g) the sampling must be started within 4 hours of the fire being extinguished and overhauled; h) records must be kept relating the time that the fire was out, sampling was started and ended; i) a schematic drawing must be made noting the sampling location, fire location, etc.

The third criteria are contained under the broad category of field sampling and are typically dictated by the laboratory receiving the samples. Galson Laboratories provided specific instructions for sample collection. For any sampling that is to be done and for all of the samples described below a complete and thorough set of sampling instructions can and should be obtained from Galson Laboratories or the laboratory conducting the analysis. An overview of the general guidelines used for this research are as follows: a) all air handling pumps were calibrated prior to usage to ensure proper air flow settings; b) the pumps for HCN, acid, PNAH, and aldehydes were located at a height of 5' 10" above the floor; c) the CO, CO2, Relative Humidity, and Temperature monitor, known as an IAQRAE™ was placed in operation 4-6 feet from the floor as soon as the sampling location was determined. As mentioned earlier, the sample collection procedures are largely dictated by the laboratory. For accuracy, the actual procedures used as a part of this research are included for each tested component.

The PNAH profile included testing for the following five compounds: Anthracene, Benzo (a) pyrene, Chrysen, Phenanthrene, and Pyrene. The testing method number is the OSHA 58 method (OSHA, 1986) which utilizes cassettes containing glass fiber filters (GFF), air tubing, and an air pump set at 2.0 liters per minute (lpm). The basic steps in the field include: connecting an Aircheck® 52 pump to 3/8 inch Tygon air tubing that is outfitted with a plastic luer lock adapter and an air flow regulator, checking the air flow rate by attaching an air flow rotameter, and attaching the pump and tubing onto the tripod in preparation for insertion of the testing cassette. The testing cassette was inserted onto the tubing and the pump was started for a minimum of 10 minutes. When the appropriate time had elapsed, the pump was turned off, and the cassette was removed from the tubing. The GFF was removed from the cassette and placed in a glass vial, which was sealed with a cap containing a polytetrafluoroethylene (PTFE) liner. The sample was then refrigerated, kept out of sunlight, and shipped to the laboratory cold within 24 hours of collection.

The aldehyde profile included testing for Benzaldehyde, Veleraldehyde, Propionaldehyde, Butyraldehyde, Crotonaldehyde, Formaldehyde, Isovaleraldehyde, and Acetaldehyde. The testing method used was the NIOSH 2016 method (Schlecht, O'Connor, 2003), which utilizes a sorbent tube containing silica gel, air tubing, and an air pump set at .4 liters per minute (lpm). The basic steps in the field include: connecting an Aircheck® 52 pump to 1/4 inch Tygon air tubing which is outfitted with a plastic luer lock adapter and air flow regulator, checking the air flow rate by attaching an air flow rotameter, and attaching the pump and tubing onto the tripod in preparation for insertion of the testing ampule. The testing ampule ends are broken with a tube breaker and the sorbent tube is inserted onto the tubing and the pump is started for a minimum of 10 minutes. When the appropriate time has elapsed, the pump is turned off, and the sorbent tube is removed from the tubing. The sorbent tube ends are capped and the tube is refrigerated, kept out of sunlight, and shipped to the laboratory cold within 24 hours of collection.

The acid profile included testing for Sulfuric Acid, Phosphoric Acid, Hydrogen Bromide, Hydrochloric Acid, Hydrofluoric Acid, and Nitric Acid. The testing method number is the NIOSH 7903 method (Schlecht, O'Connor, 2003), which utilizes sorbent tubes, air tubing, and an air pump set at .5 liters per minute (lpm). The basic steps in the field are identical to those described for the aldehyde sample collection. The only exception is that refrigeration is not important for the acid sorbent tube.

Hydrogen Cyanide (HCN), because of its unique properties, required testing by itself. The testing method number is the NIOSH 6010 method (Schlecht, O'Connor, 2003), which utilizes sorbent tubes, air tubing, and an air pump set at .2 liters per minute (lpm). The basic steps in the field are identical to those described for the aldehyde sample collection. The only exception is that refrigeration is not important for the HCN sorbent tube.

The VOC profile tested for the 63 most prevalent compounds found in the sample by using a library search of thousands of VOC signatures (see Appendix C for the list of compounds). The testing method number is the OSHA TO15 method (OSHA, 2003). The actual device used to collect an air sample is an evacuated air cylinder (mini can) and a quick grab regulator. The mini can holds 400cc of air and is outfitted with a quick grab regulator, which regulates the flow of air to a constant rate from vacuum pressure. Sampling in the field is accomplished by: a) positioning the sampler and the mini can in the atmosphere to be sampled; b) attaching the quick grab regulator to the mini can; c) allowing the mini can to draw air for the pre-determined time (10 minutes in this case); and d) removing the quick grab regulator. The sample is contained within the mini can and shipped to the laboratory within 24 hours.

CO and CO2 along with incidentals such as relative humidity and temperature were recorded by an IAQRAE™ air sampling monitor. The IAQRAE draws an air sample and analyzes same, every 60 seconds. All of this information is downloaded into a computer for interpretation.

The ability to replicate this step is of very high importance. It is important to replicate the actual criteria described, but not important that there is an exact match of contents burned. The only feasible way to replicate the exact products that burned would be in a laboratory setting, which would allow the researcher to decide what products to burn.

The sixth step in this research consisted of an in-depth study of allowable limits for toxic, corrosive, or asphyxiating substances. PEL and TLV limits were ascertained from a variety of sources. While these values are the measure by which the air sampling results will be judged, it is important to note that this research is more focused on identifying the different substances in the air and less on whether a limit is reached. That is not to say that reaching a limit is acceptable, but reaching the limit is not the determining factor of what should, or should not, be acceptable to breathe.

The seventh step was a study of respiratory protection options available and appropriate for the resulting compounds found in Step Five. The study compared/ contrasted NIOSH, OSHA, and NFPA. Ultimately, all three of these entities have very similar protocol and procedures with respect to respiratory protection.

The limitations with this research were mostly associated with the limited timeframe assigned to the research. All fire departments within Hamilton County, Indiana, and several in surrounding counties were notified of the study. Two factors conspired to create a sample size limitation. First, there was an uncharacteristic lack of fires during the timeframe of this study (August 2007 to January 2008). Four samples were ultimately retrieved. Secondly, the financial impact of each sample set was sufficient to maximize the number of allowable sample sets to five.

Another limitation associated with this research was determining what analytes to test. This proved to be a decision that was not anticipated. Therefore, it stands to reason that certain compounds could have been present, but were not tested due to the constraints of finances and resources. Every effort was made to include the most likely and damaging compounds in this research.

The amount of time that passed from the time that overhaul was completed and the samples were drawn varied from sample set to sample set. This potentially allowed for the air quality to improve through both natural and man-made air currents. This limitation is inter-related to the limitation caused by the lack of fires and the need to travel great distances for fires that met the research criteria.

Air currents within a structure that has burned are almost always present to some degree. This researcher found it difficult, on occasion, to control natural air currents. This may have negatively impacted the results of some sample sets. The limitation would have allowed for the air within the burnt structure to dilute or clear at an accelerated rate, causing the sample result to indicate a low reading.

Finally, there was a limit to the amount of time that a sample could be drawn. Typically, investigators were waiting to conduct an investigation while the samples were being drawn. Every effort was made to allow the incident to progress at a “normal” pace; extending the sample time would have negatively impacted the incident and possibly the responding department. Therefore, some samples could have indicated higher readings if there would have been more time available for air collection. As it was, the 10-minute criteria, as described in the procedures, were the absolute minimum time that samples were drawn.

Results

The purpose of this research was to collect and analyze data on air quality, specifically after a fire, to determine what level of protection is necessary for members operating at a fire incident after SCBA removal. Five research questions guided the research.

The first research question asked why study the air quality inside of structures from the point of SCBA removal to the fire suppression crew's departure from the scene? The literature review indicated that a gap in respiratory protection does exist after the fire is extinguished for at least some portion of the fire service, including NFD. For example, the September 2007 *Fire Engineering* article referenced in the literature review indicated that 21 of 24 departments questioned don't wear an SCBA during overhaul (Coleman et al., 2007). The NFD SOG allows firefighters to remove their SCBA if O2 is above 20%, CO is below 35ppm, and Lower Explosive Levels (LEL's) are below 10%. While these aren't the only criteria, they are the most restrictive and constitute the bulk of the criteria used in the field to determine doffing timeframes. A review of the results of all four sample sets (Appendix F, H, J, and L) indicated a negative correlation between the presence of harmful or toxic compounds and the O2 level, CO level, or the LEL. Further, the current monitoring instruments utilized by NFD are only able to detect O2, CO, and LEL and are unable to detect the toxic compounds that may or may not be present in a burnt structure.

The internal questionnaire (Appendix C) asked in question 8 after a fire, how often do you have discolored nasal discharge or phlegm? The results of this question revealed that 33% of respondents indicated a negative response while 66% indicated a positive response. This indicates that 66% of the members of NFD are inhaling, to some degree, the byproducts of combustion. This result is a glaring indicator that NFD should study the air quality inside of structures that have burned from the point of SCBA removal to the fire suppression crew's departure from the scene. Ultimately, the study of air quality as described will aid in the formation of a risk/ benefit analysis and potentially reduce the likelihood of injury/ illness to firefighters in either the acute or the chronic sense.

The second research question asked what particulate matter or gas is in the air from the point of SCBA removal until fire suppression crews depart the scene? All four sample sets indicated varying degrees of particulate matter and gas. The most significant of which are indicated in Table 2.

