Report of the Investigation Committee into the Cyanide Poisonings of Providence Firefighters

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EXECUTIVE SUMMARY

In the afternoon of March 23, 2006 a Providence Firefighter was diagnosed as having cyanide poisoning after working at a building fire at 1197 Broad Street earlier that day. On March 24, 2006 at 02:23 hours, Firefighter Kenneth Baker suffered at heart attack while operating at a house fire at 70 Ralph Street. Firefighter Baker was found to have had high levels of cyanide in his body. Firefighter Baker had previously worked at a fire at 125 Knight Street earlier in the shift, but did not work at the Broad Street fire.

In the aftermath of the three fires, a total of 28 members sought medical follow up, 27 of whom were tested for cyanide poisoning. Eight members were found to have elevated levels of cyanide, four of whom worked at the Broad Street fire, and four of whom worked at the Knight Street fire. Numerous other members reported symptoms consistent with cyanide poisoning, including headaches, weakness and fatigue, nausea, and shortness of breath.

Extensive research by the investigative committee disclosed:

- Accidental or intentional sources of the cyanide poisoning through ingestion were ruled out.

- Overwhelming evidence exists that cyanide is present in fire smoke more commonly and in greater quantities than previously believed due to modern materials such as plastics, rubber, asphalt, and polyacrylonitriles.

- There are a number of reasons why the cyanide problem has gone unrecognized by firefighters and the medical community, including:
    - Symptoms of cyanide poisoning are similar and commonly attributed to carbon monoxide poisoning
    - The blood test for cyanide poisoning is not readily available in most hospitals
    - Doctors do not routinely order cyanide tests on firefighters or smoke inhalation patients because the test results for cyanide commonly takes from two hours to one week to come back, making it diagnostically useless given that the half-life of cyanide in the body is one-hour

- Cyanide can cause cardiac arrhythmias and other medical conditions commonly being experienced by firefighters

- The effects of cyanide on the heart may show up days to weeks after the exposure

The investigation committee concluded that:

- The cyanide exposures that occurred on March 23 and 24, 2006 were the result of an accidental exposure to hydrogen cyanide that was generated from the burning fuels at two and possibly all three of the incidents.

- The exposure that led to high cyanide levels in FF Baker probably occurred at the Knight Street fire.

- Many of the firefighters who tested normal for cyanide after the fires, may have had high levels of cyanide at the fire scenes and immediately thereafter, but due to the short half-life of cyanide and the length of time between the exposures and the blood draw, their cyanide levels returned back to normal. Many other firefighters who did not go for testing, but experienced symptoms of weakness, fatigue and headaches after the fires may well have had toxic levels of cyanide immediately after the fire.

- The committee concurrs with the growing list of experts who have concluded that hydrogen cyanide poses a much more significant problem to firefighters than previously believed. “It would appear that the Providence Fire Department and Rhode Island Hospital may have run into the tip of a very large iceberg.”

- Given the steep dose-effect curve of cyanide, it is likely that firefighters are routinely being exposed to dangerous levels of cyanide at fires without realizing it.

Recommendations include additional training, acquisition of cyanide detection equipment, development of new operational policies and tactics, expedited approval of a cyanide antidote presently in use in France (hydroxocobalamin), additional research into the connection between cyanide and cardiac arrhythmias/firefighter heart attacks, and additional research into a number of cyanide related matters.

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INTRODUCTION

On Thursday, March 23, 2006 at 10:31 hours, the Providence Fire Department responded to a building fire in a fast food restaurant at 1197 Broad Street.[1] The fire itself was relatively uneventful. After the fire a member of Engine 3's crew began to experience symptoms including headache, dizziness, difficulty breathing, and a cough. Members also reported that at times he was talking incoherently. At 14:15 hours the member was transported to Rhode Island Hospital, a Level I Trauma Center and teaching hospital affiliated with Brown University Medical School.

In the emergency room, Dr. Kenneth A. Williams, MD, FACEP, Clinical Associate Professor of Emergency Medicine at Brown University Medical School, observed the firefighter and instructed the attending physicians to also check the member for cyanide poisoning. This was unusual in that firefighters exhibiting such symptoms are commonly tested for carbon monoxide poisoning after fires, but not normally for cyanide poisoning.

When the member's blood work came back he indeed was found to have high levels of blood cyanide at 57 ug/dL.[2] The member was placed on antidote therapy for cyanide poisoning. Upon learning that the Engine 3 firefighter had high levels of cyanide, the department contacted all of the members who had responded to the Broad Street fire, and recommended that if any were experiencing symptoms they should go to Rhode Island Hospital to be evaluated for cyanide poisoning. Sixteen members sought medical attention, fourteen of whom went to Rhode Island Hospital. Of these fourteen, four were found to have whole blood cyanide levels above 20 ug/dL.

Later on March 23, 2006, at 17:35 hours, the Providence Fire Department responded to a fire in a six-unit residential apartment building at 125 Knight Street.[3] The Knight Street fire was in a different part of the city, and occurred close to shift change after most of the personnel who had been working for the Broad Street fire had been relieved. In addition, about half of the units that responded to the Knight Street fire had not responded to the Broad Street fire. The Knight Street fire was again, uneventful. There were no injuries reported at the Knight Street fire.

At 02:07 hours on March 24, 2006 the Providence Fire Department responded to a house fire at 70 Ralph Street.[4] All of the units responding to the Ralph Street fire had previously responded to the Knight Street fire. At approximately 02:23 hours, Firefighter Kenneth Baker, the chauffeur of Engine 6, collapsed at the scene suffering a heart attack. FF Baker was immediately attended to by emergency medical personnel, provided with advanced life support on scene, and promptly transported him to Rhode Island Hospital where he was successfully resuscitated. In light of the cyanide poisoning cases from the previous

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[1] Incident Number 8306

[2] Micrograms per deciliter. Rhode Island Hospital considers 0 to 20 ug/dL of cyanide as normal in a whole blood cyanide test. The test took approximately two hours to complete, and by the time the results were known, many members that had worked at the Broad Street fire had already been relieved.

[3] Incident Number 8352

[4] Incident Number 8393

day, FF Baker was tested for cyanide. The lab results showed that FF Baker had a whole blood cyanide level of 66 ug/dL.

After consulting with doctors at Rhode Island Hospital, all members who responded to any of the three fires where then instructed to go to Rhode Island Hospital if they experienced any symptoms that could be related to cyanide poisoning. A total of twenty-eight members sought medical care, twenty-seven of whom had their cyanide levels tested. A total of eight member tested high (above 20 ug/dL) for cyanide.

As a result of these events, Fire Chief David Costa appointed this five member committee to investigate the causes of the cyanide poisoning, to review existing policies and procedures, and to make recommendation to prevent such an occurrence from happening again. [5]

[5] Joint Memorandum 24 -2006. See Appendix A.

BACKGROUND

Part 1 - Cyanide

CHEMISTRY OF CYANIDE

Cyanide is the generalized name for a group of a chemical compounds that contain one atom of carbon triple bonded to one atom of nitrogen. See Illustration 1. Cyanide is frequently abbreviated as CN, the C representing one carbon atom and the N representing one nitrogen atom. Cyanides may be natural or man made, and may exist as solids, liquids or gasses.

The triple bond that exists between the carbon and nitrogen atoms of a cyanide molecule is a particularly strong bond, one that cannot normally be created by the combustion of a carbon containing compound in the presence of atmospheric nitrogen under normal atmospheric conditions. [6]

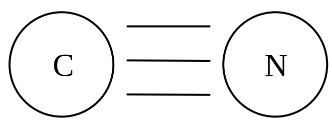

Illustration 1

A cyanide molecule is readily capable of bonding with another atom or compound. The type of atom or compound that the cyanide molecule bonds to determines the properties and toxicity of the resulting product. There are a vast number of cyanide containing compounds, each with distinct chemical properties. For example, if the cyanide molecule bonds to hydrogen, hydrogen cyanide is formed.[7] If the cyanide molecule joins to an alkyl group, a nitril is formed. Thiocyanates are group of cyanides with a sulfur molecule attached. [8] Other common examples of cyanide include sodium cyanide (NaCN), and potassium cyanide (KCN).

Many products in common use in today's society contain cyanide. Cyanide is present in plastics, polyurethane, various types of foam, synthetic fibers and pesticides.[9] In addition cyanide is used in electroplating, pharmaceutical, cosmetic, computer electronics, photographic developing, and metallurgy industries. [10] [11] Cyanide is found in over 2,650 plant species. Fruits and nuts such as almonds, lima beans, soy, bamboo shoots all contain cyanide. Fruits that have a pit also contain small quantities of cyanide and chronic consumption of the cassava root (tapioca) has been associated with cyanide

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[6] Dr. James Mugyar, Professor of Chemistry, Rhode Island College, Providence, RI.
[7] Draft Toxilogical Profile for Cyanide, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, (Sept., 2004). Hereinafter cited as ATSDR (2004)
[8] ATSDR (2004), p. 2.
[9] ATSDR (2004), p. 152
[10] Stephen W Borron,. http://www.emedicine.com/EMERG/topic118.htm
[11] ATSDR (2004), p. 154

poisoning.[12] Not all cyanide-containing substances are harmful. Vitamin B-12 contains cyanide and is beneficial to our health.[13]

Table 1 - Materials with HCN

Plastics	Melamine
Polyurethane foam	Polyester wadding
Neoprene foam	Nitriles and polyacrylonitriles
Asphalt	Nylon
Rubber	Pesticides
Insulation resins	Wool, wood, paper

Some forms of cyanides are highly toxic and can kill within a few minutes of exposure. Other forms of cyanide are better tolerated. Because of its lethality, hydrogen cyanide has been used as a chemical agent in gas chambers and as a weapon of war.[14] Cyanides have also been used in assassinations and mass suicides, and concerns exist over the possible use of cyanides by terrorists as a weapon of mass destruction. [15]

The toxicity of cyanide is dependent upon the type of cyanide, the concentration, and the route of exposure. Cyanides that release the cyanide anion, $(CN)^{-1}$, a negatively charged ion, are highly toxic.[16] Compounds that do not release a cyanide anion are not as poisonous.[17]

CYANIDE EXPOSURES

Cyanide is present in small quantities in the air, water and soil around us. At any given time our bodies contain fluctuating levels of cyanide in various forms.

> *The general population is exposed to cyanides primarily by ingestion of food and water, and to a lesser degree, by inhalation. The cyanide content in unpolluted air averages 160–166 ppt (0.180–0.187 mg/m^3); assuming a ventilation rate of 20 m^3/day, the average intake from air is about 3.8 ug/day for the nonurban, nonsmoking population. Cyanide levels in smoke from U.S. commercial cigarettes range from 10 to 400 ug/cigarette for mainstream (inhaled) smoke and from 0.006 to 0.27 ug/cigarette for sidestream smoke. The cyanide content in drinking water in 71 out of 73 urban areas in Canada was <1 ug/L; the value for two other cities was 11 ug/L. Assuming that adults ingest two liters of water per day, the cyanide intake from drinking water ranges from <2 to 22 ug/day. Mean cyanide concentrations have been reported for some food products: cereal grains (0.002–0.45 ug/g), soy protein products (0.07–0.3 ug/g), canned unpitted fruits (0–4*

[12] ATSDR, (2004), p. 6-7
[13] ATSDR, (2004), p. 7.
[14] CDC, "Fact Sheet, Facts about Cyanide", Feb 26, 2003
[15] Eckstein M, Cyanide as a Chemical Terrorism Weapon, JEMS (Summer, 2004).
[16] R. Edwards,"Fire Chem I, The Basics of H.T.M." 5th edition
[17] R. Edwards,"Fire Chem I, The Basics of H.T.M." 5th edition

ug/g), commercial fruit juices (1.9–4.6 mg/L), and U.S. lima beans (0.10–0.17 mg/g).[18]

Cyanide poisonings most commonly occur through industrial exposures, intentional acts, and smoke inhalation. [19] Among these, the most common cause of acute cyanide poisoning is the inhalation of fire smoke.[20] Hydrogen cyanide is emitted from the combustion of burning fuels that contain the cyanide molecule. Hydrogen cyanide is released from burning plastics, polyurethane foam, polyacrylonitriles, rayon, wool, vehicle exhaust, and cigarettes.[21] Studies have shown that high temperature low oxygen conditions tend to yield higher levels of hydrogen cyanide when such fuels burn.[22]

In addition, through a process known as quantitative decomposition, cyanide containing products such as plastics can release significant quantities of hydrogen cyanide prior to ignition.[23] Some researchers have concluded that gases emitted during the quantitative decomposition stage of a fire are more toxic than those emitted during actual burning.[24]

A recent article published by Eckstein and Maniscalco in March, 2006 in *Pre-Hospital and Disaster Medicine*, documented that "cyanide exposure is: (1) to be expected in those exposed to smoke in closed-space fires; (2) cyanide poisoning is an important cause of incapacitation and death in smoke-inhalation victims; and (3) that cyanide can act independently of, and perhaps synergistically with, carbon monoxide to cause morbidity and mortality."[25]

Eckstein and Maniscalco's work confirms research conducted in France and other European countries that long ago concluded that hydrogen cyanide was playing a much more important role is smoke inhalation deaths and injuries than previously believed. [26] However, other researchers have come to a contrary conclusion regarding the role of cyanide in smoke inhalation.[27]

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[18] ATSDR (2004), p. 191.
[19] ATSDR, (2004), p. 13.
[20] Donald W. Walsh, Daniel J. O'Brien, Jefferey L. Arnold; Fire EMS Magazine, "Cyanide Poisoning: Not just a HAZMAT Issue" September 1, 2004
[21] ATSDR, (2004), pp. 2, 3, 9, 159 to 165.
[22] Alcorta R, "Smoke Inhalation & Acute Cyanide Poisoning", JEMS (Summer, 2004)
[23] Wallace, Deborah, "In the mouth of the Dragon: toxic fires in the age of plastics", 1990
[24] Wallace, Deborah, "In the mouth of the Dragon: toxic fires in the age of plastics", 1990
[25] Eckstein M and Maniscalco PM, *Focus on Smoke Inhalation - The Most Common Cause of Acute Cyanide Poisoning*, Prehospital and Disaster Medicine http://pdm.medicine.wisc.edu Vol. 21,No. 2, (Mar-Apr, 2006)
[26] Baud FJ, Barriot P,Toffis V, et al:"Elevated blood cyanide concentrations in victims of smoke inhalation." *New England Journal of Medicine.* 325:1761–1766, 1991.
[27] Barrillo DJ, Goode R, Esch V. Cyanide poisoning in victims of fire: analysis of 364 cases and review of the literature. J Burn Care Rehabil 1994;15:46-57.

HYDROGEN CYANIDE

"Hydrogen cyanide is a colourless or pale blue liquid or gas with a faint bitter almond-like odour. Hydrogen cyanide is used primarily in the production of substances such as adiponitrile, methyl methacrylate, chelating agents, cyanuric chloride, methionine and its hydroxylated analogues, and sodium and potassium cyanide." [28]

Hydrogen cyanide is generated when a fuel that contains cyanide burns. The production of hydrogen cyanide in a fire is dependent upon several factors that include the chemical composition of the material burning, the oxygen content in the room, the temperature of the combustion process, and the presence or absence of ventilation.[29] Although most fuels contain carbon, and the atmosphere is 79% nitrogen, it is highly unlikely that cyanide could be created under normal fire conditions due to the conditions required to form the triple bond.[30] Rather, the CN molecule must exist in the fuel prior to the fire, in order for hydrogen cyanide to be released during the fire.

When a fuel that contains cyanide molecules begins to burn, hydrogen cyanide is the most likely form of cyanide to be released.[31] Hydrogen cyanide then mixes with other toxic gases and byproducts of combustion to produce a highly toxic mix of substances. Some have theorized that cyanide may work synergistically with other fire gases such as carbon monoxide to incapacitate and suffocate those exposed to fire smoke. [32] In 2004, Dr. Richard Alcorta, MD, FACEP, reviewed studies conducted in Paris and Dallas, concluding that high blood cyanide levels showed a direct relationship with the probability of death in smoke inhalation patients, suggesting that hydrogen cyanide may play a more significant role than carbon monoxide in smoke inhalation deaths.[33] Numerous other researchers have reached similar conclusions about the role of cyanide in fire smoke. [34]

In 2004, the International Programme on Chemical Safety stated:

> *A fire fatalities study in Maryland, USA, covering mostly residential fires over a 6-year period during which 523 fire fatalities occurred as a result of 392 fires, was reported by Birky & Clarke (1981). Although the predominant cause of death was attributed to carbon monoxide, toxic levels of hydrogen cyanide were found in the blood of a substantial percentage of the victims. A study of blood cyanide*

[28] International Programme on Chemical Safety (IPCS), Concise International Chemical Assessment Document 61, HYDROGEN CYANIDE AND CYANIDES: HUMAN HEALTH ASPECTS, ©World Health Organization 2004, http://www.inchem.org/documents/cicads/cicads/cicad61.htm#4.0, hereinafter cites as CICAD 61.