Table 2

Sample set significant results

Compound	LOQ ug	ppm range	sample set exhibiting results
Propionaldehyde	.1	.011 to .028	1, 3, 4
Crotonaldehyde	.1	.013	1
Formaldehyde	.04	.0076 to .15	1, 2, 3, 4
Acetaldehyde	.04	.022 to .064	1, 2, 3, 4
Benzaldehyde	.1	.016	3
Butyraldehyde	.1	.013 to .020	3, 4
Compound	**LOQ ppbv**	**ppbv range**	**sample set exhibiting results**
Propylene	5	6 to 8	1, 2, 4
Acetone	5	24 to 64	1, 2, 3, 4
Compound	**LOQ ppbv**	**ppbv range**	**sample set exhibiting results**
Isopropyl Alcohol	5	17	1
Benzene	5	15 to 132	1, 3, 4
Toluene	5	8 to 40	1, 3, 4
Styrene	5	5 to 85	1, 3, 4
Acetaldehyde	5	8.1 to 11	2, 4

Ethanol	5	15 to 27	2, 3
Decane	5	13	2
Undecane	5	7.4	2
Naphthalene	5	7.4	2
Propane	5	15	3
2-Propenoic acid, 2-methyl, methylester	5	16	3
Phenylethyne	5	14	3
Indene	5	25	3
Naphthalene	5	22	3
Tetrahydrofuran	5	11	4

Note: ug-micrograms, LOQ-level of Quantitation, ppbv- parts per billion by volume, ppm-parts per million

The significant results listed in Table 2 indicate the presence of formaldehyde, acetaldehyde, and acetone to some degree at every fire sampled, while benzene, styrene, toluene, propylene, and propionaldehyde were present at 3 of the 4 fires. The detected levels were below the OSHA PEL or ACGIH TLV as applicable, and listed in Appendix E. As Table 2 indicated, a variety of compounds were discovered at some fires, but not necessarily at all fires. Air monitoring of these four sample sets indicated negligible levels of CO, and CO2. A surprising and completely relevant finding to the NFD Respiratory SOG is that extreme caution should be used when considering utilizing CO as the only indicator gas for SCBA removal.

The literature review section of this paper describes three separate but similar studies of air quality. The NIST testing, which was conducted during the suppression phase, revealed high yields of CO, CO2, HCl, and HCN (Gann et al., 2003). The ATF study, which was done during the investigation phase, revealed varying concentrations of HCN, inorganic acids, aldehydes, PNAH's, and VOCs (Kinnes & Hine, 1997). The Phoenix research, which was conducted during the overhaul phase, indicated high yields of acrolein, CO, formaldehyde, glutaraldehyde, benzene, NO2, SO2, and PNAH's (Bolstad et al., 2000).

As described by the ATF study (Gann et al., 2003), the fire scene occurs in three distinct phases: suppression, overhaul, and investigation. This research combines results from all three of these phases as well as the timeframe or gap that exists between overhaul and investigation. In the case of all phases, toxic compounds were present during every timeframe that was tested. These results indicate just how difficult it is to predict all of the potential compounds that can be found in a burnt structure. Therefore, the answer to Research Question Two is impossible to answer exactly but can be answered in the general sense as follows: Any number or combination of harmful/ toxic compounds can be present at every phase of fire and at every fire.

The third research question asked given the particulate matter or gas present, what are the potential health risks to personnel that inhale these products? The health risks, potential or actual, are proving to be very diverse. As described in the literature review, CO is garnering much attention from the IAFF as being a contributing factor to cardiac arrests. Likewise, Michael Lee (2007) indicated a strong possibility that cyanide poisoning is responsible for some portion of the cardiac arrests experienced by firefighters. This research revealed a negative result with respect to CO and HCN. These two compounds are getting national attention from organizations such as the IAFF and IAFC and steps are being taken to attempt to reduce the risks to firefighters from these compounds.

The results of this research indicated that aldehydes were present at every fire sampled. An article in *Burning Issues* (2001), listed some of the health effects of the aldehyde group as toxic, and carcinogenic, and can cause liver lesions, nasal cancer, and growth retardation.

The VOCs that were found at three of the four fires were benzene, toluene, propylene, and styrene. The adverse health characteristics associated with benzene include acute toxicity, mucous membrane irritation, neurological symptoms, and acute myeloid leukemia (*Burning Issues*, 2001). Toluene exposure can cause dizziness, headache, confusion, impaired coordination. Toluene is neurotoxic and causes neurobehavioral changes and liver, kidney, and nose erosion. Chronic toluene exposure causes permanent damage to the brain (2001). Propylene is a Group C carcinogen which classifies it as possibly a human carcinogen (EPA, 2004). Styrene exposure affects the central nervous system. Effects of styrene exposure include subjective complaints of headache, fatigue, dizziness, confusion, drowsiness, malaise, difficulty in concentrating, and a feeling of intoxication. Styrene is classified as a potential human carcinogen (OSHA, 2003, December).

There are roughly 15 other compounds listed in Table 2 that were identified as present in at least one sample set. The majority of these are classified as VOCs and can generally be characterized, from a health effects standpoint, as causing irritation, headaches, loss of coordination, nausea, cancer , damage to liver, kidney and central nervous system, while for other VOCs the health effects and carcinogen values are still unknown (EPA, 2007).

The effects of these products on humans are greatly dependent on the quantity of the compound inhaled and the duration associated with the inhalation event. The health risks described will vary from situation to situation. It was also discovered that some of these compounds will accumulate in the body. Therefore, it is possible that a person could accumulate many of these compounds over several events, creating a reactionary dose much higher than any single original exposure dose. The results in Table 2 also indicate that a single exposure event can result in exposure to multiple compounds at once. The health effects of this phenomenon were unattainable, but it is highly doubtful that the outcome would improve.

The Fourth Research Question asked given the particulate matter or gas present, what level of respiratory protection is most appropriate for the protection of our members? Appendix A lists the recommended respiratory protection based on the APF for a combination gas/vapor and particulate respirator. As the APF number indicated the best protection is afforded the wearer of a pressure-demand self-contained respirator equipped with a full facepiece. The exact degree of protection is directly related to the desired APF of any one entity, therefore ascertaining the appropriate protection in an unknown substance or substances is, to a degree, culturally driven and undeterminable.

The answer to the fourth research question may well rest in two documents. As described in the literature review, OSHA 29CFR1910.134 (d) (1) (iii) "….Where the employer cannot identify or reasonably estimate the employee exposure, the employer shall consider the atmosphere to be IDLH (OSHA, 2007)." NIOSH, as stated in the literature review, recommends that users entering an IDLH atmosphere utilize only an SCBA or supplied air respirator (NIOSH, 2004). This research has proven unequivocally that NFD firefighters are incapable of determining exactly what substances are in the air after a fire and therefore must consider the environment IDLH and wear an SCBA whenever entering that environment.

The Fifth Research Question asked given the appropriate respiratory protection, what would the response be from the members of the NFD to having to wear respiratory protection during times that they historically did not? The internal questionnaire that was circulated and described in the procedures section is contained within this document as Appendix B. The responses, as raw numbers and as percentages, are listed beside the corresponding question in Appendix C.

The results of this questionnaire indicated that the respondents had some prior experience with a variety of different respiratory protection. This allowed their responses to the opinion questions to carry a degree of validity since they do, in fact, have a working knowledge of the different respirators referenced in the questionnaire. Demographically, the questionnaire captured a representative sample of NFD, as described in the procedures section. A total of 69 NFD line personnel responded to this questionnaire.

Question Five allowed for the respondents to pick their personal preference when given a choice of four respiratory protection options. The response indicated that 48% preferred the SCBA over all other choices. The next closest respiratory protection choice was the SCBA mask with canister attachment, which 28% chose.

Question Six asked the opinion of the respondent with respect to what type of respiratory protection is appropriate for overhaul operations. Forty-five percent of respondents favored the SCBA while the next most preferred choice, the half-mask canister respirator, appealed to 22% of respondents. In Question Seven, the respondents indicated that 30% are currently wearing an SCBA during overhaul, while 52% choose to wear no respiratory protection.

Questions Nine and Ten indicated incongruous results. Question Nine asked respondents how they would feel about wearing some type of respiratory protection anytime that they enter a structure that has burned (within the past eight hours). Roughly 80% of the respondents indicated that it would depend on the type of respiratory protection that they would have to wear. When compared to Question Ten that asked the respondents to choose the type of respiratory protection that they would prefer to wear as described in Question Nine, 53% chose "whatever would best protect me," while 20% chose an SCBA. So in one question 80% answered that the decision to wear or not to wear depended on the respiratory protection type, while in the next question, 53% opted for “whatever protects me best.” This information is somewhat confusing and lacks a good logical center.

Ultimately, the indications from the members of the NFD are that the majority picked the SCBA as their first choice for respiratory protection, including during overhaul. The majority want to wear the respiratory protection that best protects their respiratory system. The majority indicated a concern about the type of respiratory protection that may be required. These indicators reveal that, overall, the NFD would display a positive response to having to wear respiratory protection during times that they historically did not.

This research indicates several noteworthy findings that apply directly to the NFD and the respiratory protection SOG currently being used. The air monitors that are currently in use at NFD to determine CO, O2, and LEL levels are not capable of identifying all of the other toxic compounds that may be in the air, thus allowing an incident commander or safety officer to allow removal of SCBA’s and expose our members to unknown compounds. There is not a correlation between CO levels and toxic compound levels. This indicates that a gap in respiratory protection does exist at NFD. Further proof of exposure is indicated by the 66% positive response to discolored nasal discharge or phlegm, as indicated by the questionnaire. Toxic compounds were discovered at every fire that was sampled as a part of this research as well as in all three research studies (NIST, ATF, Phoenix) that were cited during this research. Many of the toxic compounds that were studied cause the exposed to exhibit confusion, headaches, and dizziness. These signs can be mistaken for normal fatigue or exertion, which could add to the lack of detection. The research indicates that there can be a cumulative effect of these compounds, which could result in higher retained levels than any single original exposure level.

There were two findings that were unanticipated. The first was the negative correlation between CO levels and toxic compound levels. This dramatically impacts the current practice of using CO as the SCBA removal catalyst. Secondly, it was surprising to find that 66% of the NFD respondents exhibited signs of potential exposure. The anticipation was that there would be some degree of this because of the nature of the SOG, but it was surprising to find that the number was so high.

The conclusions of this research clearly indicate that: a) there are toxic compounds in the air for extended periods of time after extinguishment; b) the health risks associated with exposure to these toxic compounds could be significant; and c) an SCBA is the only appropriate respiratory protection for the post fire incident scene.

Discussion

This research indicated results that were consistent with similar research conducted by other entities. There was limited, if any, prior research that exactly matched this study, but there were three studies that were similar and aided this researcher immensely. The findings of other researchers indicated patterns that were similar to this research.