[29] Robert Schnepp, "Where There's Fire, There's Smoke!" Cyanide and Modern Fires EMD Pharmaceuticals, 2005

[30] Dr. James Mugyar, Professor of Chemistry, Rhode Island College, Providence, RI.

[31] Eckstein and Maniscalco, (2006)

[32] Norris JC, Moore SJ, Hume AS, Synergistic lethality induced by the combination of carbon monoxide and cyanide, Toxicology, 1986 Aug; 40 (2): 121-129.

[33] Alcorta (2004)

[34] Eckstein and Maniscalco, (2006); Silverman SH, Purdue GF, Hunt JL, Bost RO, Cyanide toxicity in burned patients, J Trauma, 1988 Feb; 28 (2): 171-176.

and carboxyhaemoglobin concentrations in 18 victims found dead in buildings after fires indicated that 50% of the victims had been exposed to toxic levels of hydrogen cyanide and 90% to toxic levels of carbon monoxide (Lundquist et al., 1989). Eighty-eight per cent of the fatalities in fire deaths in Glasgow, Scotland, during the period 1976–1979 had elevated blood cyanide levels; 31% had toxic levels of cyanide, and 12% would have shown severe cyanide poisoning (Anderson & Harland, 1982). Alarie (2002) reviewed the carboxyhaemoglobin and cyanide in blood of fire and non-fire victims resulting from 15 major episodes during the years 1971–1990 in France, the USA, and the United Kingdom. Analysis revealed that hydrogen cyanide is likely to be present in appreciable amounts in the blood of fire victims in modern fires. A review of the resultant mechanism of action of acute carbon monoxide and cyanide exposure and how they may interact concluded that it remains difficult to attribute death in fires to inhalation of hydrogen cyanide per se, given the complexity of interactions of smoke components (principally carbon monoxide). [35]

According to the NIOSH Pocket guide, hydrogen cyanide has an Immediately Dangerous to Life and Health (IDLH) level of 50 ppm.[36] According to OSHA, hydrogen cyanide has a vapor density of .94, and is highly flammable with a flashpoint of 0^{o} F and a flammable range between 5.6 and 40%. [37] When released into the environment, hydrogen cyanide will dissipate, but may remain in the environment for years, with a half-life that is estimated to be one to three years.[38]

MEDICAL ASPECTS OF CYANIDE

The toxicity of cyanide is related to its ability to inhibit aerobic respiration. The CN molecule has a high affinity for a key enzyme in the aerobic pathway, cytochrome c oxidase. [39] Cyanide in sufficient quantities will shut down the aerobic pathway at the sub-cellular (mitochondria) level, leaving cells to rely solely on anaerobic respiration. Anaerobic respiration results in a build up of lactic acid and other toxic substances in tissues and organs. [40] This less effective anaerobic pathway soon becomes incapable of providing the energy required by the cells of the body to sustain life. The CN molecule also has an affinity for hemoglobin, which in turn reduces the oxygen carrying capacity of the blood.[41] In addition, the cyanide molecule can inhibit approximately 40 other enzymes, which contribute to its toxicity.[42]

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[35] CICAD61 (2004)
[36] NIOSH Pocket Guide to Hazardous Chemicals, NIOSH Publication No. 2005-151 (2005)
[37] Occupational Safety and Health Guideline for Hydrogen Cyanide, OSHA http://www.osha.gov/SLTC/healthguidelines/hydrogencyanide/recognition.html (2006)
[38] ATSDR (2004) p. 3.
[39] ATSDR (2004) p. 99.
[40] A cell that is limited to anaerobic respiration quickly builds up toxic levels of lactic acid as opposed to the normal byproducts of aerobic respiration, carbon dioxide and water. As a result, lactic acid levels can be an important measure of cyanide toxicity.
[41] ATSDR (2004) p. 14
[42] CICAD61 (2004)

Cyanide can enter the body through inhalation, ingestion or absorption. The severity of the cyanide toxicity is dependent upon the type of cyanide involved, route of entry, dosage, and the rapidity of symptom onset. [43] Cyanide compounds that readily release the cyanide anion (CN^-) are more toxic.[44]

Organs such as the heart and central nervous system are heavily dependent upon oxygen, and the aerobic energy pathway.[45] Even in an atmosphere with normal oxygen levels, cyanide poisoning inhibits the body's use of oxygen. Early signs of acute cyanide poisoning include rapid pulse, difficulty breathing, general weakness, headache, excitement, giddiness, vertigo, and confusion.[46] Late signs of cyanide toxicity are nausea, hypotension, tremors, cardiac arrhythmias, coma, and non-cardiac pulmonary edema.[47] Cyanide toxicity resembles the signs and symptoms of carbon monoxide poisoning and oxygen deprivation, leading some to speculate that the actual role of cyanide poisoning amongst smoke inhalation victims is considerably higher than previously recognized. [48] Writing in *Pre-Hospital and Disaster Medicine*, Eckstein and Maniscalco in 2006 stated:

> *Effective prehospital management of smoke inhalation-associated cyanide poisoning is hampered by a lack of awareness of smoke caused by fires as an important cause of cyanide toxicity. Additionally, prehospital management of acute cyanide poisoning is inhibited by the absence of a rapidly returnable diagnostic test to facilitate its recognition*….[49]

Correlating cyanide exposure to symptoms and mortality has proven difficult for a variety of reasons. Part of the reason is a lack of toxicity data on humans and animals, as well as the difficulty in accurately assessing blood cyanide levels. [50] The length of time between the exposure and the blood draw, as well as how the samples are handled can significantly impact blood cyanide lab results. [51]

EXPOSURE LEVEL

The average fatal concentration of hydrogen cyanide has been estimated to be 546 ppm for 10 minutes.[52] Lesser concentrations over longer periods of time have proven fatal in anecdotal reports.[53] The estimated fatal dose of orally ingested cyanide is 1.52 mg/kg, but

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[43] Stephen W Borron,. http://www.emedicine.com/EMERG/topic118.htm
[44] ATSDR (2004) p. 14.
[45] Id.
[46] Id.; Alcorta (2004); Eckstein and Maniscalco, (2006)
[47] Stephen W Borron,. http://www.emedicine.com/EMERG/topic118.htm
[48] Eckstein and Maniscalco, (2006); Schnepp, (2005)
[49] Eckstein and Maniscalco, (2006), p. 49.
[50] Birky MM, Clarke, FB, Inhalation of Toxic Products from fires, Bull NY Acad Mcd, Vol. 57, No. 10, December, 1981; Eckstein and Maniscalco, (2006)
[51] Eckstein and Maniscalco, (2006)
[52] ATSRD (2004), p. 27 – 28.
[53] Id.

deaths have been documented as low as .56 mg/kg.[54] Dermal exposure to cyanide is much slower, and is generally considered to be less of a threat than inhalation or ingestion. [55] The potential for skin absorption is based on the type of cyanide, the condition of the skin, and the location on the body.

The human body will generally absorb 58% of any hydrogen cyanide that is breathed into the lungs.[56] Once inhaled hydrogen cyanide will rapidly be absorbed into the blood stream. Symptoms may appear within seconds of breathing in hydrogen cyanide.[57]

In the blood stream, cyanide will interact with a variety of substances, some of which will result in toxicity (cytochrome c oxidase and hemoglobin), and some of which help serve to help detoxify the cyanide. [58] Cyanide is normally detoxified in the liver by the enzyme rhodanese. Rhodanese catalyses the transfer of the sulfane sulfur of thiosulfate to the cyanide ion to form thiocyanate, a non-toxic byproduct. Approximately 80% of the cyanide in the body is detoxified by this pathway. The limiting factor in this pathway is the presence of thiosulfate.[59]

A secondary metabolic pathway for detoxification exists whereby cyanide binds with cystine to yield cysteine and β-thiocyanoalanine. β-thiocyanoalanine is then converted to 2-imino-4-thiazolidine carboxylic acid and excreted in urine.[60]

Some cyanide will bind in the blood with methemoglobin. Cyanide has a strong affinity for methemoglobin and once bound will no longer be available as a toxin.[61] Cyanide may also bond with hydroxocobalamin (Vitamin B12a) to yield cyanocobalamin (Vitamin B12). [62] Hydroxocobalamin has been used in Europe for about ten years as an antidote for cyanide poisoning, and has been used by the Paris Fire Brigade to treat smoke inhalation victims with remarkable success.[63]

CYANIDE DOSES

Just as small amounts of cyanide are present in the environment, small amounts of cyanides are normally present in humans. Normal levels of whole blood cyanide are believed to be between 0 to 20 micrograms per deciliter (ug/dL). [64] Smokers tend to have higher levels of cyanide than do non-smokers. However, experts disagree as to the

[54] Id.
[55] Id., p. 74.
[56] ASTDR (2004), p. 83.
[57] CICAD 61
[58] CICAD 61
[59] Id.
[60] ASTDR (2004), p. 121-122.
[61] Dr. Stephen W. Borron, Clinical Professor of Emergency Medicine, University of Texas Health Science Center, Consulting Toxicologist, South Texas Poison Center (April 16, 2006).
[62] CICAD 61
[63] Fortin JL, Ruttiman M, Domanski L, Kowalski, JJ, Hydroxycobalamin Treatment for Smoke Inhalation-Associated Cyanide Poisoning, JEMS, (Summer, 2004)
[64] Berlin C. 1977. Cyanide poisoning--A challenge. Arch Intern Med 137:993-994.

significance of the difference between cyanide levels in smokers and non-smokers, with some concluding that due to the short half-life of cyanide in the blood, it is not a reliable measure of smoking,[65] while others conclude there is a significant and measurable difference. [66]

Cyanide levels as low as 50 ug/dL (.05 md.dL) in the blood have proven to be toxic, and blood cyanide levels of 250 to 300 ug/dL have been determined to be fatal.[67] However, the use of blood cyanide lab results is frought with problems.

> With a half-life of one hour, cyanide is short lived in the bloodstream.[11] Because blood samples rarely are obtained within the short time required for accurate measurement of peak concentrations of cyanide, measured concentrations often are erroneously low. Furthermore, even when blood samples are obtained promptly after exposure, the influence of various incident- and victim-specific factors (e.g., carboxyhemoglobin saturation of sampled blood, methemoglobin content of sampled blood, time between blood sampling and assay, storage temperature of blood samples) on the measured concentration of cyanide can complicate the interpretation of assay results or introduce sources of error.[68]

Not all authorities agree upon what constitutes a "normal" level of cyanide, versus a toxic level. Dr. William Bastan, Director of the Toxicology Laboratory at Rhode Island Hospital researched this issued thoroughly for the investigation committee and generated the information contained in Table B-1.

Table B-1

SOURCE	NORMAL	TOXIC
Rhode Island Hospital	<20 ug/dL	>20 ug/dL
Hamilton[69]	<20 ug/dL	>50 ug/dL
ARUP Lab, Univ. of Utah	<20 ug/dL	>50 ug/dL
Quest Diagnostics	<10 ug/dL	>20 ug/dL
Marquette General Health Systems	<20 ug/dL	>20 ug/dL
University of Michigan	<15 ug/dL	>50 ug/dL
Tietz[70]	<20 ug/dL	>20 ug/dL
Mayo Medical Lab	<20 ug/dL	>200 ug/dL

[65] Lundquist P, Rosling H, Sorbo B, Tibbling L, Cyanide Concentrations in Bloodafter Cigarette Smoking, as Determined by a Sensitive Fluorimetric Method, CLIN. CHEM. 33/7, 1228-1230 (1987)
[66] Tsuge K, Kataoka M, and Seto Y, Cyanide and Thiocyanate Levels in Blood and Saliva of Healthy Adult Volunteers, Journal of Health Science, 46(5) 343–350 (2000)
[67] Baskin, SI, Brewer, TG, Cyanide Poisoning, Chapter 10 in Medical Aspects of Chemical and Biological Warefare, (1997), p. 276; Alcorta (2004), p 11.
[68] Eckstein and Maniscalco, (2006), p. 50.
[69] Hamilton HE, Street EW, Beckman Royder M, Adams K, Cyanide and Thiocyanate by Microdiffusion and Spectrophotometry, Selected Methods of Emergency Toxicology, Vol. 11, AACC Press, 1986
[70] Tietz Textbook of Clinical Chemistry, 2nd Ed., WB Saunders Company, 1994

DOSE EFFECT CURVE

According to the International Programme on Chemical Safety Research, the dose-effect curve for cyanide toxicity in humans is steep.[71] As a result, slight effects may be felt initially by those exposed to cyanide poisoning, owing to the early operation of detoxification pathways and metabolites such as thiocyanate removing free cyanide before it can do much harm. However, as exposure to cyanide continues, the body's ability to compensate and detoxify cyanide becomes overwhelmed, resulting in more serious symptoms and possibly death occurring more abruptly.

> "The dose–effect curve of the acute effects in humans is steep. Whereas slight effects occur at exposure to hydrogen cyanide levels of 20–40 mg/m^3, 50–60 mg/m^3 can be tolerated without immediate or late effects for 20 min to 1 h, 120–150 mg/m^3 is dangerous to life and may lead to death after 0.5–1 h, 150 mg/m^3 is likely to be fatal within 30 min, 200 mg/m^3 is likely to be fatal after 10 min, and 300 mg/m^3 is immediately fatal. It should be emphasized that this represents crude average exposure estimates, based on various studies (DECOS, 2002)." [72]

Thus, exposure to high doses of cyanide over a short period of time are more likely to be more lethal than exposure to smaller doses over an extended period of time, owing to the existence of the detoxification pathways that can help manage cyanide levels.[73]

CYANIDE ANTIDOTES

The standard antidote treatment for cyanide poisoning in the United States consists of the administration of a three-drug series using amyl nitrate, sodium nitrite, and sodium thiosulfate.[74] The drugs are organized into kits commonly referred to as Taylor, Lilly or Pasadena cyanide antidote kits, depending upon manufacturer. This antidote procedure carries with it certain harmful side effects, such as decreasing the amount of available hemoglobin in the blood and severe hypotension, that generally prohibit its field use for smoke inhalation victims. [75]

Other countries have utilized alternative methods of treating smoke-related cyanide poisoning. In German, 4-dimethylaminophenol (DMAP) has been used as a cyanide antiodote. In England, dicobalt ededate has been used to treat cyanide poisoning.

In France, a chemical pre-cursor of Vitamin B12 known as hydroxocobalamin is routinely administered to victims of smoke inhalation victims to combat cyanide

[71] CICAD 61 (2004)
[72] CICAD 61 (2004)
[73] Baskin, SI, Brewer, TG, Cyanide Poisoning, Chapter 10 in Medical Aspects of Chemical and Biological Warfare, (1997), p. 276.
[74] Aaron, CK, Cyanide Antidotes, published in Goldfrank's Toxicologic Emergencies, 5th Ed., Appleton & Lange Publ., (1994) p. 1228
[75] Alcorta, (2004) p. 14

poisoning.[76] Hydroxocobalamin combines with cyanide to form Vitamin B12, or cyanocobalamin. Cyanide so bound to hydroxocobalamin is no longer toxic and can be eliminated through urine. Proponents of hydroxocobalamin claim it has substantially less side effects than the three drug series used in the United States.[77] It is considered safe enough that it can be administered in a pre-hospital environment in France to smoke inhalation patients without first performing blood tests to determine the patient's cyanide or lactic acid level. Hydroxocobalamin is currently not approved for use in the United States, but is under consideration by the FDA.

DERMAL ABSORPTION OF HYDROGEN CYANIDE AND OTHER CYANIDES

Hydrogen cyanide is readily absorbed following inhalation and oral ingestion, and can be absorbed following dermal exposure, but the principal route of occupational exposure to cyanides is via inhalation.[78] The ATSDR document reports that the occupational groups susceptible to inhalation and dermal absorption of cyanides are the electroplating, metallurgy, cynaotype printing, pesticide application, firefighting, steel manufacturing and gas work operations.[79]

Skin absorption of cyanides may be significant under some circumstances, particularly when airborne concentrations are very high, such as in fumigation operations.[80] One study concluded that concentrations of 7,000 to 12,000 mg/m^3 of hydrogen cyanide for 5 minutes was fatal to workers wearing self-contained respirators.[81] The amount and rate of absorption of cyanides from aqueous solutions or atmospheric hydrogen cyanide depend upon factors including the presence of moisture in the skin, concentration of the cyanide, the pH of the solution, the surface area of contact, and the duration of contact.[82] Most authorities agree that dermal absorption of hydrogen cyanide is much slower than pulmonary absorption.[83]

Data on dermal absorption of cyanide other than cases of acute toxicity are somewhat limited. The ATSDR document found no studies regarding quantitative absorption in