The NIST study, conducted during the suppression phase, revealed high levels of CO, CO2, HCl and HCN, but did not reveal any substantial VOC or aldehyde compounds (Gann et al., 2003). The Phoenix study, conducted during overhaul, revealed high levels of CO, aldehydes, VOCs, PNAH, and acids (Bolstad et al., 2000). This study, conducted between the overhaul phase and the investigation phase, revealed levels of aldehydes, and VOCs. Finally the ATF study, conducted during the investigation phase, revealed high levels of HCN, acids aldehydes, PNAH, and VOCs (Kinnes & Hine, 1997).

All of the prior studies when compared to the present study yielded very similar results. The one noted difference between the prior studies and this current study rests in the activity level within the structure. The three prior studies had no work level restrictions and allowed normal fire ground functions to continue, whereas this study restricted the activity level within the structure. The implications of this are that the various toxic compounds are ever present, but some compounds may require a degree of agitation to become airborne and ultimately detectable by researchers.

This researcher has interpreted the results of this study and found that the original concern "…the potential for our members to be exposed to harmful airborne products," is valid. The NFD should be concerned about the findings of this study. Any number of toxic compounds is present, in every timeframe tested, in a burnt structure. The current NFD practice of removing SCBA's based on acceptable CO, O2 and LEL levels is not an indicator of a safe environment and should be discontinued. The members of the NFD, while not currently exhibiting an increased cancer rate, are prone to same based on statistics of other researchers. While a clear linkage was not drawn and may never be drawn between the increased cancer rates among firefighters and the exposure to toxic compounds, the prudent leader should anticipate this linkage and take all steps to reduce the risk.

The fire service, along with supporting agencies such as: OSHA, NIOSH, and NFPA, is working diligently to provide firefighters with the best protective equipment possible, the cost is that there is an added physical burden placed on the wearer of an SCBA. The results of this study indicate that wearing this equipment at all times is prudent. The NFD currently utilizes an SCBA during suppression activities, but neglects to do so, by policy, during the remaining phases of the fire scene. In terms of the fire scene continuum it is apparent that the majority of loss stoppage occurs during the suppression phase. This allows the fire scene to proceed at a more controlled pace through the remaining phases of the incident. Perhaps by conducting deliberate rehabilitation of our firefighters, properly rotating our personnel, and slowing the pace of the scene, the added burden of SCBA usage can be decreased sufficiently.

The cultural element of change is often the most difficult to manage. This research indicates that the members of the NFD are actually prepared for an upgraded respiratory SOG, which would require more SCBA usage. The results of the internal questionnaire indicate that the majority of the respondents are either a) increasing SCBA usage on their own, or b) are anticipating the need to increase SCBA usage. This is an indication of a health and safety conscious workforce and is extremely beneficial.

The implications of this study for the members of the NFD are not easily measured but could be very significant. Cancer and other malignant ailments are often difficult to trace to their origin. All indications from this research consistently suggest that breathing toxic compounds will increase an individual's risk of cancer. The current cancer rate of NFD retirees is relatively small. By simply increasing the number of employees and the number of fires and nothing else, it is projected that there would be an increased rate of cancer and other ailments that could be associated with a lack of respiratory protection. Proactively restricting the amount of time that NFD members are allowed to operate at structure fires without SCBA's should significantly reduce the projected health risk to the members of the NFD in both the acute and chronic sense.

Organizationally, the fire service led by the IAFC, USFA, the IAFF and others have diligently worked to identify and steer the fire service clear of pitfalls that act as impediments to forward progress in regards to safety. The IAFF is now mounting a strong campaign aimed at reducing the acute problem of CO poisoning of firefighters. This research indicates that the respiratory protection problem is not limited to CO poisoning. This researcher would suggest that coupling the CO poisoning efforts of the IAFF with the results of this research could, in fact, save just as many lives in the chronic sense as the IAFF CO initiative will in the acute sense.

Recommendations

The problem that this research addressed was that the NFD does not know what particulate matter or gases are inspired by our members after the order to remove air packs is given. The purpose was to collect and analyze data on air quality, specifically after a fire, to determine what level of protection is necessary for members operating at a fire incident after SCBA removal. Through this research a course of action can now be enacted.

This research revealed that the members of the NFD, operating in the current fashion, are being exposed to potentially harmful compounds. Therefore, it is recommended that the NFD stop allowing members to conduct overhaul and post-fire functions in and around burnt structures without the respiratory benefit of an SCBA. Technically, this can easily be accomplished by adjusting the SOG to reflect these changes.

The implications of this study should be communicated to other stake holders. Including, but not limited to Indiana Department of Homeland Security, USFA, IAFF, IAFC, IAFF Local 4416, and others that may benefit from the knowledge of these results and the increased potential for harm to firefighters that would result from not dispersing this information could be substantial. Therefore, it is recommended that a means of communication be established and implemented to carry the message of this research forward.

The cultural atmosphere at NFD must be considered, although the research indicates that the cultural tone, at this time, is open to the idea of increasing the level of respiratory protection required of the NFD members. Open-format training should be conducted to reveal the research results and allow for feedback and interaction among the NFD membership.

The research indicated that firefighters are at an increased risk for certain cancer types. Typically, cancer is a chronic or long-term ailment, in that cancer usually develops over time and not immediately following a fire. It is proposed that studying the long-term health trends of NFD members both active and retired along with the long-term health trends of the global fire community should assist researchers to identify areas needing further research and modification, if necessary.

The purpose of this research has been met, but a related recommendation has surfaced. It is recommended that research be conducted on a much larger scale to determine why firefighters are experiencing an increased rate of cancer. Cancer is an unacceptable and unjust end to one of the noblest of careers, especially if the cause of the cancer rests within the career. It is the hope of this researcher that a more focused research effort be placed on the topic of chronic health issues as they pertain to firefighters.

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Appendix A

NIOSH Respiratory Protection Selection by APF and type

Combination Gas/Vapor and Particulate Respirators

Assigned protection factor (APF)	Type of Respirator
10	-Any air-purifying half-mask respirator equipped with appropriate gas/vapor cartridges[2] in combination with appropriate type of particulate filter. -Any full facepiece respirator with appropriate gas/vapor cartridges in combination with appropriate type of particulate filter. -Any negative pressure (demand) supplied-air respirator equipped with a half-mask.
25	-Any powered air-purifying respirator with a loose-fitting hood or helmet that is equipped with an appropriate gas/vapor cartridge in combination with a high-efficiency particulate filter. -Any continuous flow supplied-air respirator equipped with a hood or helmet.

50	-Any air-purifying full facepiece respirator equipped with appropriate gas/vapor cartridges in combination with an N-100, R-100 or P-100 filter or an appropriate canister incorporating an N-100, P-100 or R-100 filter. -Any powered air-purifying respirator with a tight-fitting facepiece (half or full facepiece) equipped with appropriate gas/vapor cartridges in combination with a high-efficiency filter or an appropriate canister incorporating a high-efficiency filter. -Any negative pressure (demand) supplied-air respirator equipped with a full facepiece. -Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece). -Any negative pressure (demand) self-contained respirator equipped with a full facepiece.
1,000	-Any pressure-demand supplied-air respirator equipped with a half-mask.
2,000	-Any pressure-demand supplied-air respirator equipped with a full facepiece.
10,000	-Any pressure-demand self-contained respirator equipped with a full facepiece. -Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus.

(NIOSH, October, 2004, pp 6-7)

Appendix B

Respiratory Protection Questionnaire

	Noblesville Fire Dept. 135 South 9th Street Noblesville, IN 46060	**Respiratory Protection Questionnaire**

Please take a moment to help me gauge your feelings about the Respiratory Protection Program at the Noblesville Fire Department for a research project I am conducting.

Demographic

1. How long have you worked at NFD? ☐ 1-5 Years ☐ 6-10 Years ☐ 11-15 Years ☐ 16-20 Years ☐ Over 20 Years	2. On average, how often do you think that you enter a smoke filled environment in a year? ☐ Never ☐ 1-5 Times per year ☐ 6-15 Times per year ☐ 16-25 Times per year ☐ Over 25 Times per year
3. What is your current rank/position? ☐ Firefighter ☐ Engineer ☐ Lieutenant ☐ Captain ☐ Administrator	4. What types of respiratory protection have you used in the past? (Check all that apply) ☐ N95 Particulate Respirator ☐ Half-mask Canister Respirator ☐ SCBA mask with Canister Attachment

Opinion Element

5. If you have to wear respiratory protection, which type is your preferred appliance? (Place in order from 1 to 4 based on your preference.) ☐ N95 Particulate Respirator ☐ Half-mask Canister Respirator ☐ SCBA mask with Canister Attachment ☐ SCBA mask with Bottle	6. What type of respiratory protection, in your opinion, is appropriate for overhaul operations? ☐ N95 Particulate Respirator ☐ Half-mask Canister Respirator ☐ SCBA mask with Canister Attachment ☐ SCBA mask with Bottle

7. Policy does not mandate respiratory protection for the period after overhaul. Do you wear respiratory protection anyway? If so, what type of respiratory protection do you typically wear?	8. After a fire, how often do you have discolored nasal discharge or phlegm?
☐ N95 Particulate Respirator ☐ Half-mask Canister Respirator ☐ SCBA mask with Canister Attachment ☐ SCBA mask with Bottle ☐ I don't wear any respiratory protection	☐ Never ☐ Occasionally (25%) ☐ Some of the time (50%) ☐ Most of the time (75%) ☐ Always (100%)

9. Given current documented research about the potential residual gases, vapors, etc. that follow the burning of plastics and other man-made home furnishings, how would you feel about wearing some type of respiratory protection anytime that you enter a structure that has had a fire (within 8 hours of entry)?	10. If you did have to wear respiratory protection as described in question 9, what would be your preferred choice? (Place in order from 1 to 5 based on your preference.)
☐ I already do ☐ It would depend on the type of respiratory protection that I would have to wear. ☐ It would be too restrictive; I would not support this type of policy.	☐ N95 Particulate Respirator ☐ Half-mask Canister Respirator ☐ SCBA mask with Canister Attachment ☐ SCBA mask with Bottle ☐ Whatever would best protect my respiratory system against the given gas or vapor.

Additional Comments

____

Thank you for your participation!

Appendix C

Respiratory Protection Questionnaire Response Data

	Noblesville Fire Dept. 135 South 9th Street Noblesville, IN 46060	**Respiratory Protection Questionnaire**

Please take a moment to help me gauge your feelings about the Respiratory Protection Program at the Noblesville Fire Department for a research project I am conducting.