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[76] Sauer SW, Keim ME, Hydroxocabalamin: improved public health readiness for cyanide disasters, Ann Emerg Med, June 2001; 37:635-641.
[77] Fortin, et al (2004); Sauer and Keim (2001)
[78] CICAD 61, citing Minkina NA (1988) [Hydrogen cyanides and cyanides.] In: Filov VAA, ed. [Harmful chemical substances – inorganic compounds of elements of I-IV groups.] St. Petersburg, Himiya, pp. 331-352 (in Russian).
[79] ATSDR (2004)
[80]CICAD 61, citing Minkina NA (1988) [Hydrogen cyanides and cyanides.] In: Filov VAA, ed. [Harmful chemical substances – inorganic compounds of elements of I-IV groups.] St. Petersburg, Himiya, pp. 331-352 (in Russian).
[81] CICAD 61, citing Minkina NA (1988) [Hydrogen cyanide and cyanides.] In: Filov VA, ed. [*Harmful chemical substances — inorganic compounds of elements of I–IV groups*.] St Petersburg, Himiya, pp. 331–352 (in Russian).
[82]CICAD 61, citing Minkina NA (1988) [Hydrogen cyanides and cyanides.] In: Filov VAA, ed. [Harmful chemical substances – inorganic compounds of elements of I-IV groups.] St. Petersburg, Himiya, pp. 331-352 (in Russian).
[83] ATSDR (2004)

humans after dermal exposure to cyanide gases or inorganic salts.[84] The only evidence that cyanides can be absorbed through the skin of humans is provided in case reports of the toxic effects after accidental dermal contact with cyanide. The limited data on acute poisonings is attributable in a large part to difficulties in conducting investigations due to the high acute toxicity of cyanide.[85]

The available data on the human health affects of the dermal route of exposure is often based on information extrapolated from animal testing.[86] In these studies the reports do not indicate the location of the skin area being tested, which may affect the absorption characteristics. The ATSDR document reported that the average LD50 value for dermal exposure to hydrogen cyanide for humans is estimated to be 100 mg/kg.[87]

Part 2 – The Incidents

1197 Broad Street

Building Description

The fire at 1197 Broad Street was in an occupancy called the El Fogon Restaurant. The building was a one story commercial structure built in 1970[88]. The main building measured twenty-eight feet by forty-two feet. The construction methods and floor layout reflected the style for fast food restaurants of that time period. The kitchen and food preparation areas also reflected fast food restaurant style décor. The wall finishes for this portion of the restaurant were fiber reinforced plastic (FRP) panels.

There were aspects of the building's construction that did not fit the standard definitions of the National Fire Protection Association's Standard 220, Types of Building Construction. These aspects made it difficult to classify the building's construction methods either as Non-Combustible Type II or Wood Frame Type V. Because the building's walls were not exclusively constructed of non-combustible materials, it was decided to classify the building as Wood Frame Type V, with non-standard modifications.

The building had a steel skeleton frame. The interior component of the side walls consisted of light gauge steel panels. The exterior component of the building's walls consisted of sheets of oriented strand board (OSB) with a brick veneer covering. Sandwiched between the OSB exterior and metal interior there was fiberglass insulation. See Photo 1.

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[84] Id.
[85]CICAD 61, citing Minkina NA (1988) [Hydrogen cyanides and cyanides.] In: Filov VAA, ed. [Harmful chemical substances – inorganic compounds of elements of I-IV groups.] St. Petersburg, Himiya, pp. 331-352 (in Russian).
[86]ATSDR (2004) p. 85.
[87]ATSDR (2004) p. 16.
[88] Commercial Property Tax Records, City of Providence RI

Photo 1

Large commercial windows were held in place by tubular metal frames. The windows had steel roll up burglar protection. These windows were located in the front of the building on Sides 1, 2, and 4.[89]

The roof deck consisted of light gauge metal panels placed sided by side. The roof deck was supported by a steel frame. The steel frame had two inch tubular cross members spaced approximately six feet apart that supported the metal deck roof.

On the interior of the structure, the under side of the metal deck portion of the roof was covered by rigid foam insulation panels. The rigid foam insulation panels were approximately two inches thick and could be seen throughout the structure except where heat from the fire had melted the foam. See Photo 2.[90]

[89] Under the Providence Fire Department Incident Command System, the sides of the building are designated with numbers, with Side 1 being the front, and the remaining sides being designated in a clockwise order. In addition a building is divided into 5 quadrants. Quadrant A is the corner of the building where Sides 1 and 2 meet. Quadrants B, C and D represent the other three corners designed in a clockwise fashion from Quadrant A. Quadrant E is the center of the building.

[90] Photo 2 does not depict the only area that the foam had melted, but rather one small area. The foam melted extensively in the area of origin, as well as in several other areas due to heat being conducted by the metal deck roof.

Photo 2

A decorative suspended ceiling was hung below the metal deck roof and foam panels creating a plenum space of approximately ten inches between the suspended ceiling and the metal deck roof.

On the exterior a second roof system was then laid over the metal deck roof. This portion of the roof was constructed of two inch by six inch wood joists that supported a plywood deck. See Photo 3. There was a six inch void space between roof systems. Fiber board insulation was then placed over the plywood and covered with a rubber membrane. The rubber membrane was sealed with a black tar like adhesive.

Photo 3

In addition to the roof deck, a decorative triangular shaped wood-frame façade was built around the entire roof that gave the building a mansard-like appearance. This façade created an over hang that extended five feet beyond the exterior walls. The back side of this façade (the side that faced toward the center of the building) extended vertically four feet above the flat roof deck creating an enclosure that housed roof top mechanical equipment, and hid it from anyone looking at the roof from ground level. The weather side of the vertical portion of the façade was covered with the same rubber membrane material that sealed the plywood deck.

The façade was constructed of two by four joists covered with 3/8" plywood. The façade created a triangular-shaped void space around the entire building. See Photo 4. The outer face of the façade was covered with standard asphalt shingles.

There were two additions to the building's original footprint. The first was a twenty foot by seven foot masonry (cinder block) structure on Side 3. This addition created a utility room, four feet by seven feet, and a walk in freezer that measured approximately three feet by seven feet. The utility room had an exterior door that exited to outside through Side 2. This doorway consisted of a metal covered door in a metal frame. For security purposes a steel gate was fashioned and fit into the metal frame along with the metal door.

The second addition was a wood frame structure measuring approximately twelve feet by sixteen feet, that attached directly to the utility room addition. This second addition was used for storage and the space was accessed through an exterior door on Side 2. See Photo 4.

Photo 4

The two additions had wood frame roofs which abutted the original building's façade. The roofs were covered with standard asphalt shingles. See Figure 1 for the floor plan.

Operations

At 10:35 hours on Thursday, March 23, 2006, the Providence Fire Department Bureau of Operational Control (BOC) dispatched units to 1197 Broad Street for a report of a possible building fire.[91]

The relative humidity was twenty-eight percent; the recorded high for that day was fifty seven degrees Fahrenheit. Weather records also indicate a northerly wind with sustained winds of seventeen miles per hour, and the highest gust being recorded at twenty-two miles per hour. [92]

A first alarm assignment was Engines 11, 8, 3; Ladders 5 and 1; Special Hazards1; Division 1 and Rescue 1. Because multiple calls were received reporting a building fire, the BOC also assigned Ladder 4 as the Fast Company[93] on the original dispatch.

Ladder 5 was the first unit on the scene, at 10:38 hours.[94] The officer of Ladder 5 reported a light smoke condition upon arrival. Several seconds later he reported "Code Red", the Providence Fire Department's code word for a working fire.

Ladder 5's officer and one firefighter entered the building through the front door that restaurant employees had opened. They observed the fire in the ceiling area above the frialator, and in the hood system for the frialator. The other two members of Ladder 5 went to the roof via their aerial ladder to begin roof ventilation.

At 10:40 hours Engine 8 advanced 200' of 1 ¾ " hose line through the front door on Side 1. [95] The members of Engine were directed to Side 3 Quadrant B by the officer of Ladder 5. In this area the members of Engine 8 and Ladder 5 extinguished visible fire in the ceiling area.

At 10:41 hours Division 1 arrived on scene and established Broad St. Command. [96]

Engine 3 was the third engine to arrive on scene, and advanced a second line into the building. Three members of the four man crew of Engine 3 stretched 200' of 1 ¾" hose to the interior of the structure through the front door while the chauffeur donned his gear.

At 10:44 hours Broad St. Command designated the officer of Engine 8 as the First Floor Sector officer, and assigned Engines 8 and 3, and Ladder 5 to the First Floor Sector.[97]

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[91] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1035.22. Note: The times on the digital time stamp of the recordings may differ from the times given by the dispatchers over the radio by up to two minutes due to differences in the clocks.
[92] WPRI Weather, Meteorologist Tony Patrarca
[93] FAST Company, or Firefighter Assist Search Team is a rapid intervention crew.
[94] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1038.23
[95] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1040.49
[96] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1041.26
[97] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1044.40

Smoke conditions began to become heavy. Smoke appeared to be concentrated on Sides 2 and 3. The wind also became a factor as it was blowing across the building in a northerly direction from the Side 1/4 corner to the Side 2/3 corner of the building. See Photo 5.