Demographic

1. How long have you worked at NFD?

Response			Current Demographic	
29 (42%)	☐	1-5 Years	47	48%
14 (20%)	☐	6-10 Years	22	22%
10 (14%)	☐	11-15 Years	14	14%
11 (16%)	☐	16-20 Years	10	10%
5 (7%)	☐	Over 20 Years	6	6%

2. On average, how often do you think that you enter a smoke filled environment in a year?

Response		
0	☐	Never
49 (71%)	☐	1-5 Times per year
19 (28%)	☐	6-15 Times per year
0	☐	16-25 Times per year
1	☐	Over 25 Times per year

3. What is your current rank/position?

Response			Current Demographic	
34 (49%)	☐	Firefighter	54	56%
17 (24%)	☐	Engineer	20	21%
9 (13%)	☐	Lieutenant	13	13%
7 (10%)	☐	Captain	8	8%
2 (3%)	☐	Administrator		

4. What types of respiratory protection have you used in the past? (Check all that apply)

Response		
27	☐	N95 Particulate Respirator
18	☐	Half-Mask Canister Respirator
41	☐	SCBA mask with Canister Attachment

Opinion Element

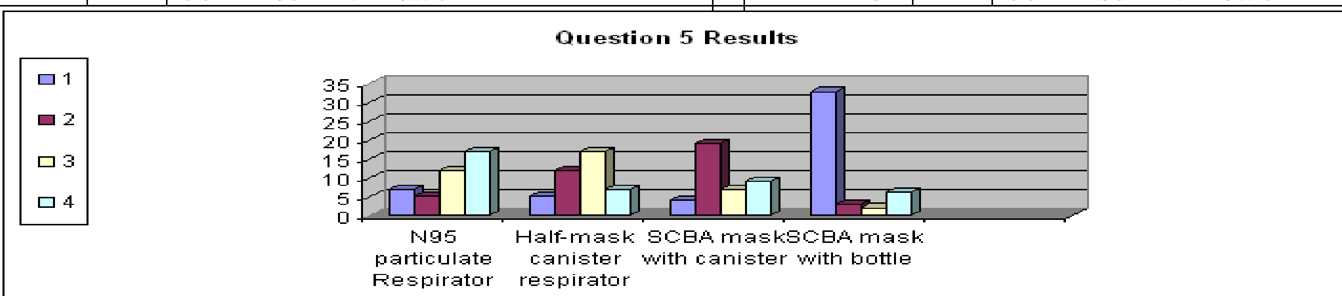
5. If you have to wear respiratory protection, which type is your preferred appliance? (Place in order from 1 to 4 based on your preference.)

See Results Below

	☐	N95 Particulate Respirator
	☐	Half-Mask Canister Respirator
	☐	SCBA mask with Canister Attachment
	☐	SCBA mask with Bottle

6. What type of respiratory protection, in your opinion, is appropriate for overhaul operations?

Response		
10	☐	N95 Particulate Respirator
15	☐	Half-Mask Canister Respirator
13	☐	SCBA mask with Canister Attachment
31	☐	SCBA mask with Bottle



7. Policy does not mandate respiratory protection for the period after overhaul. Do you wear respiratory protection anyway? If so, what type of respiratory protection do you typically wear?

Response		
7	☐	N95 Particulate Respirator
1	☐	Half-Mask Canister Respirator
3	☐	SCBA mask with Canister Attachment
21	☐	SCBA mask with Bottle
36	☐	I don't wear any respiratory protection

8. After a fire, how often do you have discolored nasal discharge or phlegm?

Response		
23 (33%)	☐	Never
29 (42%)	☐	Occasionally (25%)
7 (10%)	☐	Some of the time (50%)
5 (7%)	☐	Most of the time (75%)
5 (7%)	☐	Always (100%)

9. Given current documented research about the potential residual gases, vapors, etc. that follow the burning of plastics and other man-made home furnishings, how would you feel about wearing some type of respiratory protection anytime that you enter a structure that has had a fire (within 8 hours of entry)?			10. If you did have to wear respiratory protection as described in question 9, what would be your preferred choice? (Place in order from 1 to 5 based on your preference.)		
Response			Response		
10	☐	I already do	14 (5th)	☐	N95 Particulate Respirator
55	☐	It would depend on the type of respiratory protection that I would have to wear.	15 (4th)	☐	Half-Mask Canister Respirator
5	☐	It would be too restrictive; I would not support this type of policy.	13 (3rd)	☐	SCBA mask with Canister Attachment
			14 (2nd)	☐	SCBA mask with Bottle
			37 (1st)	☐	I don't wear any respiratory protection

Additional Comments

About You (optional)

Name		E-mail	
Address		Phone	
City, State, ZIP Code			

May we add you to our mailing list, which offers news and exciting promotions? ☐ Yes ☐ No

Thank you for your participation!

Appendix D

Volatile Organic Compound -63 compound profile

Compound List

Propylene
Chloromethane
Vinyl Chloride
Bromomethane
Vinyl Bromide
Isopropyl Alcohol
1, 1- Dichloroethene
Freon-113
Carbon Disulfide
Methyl Tert-Butyl Ether
Hexane
Chloroform
1, 2-Dichloroethane
Cyclohexane
Benzene
2, 2, 4-Trimethypentane
1, 2-Dichloropropane
Bromodichloromethane
trans-1, 3-Dichloropropene
Toluene
Methyl Isobutyl Ketone
1, 2-Dibromoethane
Chlorobenzene
Bromoform
Styrene
1, 1, 2, 2-Tetrachloroethane
1, 3, 5-Trimethylbenzene
1, 3-Dichlorobenzene
1, 4-Dichlorobenzene
Hexachloro-1, 3-Butadiene
Freon-12
Freon-114
1, 3-Butadiene
Chloroethane
Freon-11
Acetone
Methylene Chloride
Allyl Chloride
Trans-1, 2-Dichloroethene
cis-1, 2-Dichloroethylene
Ethyl Acetate
Tetrahydrofuran
1, 1, 1-Trichloroethane
Carbon Tetrachloride
1, 4-Dioxane
Heptane
Trichloroethylene
cis-1, 3-Dichloropropene
1, 1, 2-Trichloroethane
Dibromochloromethane
Methyl Butyl Ketone
Tetrachloroethylene
Ethylbenzene
m & p-xylene
o-xylene
4-Ethyltoluene
1, 2, 4-Trimethylbenzene
Benzyl Chloride
1, 2, 4-Trichlorobenzene

Appendix E

Volatile Organic Compound Profile PEL and TLV

63 VOC Profile

Analyte	**OSHA PEL (ppm)**	**ACGIH TLV (ppm)**	**Analyte**	**OSHA PEL (ppm)**	**ACGIH TLV (ppm)**
Acetone	1000		Ethylbenzene	100	
Allyl Chloride	1		4-Ethyltoluene	-	-
Benzene	1		Freon 11	1000	
Benzyl Chloride	1		Freon 12	1000	
Bromodichloromethane	-	-	Freon 113	1000	
Bromoform	0.5		Freon 114	1000	
Bromomethane	20 (ceiling)	1	Heptane	500	
1,3-Butadiene	1		Hexane	500	
Hexachloro-1,3-Butadiene	-	-	Isopropyl Alcohol	400	
Carbon Disulfide	20		Methyl Butyl Ketone	100	
Carbon Tetrachloride	10		Methylene Chloride	25	
Chlorobenzene	75		Methyl Ethyl Ketone	200	
Chloroethane	1000		Methyl Isobutyl Ketone	100	
Chloroform	50 (ceiling)	10	Methyl tert-Butyl Ether	-	50
Chloromethane	100		Propylene	-	500
Cyclohexane	300		Styrene	100	
Dibromochloromethane	-	-	1,1,2,2-Tetrachloroethane	5	
1,2-Dibromomethane	20		Tetrahydrofuran	200	
1,2-Dichlorobenzene	50 (ceiling)	25	Tetrachloroethylene	100	
1,3-Dichlorobenzene	-	-	Toluene	200	
1,4-Dichlorobenzene	75		1,2,4-Trichlorobenzene	-	5 (ceiling)
1,1-Dichloroethane	100		1,1,1-Trichloroethane	350	
1,2-Dichloroethane	200		1,1,2-Trichloroethane	10	
1,1-Dichloroethene	-	5	Trichloroethylene	100	
trans-1,2-Dichloroethene	200		1,2,4-Trimethylbenzene	-	25
cis-1,2-Dichloroethylene	200		1,3,5-Trimethylbenzene	-	25
1,2-Dichloropropane	75		2,2,4-Trimethylpentane	-	-
cis-1,3-Dichloropropene	-	1	Vinyl Acetate	-	10
trans-1,3-Dichloropropene	-	1	Vinyl Bromide	-	0.5

Analyte	OSHA PEL (ppm)	ACGIH TLV (ppm)	Analyte	OSHA PEL (ppm)	ACGIH TLV (ppm)
1,4-Dioxane	100		Vinyl Chloride	1	
Ethyl Acetate	400		m,p-Xylene	100	
			o-Xylene	100	

Appendix F

Air Monitoring sample set 1 results

Hydrogen Cyanide- Analyzed 12-3-2007, Method- NIOSH 6010 on 226-28 Media

Sample ID	Air Vol. liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
1A HCN	3	<2.6	<2.6	<2.6	<0.87	<0.78

Acids- Analyzed 11-30-2007, Method- NIOSH 7903 on 226-10-03 Media
-Air Volume- 6 liters

Sample ID	LOQ ug	Front ug	Back ug	Total ug	Conc mg/m3	ppm
1B						
Hydrogen Bromide	1	<1	<1	<1	<0.17	<0.050
Hydrochloric Acid	5	<5	<5	<5	<0.83	<0.56
Phosphoric Acid	3	<3	<3	<3	<0.5	<0.39
Hydrofluoric Acid	6	<6	<6	<6	<1.0	<1.2
Sulfuric Acid	1	<1	<1	<1	<0.2	<0.042
Nitric Acid	5	<5	<5	<5	<0.83	<0.32

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Polynuclear Aromatic Hydrocarbon- Analyzed 12-3-2007, Method OSHA 58
-Sampled on 225-7 GFF Media, Air Volume- 28 liters

Sample ID	LOQ ug	Total ug	Conc mg/m3	ppm
1C				
Anthracene	0.3	<0.3	<0.01	<0.0015
Pyrene	0.3	<0.3	<0.01	<0.0013
Chrysene	0.3	<0.3	<0.01	<0.0011
Benzo (a) pyrene	0.3	<0.3	<0.01	<0.0010
Phenanthrene	0.3	<0.3	<0.01	<0.0015

Aldehyde- Analyzed 12-3-2007, Method NIOSH 2016 on 226-119 Media
-Air Volume- 4 liters

Sample ID	LOQ ug	Front ug	Back ug	Total ug	Conc mg/m3	ppm
1D						
Benzaldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.006
Valeraldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.007
Propionaldehyde	0.1	0.27	<0.1	0.27	0.067	0.028
Butyraldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.008
Crotonaldehyde	0.1	0.15	<0.1	0.15	0.037	0.013
Formaldehyde	0.04	0.076	<0.04	0.076	0.019	0.015
Isovaleraldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.007
Acetaldehyde	0.04	0.28	<0.04	0.28	0.070	0.039

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Volatile Organic Compounds- Analyzed 11-27-2007, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
1E					
Propolyne	5	6	Freon-12	5	<5
Chloromethane	5	<5	Freon-114	5	<5
Vinyl Chloride	5	<5	1, 3-Butadiene	5	<5
Bromomethane	5	<5	Chloroethane	5	<5
Vinyl Bromide	5	<5	Freon-11	5	<5
Isopropyl Alcohol	5	<5	Acetone	5	27
1, 1- Dichloroethene	5	<5	Methylene Chloride	5	<5
Freon-113	5	<5	Allyl Chloride	5	<5
Carbon Disulfide	5	<5	Trans-1, 2-Dichloroethene	5	<5
Methyl Tert-Butyl Ether	5	<5	cis-1, 2-Dichloroethylene	5	<5
Hexane	5	<5	Ethyl Acetate	5	<5
Chloroform	5	<5	Tetrahydrofuran	5	<5
1, 2-Dichloroethane	5	<5	1, 1, 1-Trichloroethane	5	<5
Cyclohexane	5	<5	Carbon Tetrachloride	5	<5
Benzene	5	<5	1, 4-Dioxane	20	<20

<-less than mg- Milligrams m3- Cubic Meters kg-Kilograms
>-greater than ug- Micrograms l- liters NS- Not Specified
NA- not applicable ND- Not detected LOQ- Limit of Quantitation
ppbv-Parts per Billion Volume

Volatile Organic Compounds- Analyzed 11-27-2007, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
1E					
2, 2, 4-Trimethypentane	5	<5	Heptane	5	<5
1, 2-Dichloropropane	5	<5	Trichloroethylene	5	<5
Bromodichloromethane	5	<5	cis-1, 3-Dichloropropene	5	<5
trans-1, 3-Dichloropropene	5	<5	1, 1, 2-Trichloroethane	5	<5
Toluene	5	<5	Dibromochloromethane	5	<5
Methyl Isobutyl Ketone	20	<20	Methyl Butyl Ketone	20	<20
1, 2-Dibromoethane	5	<5	Tetrachloroethylene	5	<5
Chlorobenzene	5	<5	Ethylbenzene	5	<5
Bromoform	5	<5	m & p-xylene	10	<10
Styrene	5	<5	o-xylene	5	<5
1, 1, 2, 2-Tetrachloroethane	5	<5	4-Ethyltoluene	5	<5
1, 3, 5-Trimethylbenzene	5	<5	1, 2, 4-Trimethylbenzene	5	<5
1, 3-Dichlorobenzene	5	<5	Benzyl Chloride	5	<5
1, 4-Dichlorobenzene	5	<5	1, 2, 4-Trichlorobenzene	5	<5
Hexachloro-1, 3-Butadiene	5	<5			

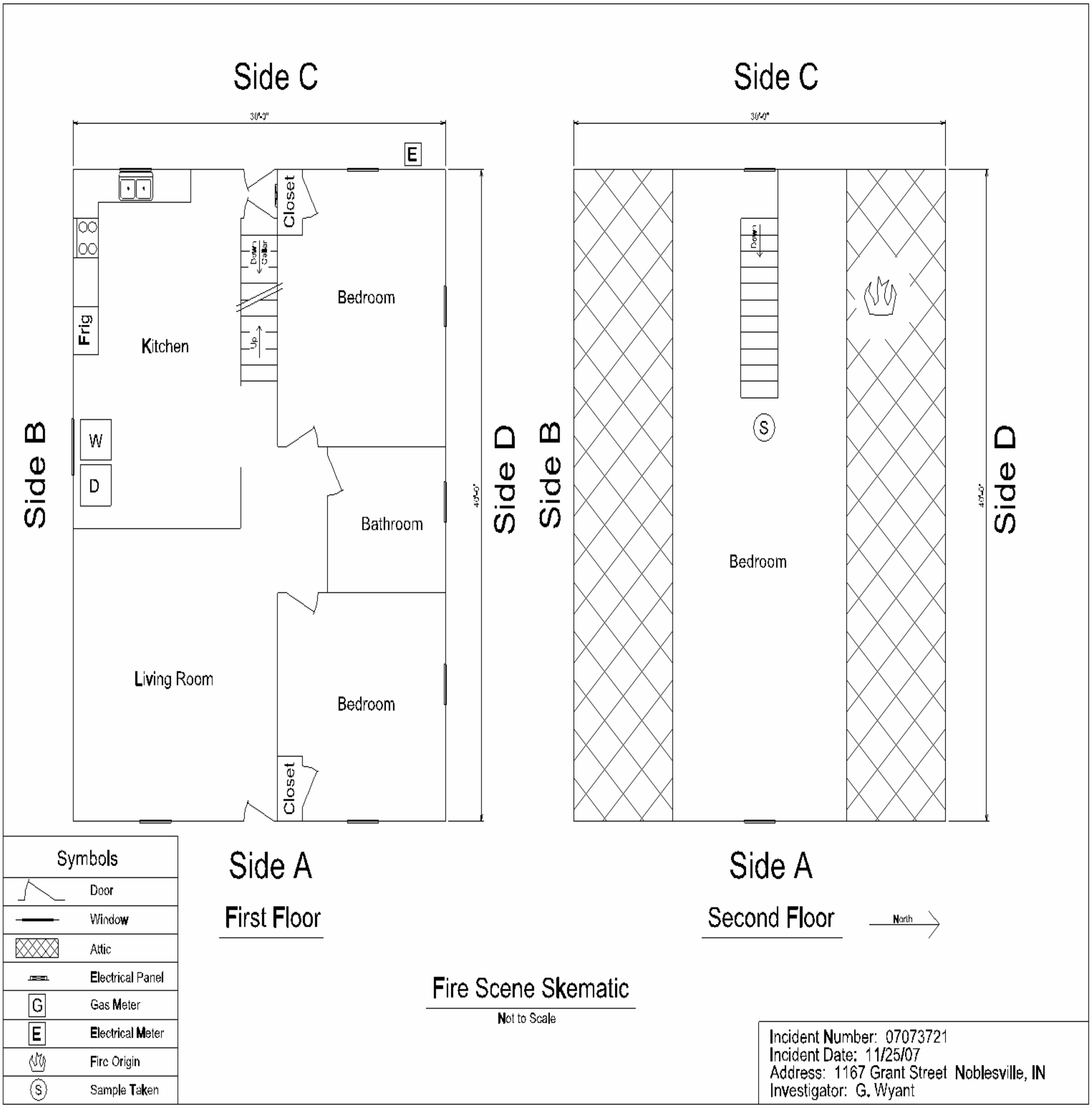
<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	LOQ- Limit of Quantitation	
ppbv- Parts per Billion Volume			

IAQRAE- Analyzed 11-25-2007, Sampled at 60 second intervals for 18 minutes

Sample ID	Peak ppm_	Peak percent	Peak degrees fahrenheit
Carbon Monoxide	2.1		
Carbon Dioxide	389		
Relative Humidity		83%	
Temperature			55.6 degrees

Appendix G

Sample Set 1- Schematic



Appendix H

Air monitoring sample set 2 results

Hydrogen Cyanide- Analyzed 12-31-2007, Method- NIOSH 6010 on 226-28 Media

Sample ID	Air Vol. liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
2A HCN	2.4	<2.6	<2.6	<2.6	<1.1	<0.98

Acids- Analyzed 12-31-2007, Method- NIOSH 7903 on 226-10-03 Media
-Air Volume- 5.5 liters

Sample ID	Air Vol liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
2B						
Hydrogen Bromide	5.5	<10	<10	<10	<1.8	<0.55
Hydrochloric Acid	5.5	<10	<10	<10	<1.8	<1.2
Phosphoric Acid	5.5	<10	<10	<10	<2	
Hydrofluoric Acid	5.5	<10	<10	<10	<1.8	<2.2
Sulfuric Acid	5.5	<10	<10	<10	<2	
Nitric Acid	5.5	<10	<10	<10	<1.8	<0.71

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Polynuclear Aromatic Hydrocarbon- Analyzed 12-27-2007, Method OSHA 58
-Sampled on 225-7 GFF Media, Air Volume- 30 liters

Sample ID 2C	LOQ ug	Total ug	Conc mg/m3	ppm
Anthracene	0.3	<0.3	<0.01	<0.0014
Pyrene	0.3	<0.3	<0.01	<0.0012
Chrysene	0.3	<0.3	<0.01	<0.0011
Benzo (a) pyrene	0.3	<0.3	<0.01	<0.00097
Phenanthrene	0.3	<0.3	<0.01	<0.0014

Aldehyde- Analyzed 12-27-2007, Method NIOSH 2016 on 226-119 Media
-Air Volume- 5.2 liters

Sample ID 2D	LOQ ug	Front ug	Back ug	Total ug	Conc mg/m3	ppm
Benzaldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.004
Valeraldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.005
Propionaldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.008
Butyraldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.007
Crotonaldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.007
Formaldehyde	0.04	0.049	<0.04	0.049	0.0093	0.0076
Isovaleraldehyde	0.1	<0.1	<0.1	<0.1	<0.019	<0.005
Acetaldehyde	0.04	0.21	<0.04	0.21	0.040	0.022