Photo 5

The chauffer of Engine 3 teamed up with the chauffer of Ladder 1 to force entry on the roll up doors using a K-12 saw to cut the padlocks. The only other egress from the structure, other than the front door, was a metal frame door on Side 2. Blocking egress from this door was a steel gate which was fitted into the doorway frame.

The members of Ladder 1 attempted to force the steel gate and metal frame door on Side 2. As they attempted to force the door, the K-12 saw being used cut-out as smoke conditions worsened in the area. The saw cut out a second time while attempting to cut the locks on the roll up doors on Side 2.

The members of Special Hazards 1 arrived on scene took over forcing the steel gate. They also assisted with forcing the roll up doors. At that time the chauffer of Engine 3 moved to the interior to rejoin his crew.

At 10:45 hours Broad St. Command radioed the First Floor Sector (Engine 8) that there was fire venting above their interior position.[98] First Floor Sector received the message and asked for additional ladder men inside to open up the ceilings on the interior.

During this same time period Ladder 1 radioed Broad St. Command and informed him that fire was venting out of the roof in the rear of the building. After making this report the entire crew of Ladder 1, moved to the interior to assist companies operating on the inside.

After establishing a water supply by laying feeders to Engine 8, Engine 11 (the second arriving engine company) stretched 200’ of 1 ¾” hose line to the exterior of side 3 of the

[98] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1045.56.

structure. They then moved their hose line to the roof of the attached walk-in freezer using a ground ladder. At 10:45 hours Engine 11 asked to have their line charged.[99]

Broad St. Command requested an additional engine and ladder at 10:47 hours. [100] At 10:50 hours Engine 3 radioed Broad St. Command and asked if the fire appeared to be darkening down on Side 2. [101] Broad St Command replied that the fire was coming out of the roof at the Side 3/4 corner. He also informed Engine 3 they may have to back out.

The First Floor Sector Officer advised Command that they were having difficulty breaking through a metal ceiling.

At 10:55 hours, the Department Safety Officer radioed the BOC requesting the time of dispatch. [102] Upon confirmation of the elapsed time, Broad St. Command ordered all companies out of the building.

Broad St Command assigned Engine 13 and Ladder 2 to Side 2 of the exterior of the building. Command then assigned Battalion 3 to be the Side 2-3 Sector Officer. Battalion 3 reported back to Command that heavy fire was venting from the roof. Broad St. Command confirmed that all companies were out of the building at 11:00 hours.[103]

At 11:03 hours, Side 2-3 Sector Officer (Battalion 3) reported to Command that good progress was being made. [104] Companies were able to open the soffits by pulling down the plywood from the building's five foot over hanging façade and apply water to the fire.

The fire was placed under control at 11:21 hours. [105] The recall of the still box was at 12:05 hours. [106]

Discussion

The fire at 1197 Broad Street apparently started in the frialator and spread to the hood system above the frialator. Restaurant employees on the scene had just begun to prepare the restaurant to open for the day when they observed the fire. The employees evacuated the restaurant and at some point apparently left the scene taking the keys to the building, which necessitated the forcible entry to various doors and security devices.

During post incident review of the fire, the officer of Ladder 5 reported the initial smoke and heat conditions to be light. On the interior of the structure he could see the fire above the frialator in the ceiling area. He also stated that fire could be seen in the hood system above the frialator.

[99] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1045.56.
[100] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1047.41.
[101] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1050.17.
[102] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1055.28.
[103] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1100.47.
[104] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1103.47.
[105] Recorded Audio Files, Providence Fire Department 2006, c1111_23_03_2005_1121.59.
[106] Providence Fire Department Incident Report #8306, (2006).

On the roof, the hood system for the frialator vented in B Quadrant (where Sides 2 and 3 join). After the fire, it was determined that the fire initially reported to be coming through the roof was actually fire coming from the roof top ventilator for the hood system See Photo 6.

Photo 6

The fire spread from the ventilator to the back side of the building's decorative façade. The fire burned into the void space within the façade, and spread around the entire façade.

After being withdrawn from the building many companies operated on Side 2 and Side 3 of the building. These companies reported operated intermittently in heavy smoke conditions as the wind would periodically blow the smoke down to ground level, and then the smoke would clear. Companies working on the exterior of Side 4 operated in essentially no smoke. Companies operating inside the building reported operating in no smoke.

Before being withdrawn the companies operating on the interior reported they had extinguished all fire visible from the inside. After some initial confusion it became apparent that the main body of the fire would only be accessible from the exterior of the building. Once the void space was opened up on all sides, the fire was contained in relatively short order. It was later determined that the roof deck was safe and companies were able to extinguish the back side of the façade from the roof.

One firefighter from Ladder 1 was transported from the scene to Rhode Island Hospital for a shoulder injury. Another fire fighter, the chauffeur of Engine 3, was later transported to Rhode Island Hospital after returning to his station. The firefighter complained of an increasing headache, difficulty breathing with shortness of breath, fatigue, a cough and rapid heart rate. Members who worked with him stated that after the fire he was talking incoherently.

125 Knight Street

Building Description

The building at 125 Knight Street was a large multiple dwelling, typical for the type of construction in the Federal Hill area of the city. From the tax records it was determined to have been built in the early1900's.[107]

The building measured fifty feet by thirty-eight feet. See Figure 2. The building was classified as a three story Wood Frame Type V construction. See Photo 7. The building contained six apartments, with two apartments on each floor. There were center stairwells on Side 1 and Side 3 of the structure. The building was partitioned in the middle by a wall running from Side 1 to Side 3, that served to separate the apartments on each floor.

Photo 7

With the exception of the first floor apartments, all apartments had access to the front and rear stairwells. The first floor apartments had egress to the rear stairwells but had separate front entrances from the street. In addition, the first floor apartment had a 3rd egress door on Side 4. There was a slight elevation difference from the front to back such that the first floor front was at street level, where as the first floor was several feet below grade in the rear.

The fire apartment was on the first floor, Side 4. The apartment had two bedroom areas, a small living room area, kitchen, and a bathroom. One bedroom was located at the rear of the apartment. The other bedroom was just to the left upon entering the door from side 1. The rear bed room was where the fire appeared to have started and had the most extensive fire damage.

[107] Property Tax Records, City of Providence RI

Operations

On the evening of 23 March 2006 at 17:37 hours the Providence Fire Department Bureau of Operational Control dispatched units to 125 Knight Street for a report of a building fire. [108] Engines 14, 3, 6; Ladders 6 and 1; Special Hazards 1; Battalion 2; and Rescue 6 were dispatched. Engine 8, who was clearing from a rescue run nearby, responded as well.

Engine 14 arrived on scene at 17:39 hours and reported a “Code Red”. [109] The officer’s size-up reported that building was a three story wood frame, six unit multiple dwelling, with fire on the first floor in the rear of the building.

Battalion 2 requested an additional Engine for a command company. He also instructed Rescue 6 to establish an EMS sector upon arrival to the scene. Battalion 2 then requested a second rescue. The chauffer of Engine 14 reported that he had a hydrant located adjacent to his truck at 17:40 hours. [110]

Battalion 2 established Knight Street Command at 17:42 hours and Engine 6 acknowledged they would lay feeders from the hydrant to Engine 14. [111] The BOC notified Command that Engine 8 was dispatched as the command company,[112] and Ladder 4 was dispatched as the Fast Company.

Engine 14 stretched 200’ of 1 ¾” hose line to Side 3 (rear) of the building and entered the rear door and stairwell. See Photo 8. Engine 14 was accompanied by two members of Ladder 6, the officer and one firefighter. The remaining two members of Ladder 6 went to the roof via Ladder 6’s aerial, to perform vertical ventilation.

[108]Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1737.39.
[109] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1739.35.
[110] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1740.29.
[111] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1742.28.
[112] A command company is a company dispatched to provide the incident commander with assistance and support in managing the incident. In this case there was some confusion as to who was the Command Company. As a result Engine 8 ended up being given a tactical assignment.

Photo 8

Engine 14 was designated as the First Floor Sector officer. Command requested an additional Engine and Ladder at 17:43 hours. [113] At 17:45 hours Command also instructed Engine 14 to check the basement and ensure there was no fire in the basement. [114] Command then asked for an additional chief officer.

Engine 3 stretched a 200' 1 ¾" hose line through the rear door to the second floor Side 3-4 of the building. Command designated Engine 3's Officer as the second floor sector officer. Command then instructed Engine 6 to be the third floor sector officer. The officer of Engine 6 apparently did not hear this message.