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Volatile Organic Compounds- Analyzed 12-27-2007, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
2E					
Propolyne	5	8	Freon-12	5	<5
Chloromethane	5	<5	Freon-114	5	<5
Vinyl Chloride	5	<5	1, 3-Butadiene	5	<5
Bromomethane	5	<5	Chloroethane	5	<5
Vinyl Bromide	5	<5	Freon-11	5	<5
Isopropyl Alcohol	5	17	Acetone	5	38
1, 1- Dichloroethene	5	<5	Methylene Chloride	5	<5
Freon-113	5	<5	Allyl Chloride	5	<5
Carbon Disulfide	5	<5	Trans-1, 2-Dichloroethene	5	<5
Methyl Tert-Butyl Ether	5	<5	cis-1, 2-Dichloroethylene	5	<5
Hexane	5	<5	Ethyl Acetate	5	<5
Chloroform	5	<5	Tetrahydrofuran	5	<5
1, 2-Dichloroethane	5	<5	1, 1, 1-Trichloroethane	5	<5
Cyclohexane	5	<5	Carbon Tetrachloride	5	<5
Benzene	5	15	1, 4-Dioxane	20	<20

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	LOQ- Limit of Quantitation	
ppbv-Parts per Billion Volume			

Volatile Organic Compounds- Analyzed 12-27-2007, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
2E					
2, 2, 4-Trimethypentane	5	<5	Heptane	5	<5
1, 2-Dichloropropane	5	<5	Trichloroethylene	5	<5
Bromodichloromethane	5	<5	cis-1, 3-Dichloropropene	5	<5
trans-1, 3-Dichloropropene	5	<5	1, 1, 2-Trichloroethane	5	<5
Toluene	5	25	Dibromochloromethane	5	<5
Methyl Isobutyl Ketone	20	<20	Methyl Butyl Ketone	20	<20
1, 2-Dibromoethane	5	<5	Tetrachloroethylene	5	<5
Chlorobenzene	5	<5	Ethylbenzene	5	<5
Bromoform	5	<5	m & p-xylene	10	<10
Styrene	5	5	o-xylene	5	<5
1, 1, 2, 2-Tetrachloroethane	5	<5	4-Ethyltoluene	5	<5
1, 3, 5-Trimethylbenzene	5	<5	1, 2, 4-Trimethylbenzene	5	<5
1, 3-Dichlorobenzene	5	<5	Benzyl Chloride	5	<5
1, 4-Dichlorobenzene	5	<5	1, 2, 4-Trichlorobenzene	5	<5
Hexachloro-1, 3-Butadiene	5	<5			

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	LOQ- Limit of Quantitation	
ppbv- Parts per Billion Volume			

Volatile Organic Compounds- Analyzed 12-27-2007, Method OSHA TO15-Mini Can -Air Volume- 400cc, Library search results

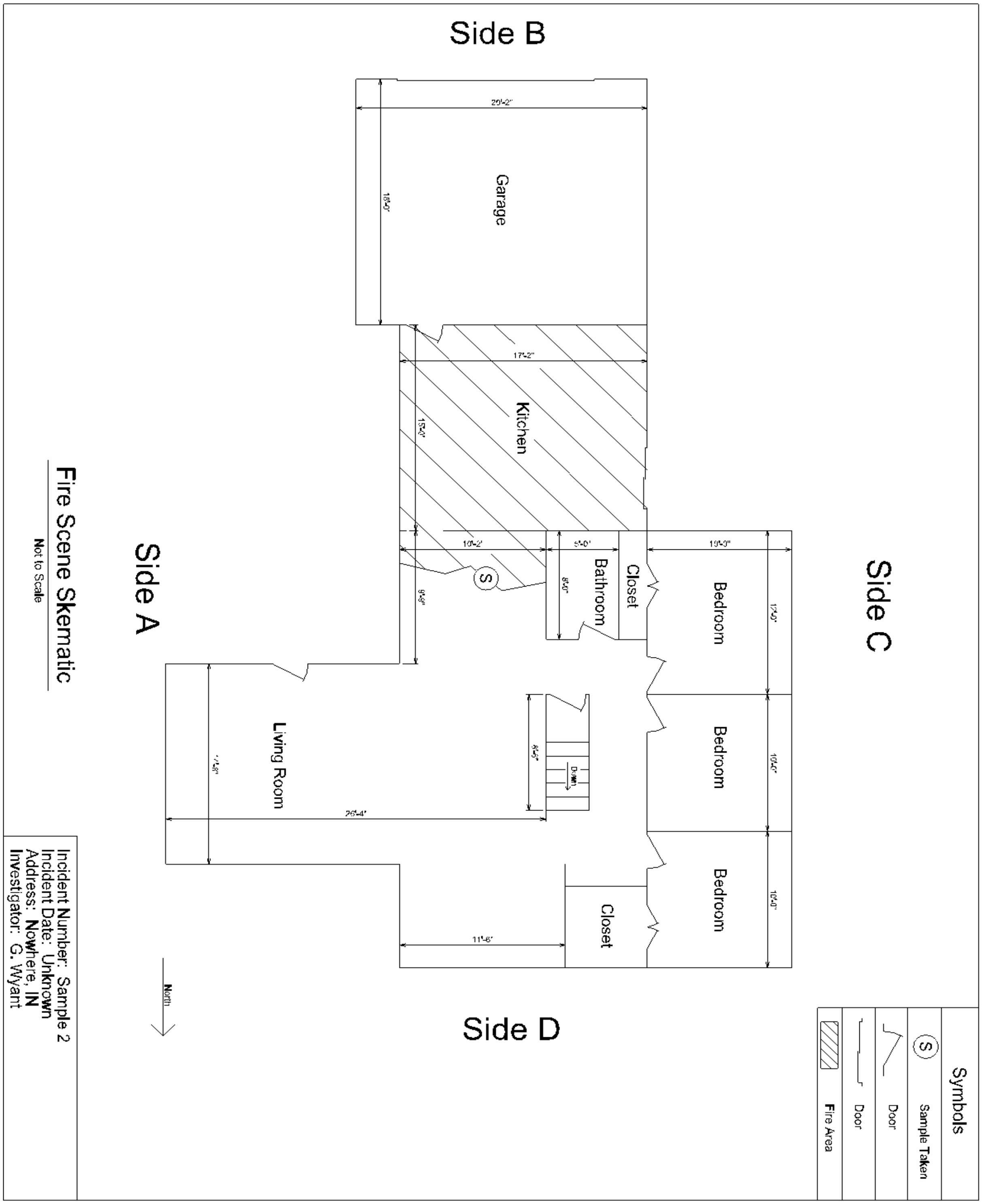
Tentatively Identified Compounds	Estimated Concentration ppbv
Acetaldehyde	11
Ethanol	27
Decane	13
Undecane	7.4
Naphthalene	7.4

IAQRAE- Analyzed 12-21-2007, Sampled at 60 second intervals for 20 minutes

Sample ID	Peak ppm_	Peak percent	Peak degrees fahrenheit
Carbon Monoxide	0.0		
Carbon Dioxide	342		
Relative Humidity		68%	
Temperature			54.7 degrees

Appendix I

Sample Set 2- Schematic



Appendix J

Air Monitoring Sample Set 3 Results

Hydrogen Cyanide- Analyzed 12-31-2007, Method- NIOSH 6010 on 226-28 Media

Sample ID	Air Vol. liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
3A HCN	2	<2.6	<2.6	<2.6	<1.3	<1.2

Acids- Analyzed 12-31-2007, Method- NIOSH 7903 on 226-10-03 Media
-Air Volume- 5 liters

Sample ID	Air Vol liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
3B						
Hydrogen Bromide	5	<10	<10	<10	<2.0	<0.60
Hydrochloric Acid	5	<10	<10	<10	<2.0	<1.3
Phosphoric Acid	5	<10	<10	<10	<2	
Hydrofluoric Acid	5	<10	<10	<10	<2.0	<2.4
Sulfuric Acid	5	<10	<10	<10	<2	
Nitric Acid	5	<10	<10	<10	<2.0	<0.78

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Polynuclear Aromatic Hydrocarbon- Analyzed 12-27-2007, Method OSHA 58
-Sampled on 225-7 GFF Media, Air Volume- 34 liters

Sample ID	LOQ ug	Total ug	Conc mg/m3	ppm
3C				
Anthracene	3	<3	<0.09	<0.0012
Pyrene	3	<3	<0.09	<0.0011
Chrysene	3	<3	<0.09	<0.0095
Benzo (a) pyrene	3	<3	<0.09	<0.00086
Phenanthrene	3	<3	<0.09	<0.012

Aldehyde- Analyzed 12-31-2007, Method NIOSH 2016 on 226-119 Media
-Air Volume- 4 liters

Sample ID	LOQ ug	Front ug	Back ug	Total ug	Conc mg/m3	ppm
3D						
Benzaldehyde	0.1	0.28	<0.1	0.28	0.070	0.016
Valeraldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.007
Propionaldehyde	0.1	0.11	<0.1	0.11	0.028	0.012
Butyraldehyde	0.1	0.24	<0.1	0.24	0.059	0.020
Crotonaldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.009
Formaldehyde	0.04	0.67	<0.04	0.67	0.17	0.14
Isovaleraldehyde	0.1	<0.1	<0.1	<0.1	<0.025	<0.007
Acetaldehyde	0.04	0.46	<0.04	0.46	0.12	0.064

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Volatile Organic Compounds- Analyzed 1-2-2008, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
3E					
Propylene	5	<10	Freon-12	5	<10
Chloromethane	5	<10	Freon-114	5	<10
Vinyl Chloride	5	<10	1, 3-Butadiene	5	<10
Bromomethane	5	<10	Chloroethane	5	<10
Vinyl Bromide	5	<10	Freon-11	5	<10
Isopropyl Alcohol	5	<10	Acetone	5	64
1, 1- Dichloroethene	5	<10	Methylene Chloride	5	<10
Freon-113	5	<10	Allyl Chloride	5	<10
Carbon Disulfide	5	<10	Trans-1, 2-Dichloroethene	5	<10
Methyl Tert-Butyl Ether	5	<10	cis-1, 2-Dichloroethylene	5	<10
Hexane	5	<10	Ethyl Acetate	5	<10
Chloroform	5	<10	Tetrahydrofuran	5	<10
1, 2-Dichloroethane	5	<10	1, 1, 1-Trichloroethane	5	<10
Cyclohexane	5	<10	Carbon Tetrachloride	5	<10
Benzene	5	132	1, 4-Dioxane	20	<40

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	LOQ- Limit of Quantitation	
ppbv-Parts per Billion Volume			

Volatile Organic Compounds- Analyzed 1-2-2008, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
3E					
2, 2, 4-Trimethypentane	5	<10	Heptane	5	<10
1, 2-Dichloropropane	5	<10	Trichloroethylene	5	<10
Bromodichloromethane	5	<10	cis-1, 3-Dichloropropene	5	<10
trans-1, 3-Dichloropropene	5	<10	1, 1, 2-Trichloroethane	5	<10
Toluene	5	40	Dibromochloromethane	5	<10
Methyl Isobutyl Ketone	20	<40	Methyl Butyl Ketone	20	<40
1, 2-Dibromoethane	5	<10	Tetrachloroethylene	5	<10
Chlorobenzene	5	<10	Ethylbenzene	5	<10
Bromoform	5	<10	m & p-xylene	10	<10
Styrene	5	85	o-xylene	5	<10
1, 1, 2, 2-Tetrachloroethane	5	<10	4-Ethyltoluene	5	<10
1, 3, 5-Trimethylbenzene	5	<10	1, 2, 4-Trimethylbenzene	5	<10
1, 3-Dichlorobenzene	5	<10	Benzyl Chloride	5	<10
1, 4-Dichlorobenzene	5	<10	1, 2, 4-Trichlorobenzene	5	<10
Hexachloro-1, 3-Butadiene	5	<10			

<-less than mg- Milligrams m3- Cubic Meters kg-Kilograms
>-greater than ug- Micrograms l- liters NS- Not Specified
NA- not applicable ND- Not detected LOQ- Limit of Quantitation
ppbv- Parts per Billion Volume

Volatile Organic Compounds- Analyzed 1-2-2008, Method OSHA TO15-Mini Can -Air Volume- 400cc, Library search results

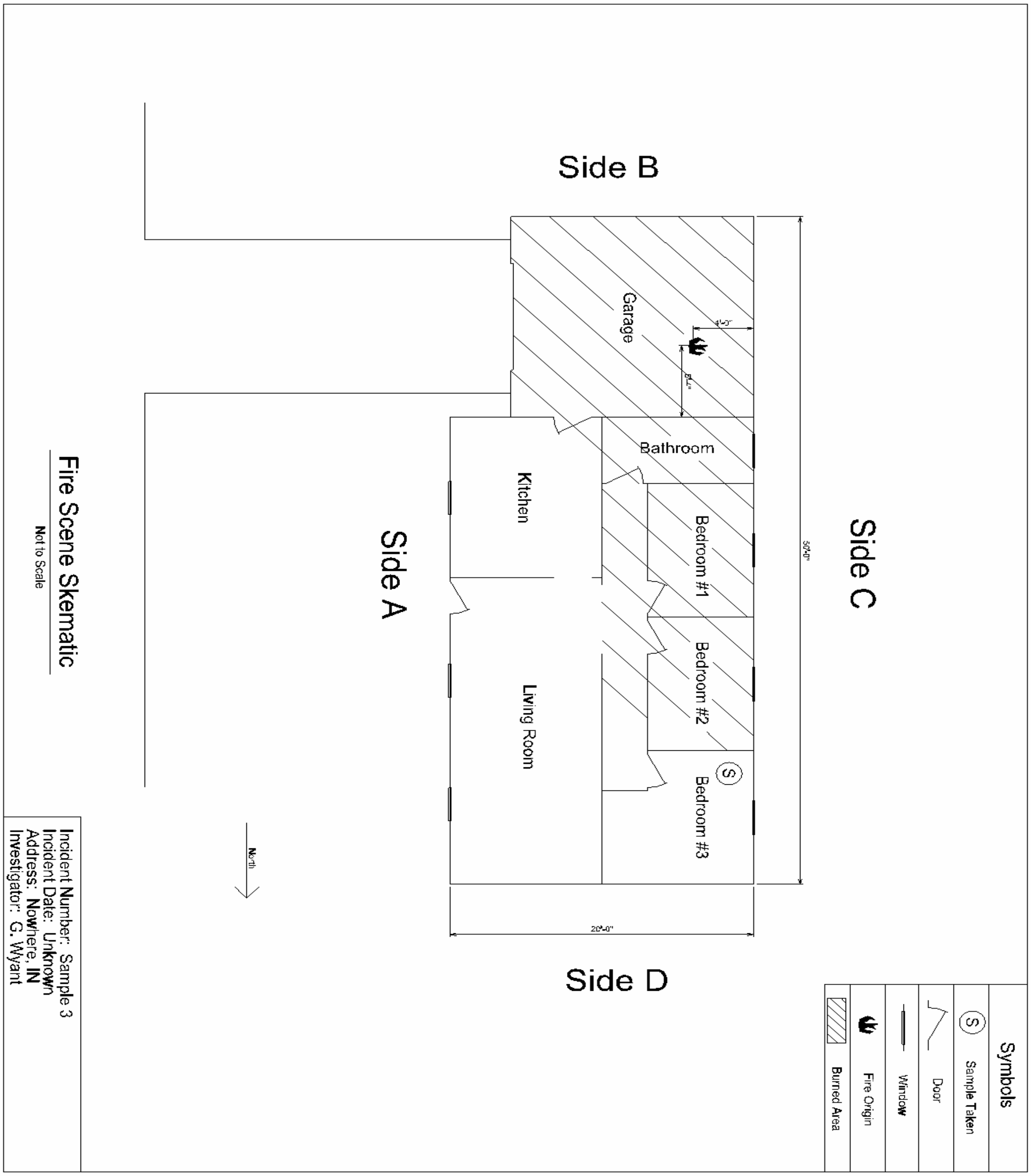
Tentatively Identified Compounds	Estimated Concentration ppbv
Propane	15
Ethanol	15
2-Propenoic acid, 2-methyl, methylester	16
Phenylethyne	14
Indene	25
Naphthalene	22

IAQRAE- Analyzed 12-26-2007, Sampled at 60 second intervals for 17 minutes

Sample ID	Peak ppm_	Peak percent	Peak degrees fahrenheit
Carbon Monoxide	0.8		
Carbon Dioxide	483		
Relative Humidity		50%	
Temperature			62.5 degrees

Appendix K

Sample 3 Structure- Schematic



Appendix L

Air monitoring sample set 4 results

Hydrogen Cyanide- Analyzed 1-29-2008, Method- NIOSH 6010 on 226-28 Media

Sample ID	Air Vol. liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
4A HCN	1	<2.6	<2.6	<2.6	<2.6	<2.4

Acids- Analyzed 1-25-2008, Method- NIOSH 7903 on 226-10-03 Media
-Air Volume- 5 liters

Sample ID	Air Vol liter	Front ug	Back ug	Total ug	Conc mg/m3	ppm
4B						
Hydrogen Bromide	5	<10	<10	<10	<2.0	<0.60
Hydrochloric Acid	5	<10	<10	<10	<2.0	<1.3
Phosphoric Acid	5	<10	<10	<10	<2	
Hydrofluoric Acid	5	<10	<10	<10	<2.0	<2.4
Sulfuric Acid	5	<10	<10	<10	<2	
Nitric Acid	5	<10	<10	<10	<2.0	<0.78

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Polynuclear Aromatic Hydrocarbon- Analyzed 1-25-2008, Method OSHA 58
-Sampled on 225-7 GFF Media, Air Volume- 38 liters

Sample ID	LOQ ug	Total ug	Conc mg/m3	ppm
4C				
Anthracene	3	<3	<0.08	<0.011
Pyrene	3	<3	<0.08	<0.0095
Chrysene	3	<3	<0.08	<0.0085
Benzo (a) pyrene	3	<3	<0.08	<0.0077
Phenanthrene	3	<3	<0.08	<0.011

Aldehyde- Analyzed 1-25-2008, Method NIOSH 2016 on 226-119 Media
-Air Volume- 4.4 liters

Sample ID	LOQ ug	Front ug	Back ug	Total ug	Conc mg/m3	ppm
4D						
Benzaldehyde	0.1	<0.1	<0.1	<0.1	<0.023	<0.005
Valeraldehyde	0.1	<0.1	<0.1	<0.1	<0.023	<0.006
Propionaldehyde	0.1	0.11	<0.1	0.11	0.026	0.011
Butyraldehyde	0.1	0.17	<0.1	0.17	0.038	0.013
Crotonaldehyde	0.1	<0.1	<0.1	<0.1	<0.023	<0.008
Formaldehyde	0.04	0.083	<0.04	0.083	0.019	0.015
Isovaleraldehyde	0.1	<0.1	<0.1	<0.1	<0.023	<0.006
Acetaldehyde	0.04	0.31	<0.04	0.31	0.071	0.039

<-less than	mg- Milligrams	m3- Cubic Meters	kg-Kilograms
>-greater than	ug- Micrograms	l- liters	NS- Not Specified
NA- not applicable	ND- Not detected	ppm- Parts per Million	
LOQ- Limit of Quantitation			

Volatile Organic Compounds- Analyzed 1-30-2008, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
4E					
Propylene	5	8	Freon-12	5	<5
Chloromethane	5	<5	Freon-114	5	<5
Vinyl Chloride	5	<5	1, 3-Butadiene	5	<5
Bromomethane	5	<5	Chloroethane	5	<5
Vinyl Bromide	5	<5	Freon-11	5	<5
Isopropyl Alcohol	5	<5	Acetone	5	24
1, 1- Dichloroethene	5	<5	Methylene Chloride	5	<5
Freon-113	5	<5	Allyl Chloride	5	<5
Carbon Disulfide	5	<5	Trans-1, 2-Dichloroethene	5	<5
Methyl Tert-Butyl Ether	5	<5	cis-1, 2-Dichloroethylene	5	<5
Hexane	5	<5	Ethyl Acetate	5	<5
Chloroform	5	<5	Tetrahydrofuran	5	11
1, 2-Dichloroethane	5	<5	1, 1, 1-Trichloroethane	5	<5
Cyclohexane	5	<5	Carbon Tetrachloride	5	<5
Benzene	5	15	1, 4-Dioxane	20	<20

<-less than　mg- Milligrams　m3- Cubic Meters　kg-Kilograms
>-greater than　ug- Micrograms　l- liters　NS- Not Specified
NA- not applicable　ND- Not detected　LOQ- Limit of Quantitation
ppbv-Parts per Billion Volume