Engine 8 deployed to Side 4 (Penn Street side) and was in the process of forcing a door that led to the fire apartment. The members of Engine 6 stretched 200" of 1 ¾" hose line to the same doorway on Side 4. Command received a report from some bystanders that a civilian may be trapped on the second floor Side 4. Apparently the bystanders saw someone try to open a window several times, only to have it slide shut.[115] Command instructed Engine 8 to enter the window via a ground ladder to search for a trapped civilian. Command informed the BOC of this at 17:45 hours. [116]

Engine 8's departure left Engine 6 alone on Side 4 at the door. The top of this door was partially burned away and heavy smoke was emanating from the doorway as Engine 6's crew attempted to remove the door.

The nozzle man for Engine 6 donned his face piece while Acting Lieutenant of Engine 6 and FF Baker completed forcing the door. Once the door was opened, the nozzleman advanced into the doorway over a pile of smoldering debris. He advanced about ten feet in to the fire area and began extinguishing fire.

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[113] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1743.29.
[114] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1743.51.
[115] It appears this may have been a member of Special Hazards that was opening the window, but smoke conditions obscured his identity.
[116] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1745.31.

Before donning their face pieces and entering the doorway, the Acting Lieutenant and FF Baker began to remove some of the burning debris from the doorway. They removed this debris using a plaster pole and halligan tool for about 2-3 minutes. After removing the debris the Acting Lieutenant and FF Baker donned their face pieces and entered the building, working in the fire room along with Engine 14. The members of Engine 6 moved their line back and forth between the fire room and living room of the fire apartment.

Command then received a radio report from Engine 14 stating that the fire was knocked down in the basement apartment.[117] Because the building was located at an intersection, Command confirmed that Side 1 of the building was Knight St., Side 3 was the rear of the building, and Side 4 was Penn Street. Command instructed the BOC to re-broadcast this message.

At 17:48 hours, Command requested the Second Floor Sector to check the room above the fire on Side 3/4. [118] He received a report from the officer of Ladder 1 that the primary search for that room was negative.

During this same transmission Command reported to the BOC that he had four lines in operation and that the fire was doubtful at that time. At 17:50 Command received a report from Special Hazards that a secondary search on the second floor was negative.[119] This was the area that a civilian was believed to have been trapped in.

Engine 8 confirmed this report after entering the window. Command then received a report from Engine 14 that the basement apartment was negative. Command then called Engine 6 over the radio for the status on the primary search on the third floor.

Engine 6 reported that he was operating on the first floor. Command informed Engine 6 he was assigned to the third floor sector. Ladder 1 radioed Command and informed him that the primary on the third floor was negative. Not hearing this transmission, the Acting Lieutenant and FF Baker made their way to the third floor. Engine 6's nozzleman remained in the fire apartment with the crews of Engine 14, Ladder 6.

The Acting Lieutenant and Baker searched the third floor apartments and notified command that the primary search on the third floor was negative. They then returned to the fire apartment and continued overhauling the fire apartment with the nozzleman.

At 17:53 hours Command called the basement sector and asked if the fire had been knocked down. Engine 14 reported affirmative.[120] Command then asked Engine 14 if he could move from the basement to the first floor, if needed.

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[117] While Engine 14 referred to this apartment as the basement apartment it was in reality the first floor apartment. The confusion was related to the fact that the first floor was partially below grade in the rear.
[118] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1748.35.
[119] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1750.10.
[120] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1753.26.

Upon hearing this request Engine 8 informed Command that his crew was in a position to redeploy to the first floor if needed. Engine 14 informed Command at 17:55 hours that Engine 14 was already in a position to cover the first floor, and that the rear of the building was slightly below grade. [121]

Knight St. Command radioed a probable will hold at 17:56 hours. [122] The fire was placed under control at 18:07 hours. [123] The recall of the still box was at 20:14 Hours. [124]

Discussion

When Engine 14 arrived fire was self venting from the window of the first floor apartment on Side 3 (Quadrant C). Engine 14 descended four stairs to the rear door of the first floor apartment. To the right of this location was the rear door for the other first floor apartment (Quadrant B).

The slight elevation difference and the actions of Engine 14 descending the rear stairs to the fire apartment created some confusion as to whether the fire was on the first floor or in the basement. Engine 14 had reported the fire to be on the first floor. Command asked Engine 14 to check the basement. Engine 14 informed Command he had knocked down the fire in the basement apartment. Command later asked the basement sector for a progress report, and Command asked Engine 14 if they were in a position to redeploy to the first floor if needed.

Engine 14 had informed Command that Engine 14 could cover the first floor, and that the rear of the building was slightly below grade. With this transmission Command asked for a face-to-face with Engine 14. It was during this face-to-face that the issue of the elevation difference was rectified.

After the fire had been extinguished it was determined that a member of Special Hazards had been performing a search in the room on the second floor Side 4. He had attempted to open a window two times and each time it slid shut. He then continued his search. This action is what was believed to have been witnessed by the bystanders, and is believed to have been the basis for the report of a victim trapped on the second floor Side 4.

The burning debris that Engine 6's Acting Lieutenant and FF Baker removed from the doorway consisted of what appeared to be a crib mattress, plastic bags of clothing, and plastic toys. In addition, the fire apartment contained a mattress, box spring, television, stereo and other items. See Photo 9. The area had wall to wall carpeting with underlayment (padding) beneath the carpet. It was apparent that the short hallway from the rear bedroom to the Penn St. side of the building was used as a storage area and not used as a regular means of egress into the apartment.

[121] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1755.08.
[122] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1756.17
[123] Recorded Audio Files, Providence Fire Department 2006, c1212_23_03_2005_1807.02
[124] Providence Fire Department Incident Report # 8352, (2006).

The firefighters who had responded reported that the fire damage in the rear bedroom was quite extensive. One fire fighter reported that only the coils remained of the mattress and box spring that was located in that room. The cause of the fire was determined to be accidental, related to careless disposal of smoking materials igniting the bed.

Photo 9

70 Ralph Street

Building Description

The building at 70 Ralph Street was single family residential home. The two story Type V wood-frame construction was built in 1930, and measured twenty-three feet by forty-four feet. [125] See Photo 10 and Figure 3. The fire was reported to be in the kitchen but was actually in the bathroom in the rear of the structure on the first floor.

[125] Property Tax Records, City of Providence RI

Photo 10

Operations

Engines 6, 8, 14; Ladders 2, 6; Special Hazards 1; Battalion 2; Rescue 2 were dispatched at 02:10 hours for a report of a kitchen fire at 70 Ralph Street.. [126]

Engine 6 arrived on scene first, and began investigating. Engine 6's crew consisted of a Lieutenant, FF Kenneth Baker (Chauffeur), and a firefighter (nozzleman). Engine 8 reported they had the hydrant at 02:12 hours. [127] At 02:13 Engine 6 reported a smoke condition on the first floor, and called a "Code Red". [128] Engine 6's Lieutenant reported that the fire was in a two story occupied dwelling. Engine 6's nozzleman stretched 200' of 1 ¾" hose line through the front door of the structure. The members of Engine 6 could see the fire was in the rear of the building.

Battalion 2 arrived on the scene and established Ralph St. Command. BOC informed Command that the Fast Company was Ladder 1. At 02:14 hours Engine 6 called FF Baker on the radio to ask that his line be charged, but the transmission was cut off. [129]

Ladder 6 arrived on scene. Two members went to the roof, while the officer and one firefighter proceeded to the first floor along with Engine 6. Engine 6 again requested that his line be charged and reported to Command that Engine 6 was operating on the first floor. This radio transmission was followed by the officer of Ladder 6 reporting to Command that the first floor primary search was complete and that it was negative. The BOC repeated this message and recorded the time as 02:16 hours. [130] Engine 6 asked to have his line charged a third time.

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[126] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0211.31.
[127] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0214.41.
[128] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0215.02.
[129] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0216.24.
[130] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0216.54.

Seconds after this block of radio transmissions, a fire fighter from Engine 8 radioed the chauffer of Engine 6 and asked if he was ready for the hydrant to be turned in. FF Baker who was chauffeuring Engine 6 replied “the hydrant is all set”.[131]

After having completed the task of establishing the water supply, the crew of Engine 8 proceeded to stretch 200’ 1 ¾” hose line to the second floor. A few moments later the E-8 firefighter who turned in the hydrant (and thus was a few minutes behind the remainder of his crew) asked FF Baker which line was Engine 8’s so he could follow it into the structure. FF Baker informed the firefighter that Engine 8’s line went around to Side 4. FF Baker then corrected himself and directed the firefighter to the correct line going to the second floor. Engine 8’s officer radioed Command and informed him that Engine 8 was on the second floor.