Volatile Organic Compounds- Analyzed 1-30-2008, Method OSHA TO15-Mini Can -Air Volume- 400cc

Sample ID	LOQ ppbv	Sample ppbv	Sample ID	LOQ ppbv	Sample ppbv
4E					
2, 2, 4-Trimethypentane	5	<5	Heptane	5	<5
1, 2-Dichloropropane	5	<5	Trichloroethylene	5	<5
Bromodichloromethane	5	<5	cis-1, 3-Dichloropropene	5	<5
trans-1, 3-Dichloropropene	5	<5	1, 1, 2-Trichloroethane	5	<5
Toluene	5	8	Dibromochloromethane	5	<5
Methyl Isobutyl Ketone	20	<20	Methyl Butyl Ketone	20	<20
1, 2-Dibromoethane	5	<5	Tetrachloroethylene	5	<5
Chlorobenzene	5	<5	Ethylbenzene	5	<5
Bromoform	5	<5	m & p-xylene	10	<10
Styrene	5	85	o-xylene	5	<5
1, 1, 2, 2-Tetrachloroethane	5	<5	4-Ethyltoluene	5	<5
1, 3, 5-Trimethylbenzene	5	<5	1, 2, 4-Trimethylbenzene	5	<5
1, 3-Dichlorobenzene	5	<5	Benzyl Chloride	5	<5
1, 4-Dichlorobenzene	5	<5	1, 2, 4-Trichlorobenzene	5	<5
Hexachloro-1, 3-Butadiene	5	<5			

<-less than mg- Milligrams m3- Cubic Meters kg-Kilograms
>-greater than ug- Micrograms l- liters NS- Not Specified
NA- not applicable ND- Not detected LOQ- Limit of Quantitation
ppbv- Parts per Billion Volume

Volatile Organic Compounds- Analyzed 1-30-2008, Method OSHA TO15-Mini Can
-Air Volume- 400cc, Library search results

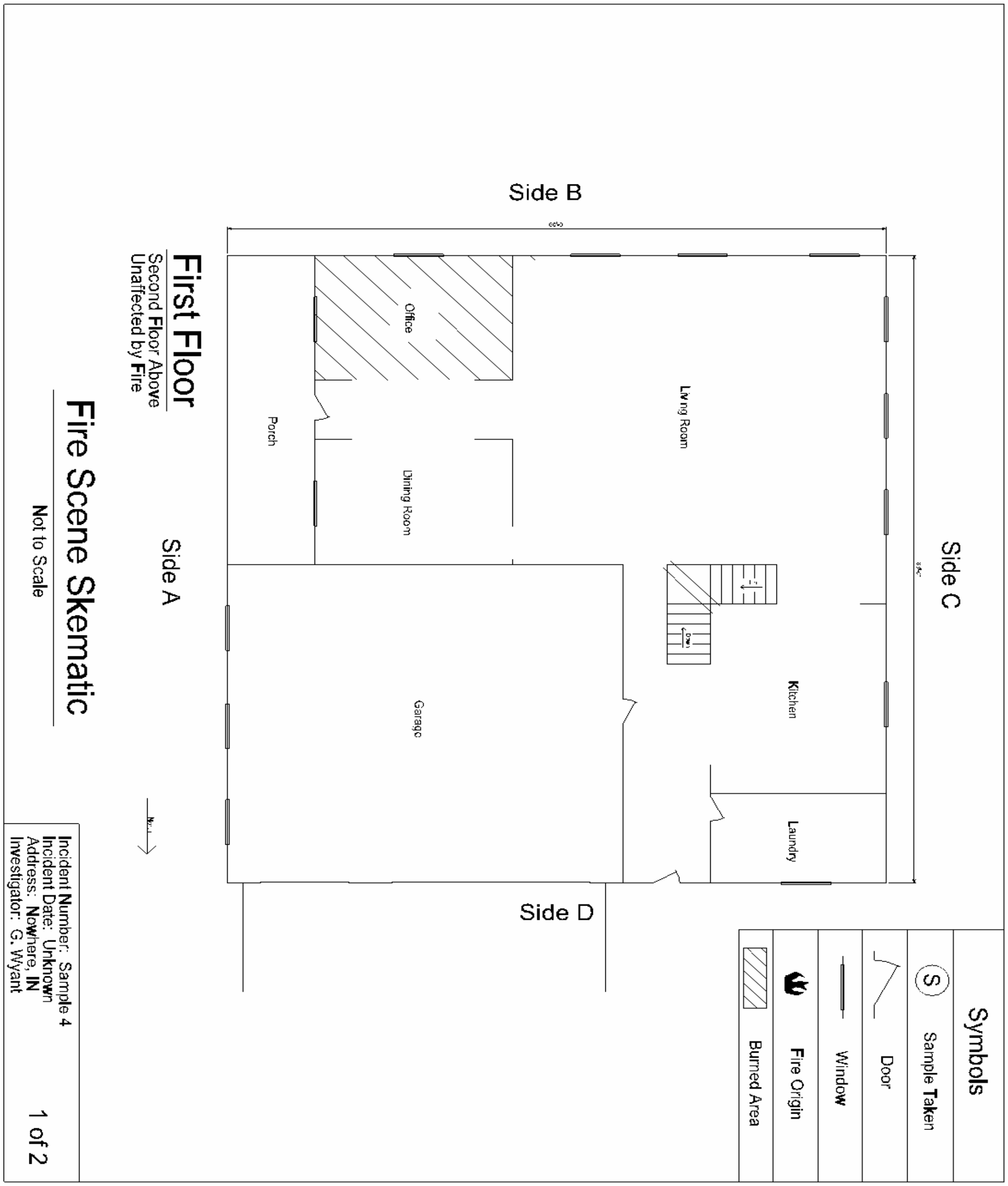
Tentatively Identified Compounds	Estimated Concentration ppbv
Acetaldehyde	8.1

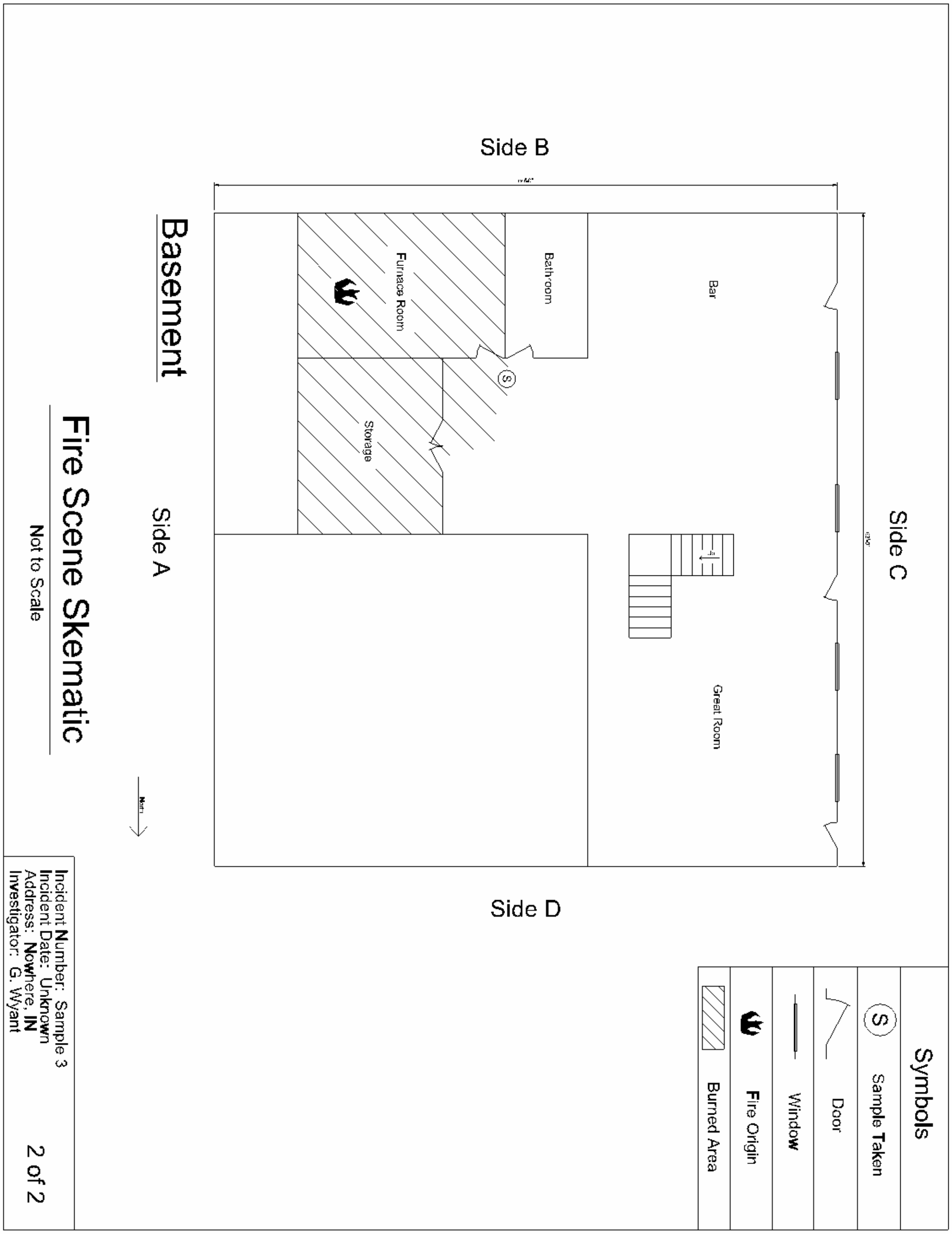
IAQRAE- Analyzed 1-23-2008, Sampled at 60 second intervals for 19 minutes

Sample ID	Peak ppm_	Peak percent	Peak degrees fahrenheit
Carbon Monoxide	0.0		
Carbon Dioxide	192		
Relative Humidity		83%	
Temperature			39.9 degrees

Appendix M

Sample Set 4- Schematic




Side B
Side C
Side D
Side A
Basement
Furnace Room
Bathroom
Bar
Storage
Great Room
Fire Scene Skematic
Not to Scale
Symbols
Sample Taken
Door
Window
Fire Origin
Burned Area
Incident Number: Sample 3
Incident Date: Unknown
Address: Nowhere, IN
Investigator: G. Wyant
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