Engine 14 stretched 200’ of 1 ¾ “hose line to Side 4 of the structure. There they found a rear door to the structure. The Captain of Engine 14 had his crew standby at this rear door in a position to back up Engine 6. The Captain entered the structure to observe operations and conditions inside the structure. Within moments after Engine 6’s handline was charged, the fire was promptly extinguished.

Special Hazards 1 reported that the primary search on the second floor was negative. At 02:22 hours Command announced that all occupants were out of the building. [132]

Observing that the fire had been knocked down, Captain of Engine 14 then went out to the street for a face to face with Command. He recalled seeing FF Baker at his position operating Engine 6’s pump. The Captain walked past Engine 6 and over to Command and informed him that the fire was knocked down and confined to the area of the bathroom on the first floor.

After this brief discussion, the Captain of Engine 14 made his way back to his crew on Side 4. Command radioed the BOC to announce the fire was confined. The BOC recorded the time as 02:23 hours. [133]

At about the same time, the Rescue Technician assigned to Rescue 2, who had been standing by the front of Engine 6, expressed some concern to FF Baker about an air conditioner in a second floor window on Side 1 of the building. Firefighters were ventilating the area and the Rescue Technician was concerned the air conditioner may come out of the window and fall when the window was opened. FF Baker moved out of the way and was standing by the drivers door of Engine 6. At this point it is believed that FF Baker was stricken by the heart attack.

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[131] Recorded Audio Files, Providence Fire Department 2006. c1111_24_03_2006_0218.05. Note that this is not the normal response one would expect when asked if an engine company is ready for the feeders to be turned in.

[132] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0224.01.

[133] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0225.12.

The Rescue Technician witnessed FF Baker lean back against the drivers door of Engine 6, and slide down coming to rest against the front wheel of Engine 6. The Rescue Technician called out FF Baker's name and went to his aide. Hearing this, the Captain of Engine 14 and his crew turned to see the Rescue Technician assisting FF Baker.

The crew of Rescue 2 and Engine 14 attended to FF Baker, retrieved a gurney, and moved him to Rescue 2. Observing the commotion, Command radioed BOC for an additional rescue. The time was 02:25 hours. [134]

The crew of Rescue 2 and Engine 14 treated FF Baker according to RI Pre-Hospital Protocols. FF Baker was found to be in ventricular fibrillation, and was defibrillated twice by EMS personnel on scene. At 02:32 hours the BOC received a cell-phone call from the Captain of Engine 14 who was in Rescue 2 requesting BOC to notify Rhode Island Hospital that they would be coming in with a firefighter. [135] The BOC received a second cell-phone call from the Captain reporting that Rescue 2 and Engine 14 were responding to RIH and to inform the hospital it was "now a code".[136] The time of the second call was recorded at 02:33 hours.

The remaining companies completed extinguishment and overhaul. At 02:58 the fire was placed under control and Command notified the BOC that companies were picking up. [137]

The still box recall was at 03:46 hours. [138]

Discussion

The fire at 70 Ralph Street was a small fire, with actual fire damage confined to the bathroom. Smoke and heat damage was extensive on the first floor and extended up to the second floor. Photo 11 shows a plastic mixing bowl that melted in the kitchen area.

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[134] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0225.33.
[135] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0232.51.

[136] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0233.51. A "Code 99", or "code" for short, is the radio message indicating a victim is unconscious and has no pulse).
[137] Recorded Audio Files, Providence Fire Department 2006, c1111_24_03_2006_0258.59.
[138] Providence Fire Department Incident # 8393 (2006)

Photo 11

Also involved in the fire was a fiberglass bathtub. See Photo 12.

Photo 12

The fire was accidental in origin, apparently starting in an electrical ceiling fan in the bathroom. Operations for this fire were routine with the exception of FF Baker's heart attack.

Part 3 – History of Unexplained Health Issues Amongst Providence Firefighters

There are three health issues amongst Providence Firefighters that over the years have been unresolved. These issues are (1) a high level of sarcoidosis amongst members, (2) an incident in 1990 in which four members of the same shift all lost vision in their left eye, and (3) a high number of members experiencing cardiac abnormalities, in particular, atrial fibrillation.

Between 1986 and 1989 five Providence firefighters were diagnosed with sarcoidosis by their private physicians. Four of the five were in the same training academy that began in April of 1979. With the assistance of Dr. David G. Kern, research was conducted to confirm the diagnosis and screen additional members of that training academy.[139] However, a causal link between the five members and an occupational cause was never established. Subsequently at least three additional cases have been diagnosed. No formal screening of the entire fire department has ever been conducted for sarcoidosis.

In 1990, four firefighters assigned to B-Group. lost vision in their left eye over the course of a three-month period. Each member was diagnosed by their private physician. One case was diagnosed as macular degeneration. One case was diagnosed as a central retinal vein occlusion. The remaining two members were diagnosed with optic neuritis. Again with the cooperation and assistance of Dr. David G. Kern, the four were evaluated by a neuro-ophthalmologist, Dr. Simmons Lessell, MD, of Harvard Medical School, and the Massachusetts Eye and Ear Institute, who confirmed the diagnoses, and concluded the four cases were unconnected. See Appendix B. Subsequently at least one additional member suffered vision loss in his left eye associated with optic neuritis.

The third area of concern is a high number of members experiencing cardiac abnormalities. This concern arose out of anecdotal information from various members who approached the investigative committee with their concerns. The committee requested the Department Safety Officer to take a closer look at the problem by researching the department's injury/exposure database. Since January 1, 2005, thirteen members of the department have submitted injury reports for cardiac abnormalities. Among these thirteen, seven members were found to have been experiencing atrial fibrillation. Three of the seven members experiencing a-fib were transported from fire scenes. It is unknown if additional members have sought treatment from their private physicians for similar conditions.

These unusual occurrences have left many in the fire department concerned about a possible occupation linkage.

[139] Kern DG, Neill MA, Wrenn DS and Varone JC, Investigation of a Unique Time Space Cluster of Sarcoidosis in Firefighters, Am Rev Respir Dis, Vol 148, pp 974-980 (1993).

4. FF Kenneth Baker

Firefighter Kenneth Baker is a 50 year old firefighter born on September 25, 1955. He is married and lives in Pawtucket, Rhode Island. FF Baker has two children and two grandchildren.

FF Baker is a Navy Veteran having served on the USS Nimitz. He was hired by the Providence Fire Department in 1992, and has fourteen years of experience. Prior to the heart attack, FF Baker had two known medical conditions: he is a Type II non-insulin dependent diabetic and he takes medication for high blood pressure. He has managed his diabetes well since it was first diagnosed in 1996. Prior to the heart attack he was generally in good health and led an active life that included bowling, riding motorcycles and hunting. Ken's medical history includes surgery in 2000 on his cervical spine, and carpal tunnel surgery in the early 1980s on his left wrist.

PROCEDURES

The cyanide exposures which occurred on 23 March 2006 triggered an automatic investigation by the Fire Department Investigative and Safety Officer, Battalion Chief Thomas Warren. Chief Warren organized the notification of members about the initial cyanide exposure, including the recommendation that members with symptoms report to Rhode Island Hospital for follow-up testing. Chief Warren immediately began collecting information relative to the incidents and cyanide poisoning. On March 24, 2006, after FF Baker's heart attack, Chief Warren went to the Air Supply Station located in Engine 5's quarters at 155 Humbolt Avenue. With the assistance of Captain David Falaguerra of Engine 5, Chief Warren obtained the air samples from both the house air supply system, and the truck-mounted system.

Four samples were tagged with the date, time, and location where the sample was taken. Chief Warren then went to Engine 6's quarters at 489 Hartford Avenue at 1245 hrs. on March 24, 2006 and collected the following personal protective equipment belong to FF Kenneth Baker and used on his work shift that started at 1800 hrs on March 23, 2006.

1 Fire helmet.
1 Pair of rubber fire boots.
1 Pair of leather firefighting gloves.
1 Pair of blue uniform pants with leather belt.
1 Pair of bunker pants with suspenders attached color yellow
1 Fire coat color yellow*
1 Scott face mask
1 4.5 Scott SCBA serial number 19700110

* The yellow fire coat was cut from the waist area to the neck area by fire department personnel during their efforts to revive FF Baker at the fire scene at 70 Ralph Street. It should also be noted that all of FF Baker's personal protective equipment was in good condition.

FF Baker's gear had been taken by members of Engine 6/Rescue 2 from the Rhode Island Hospital Emergency Room back to the fire station. The gear was found hanging in the boot room off the apparatus floor in Engine 6's quarters. The gear was retrieved from the boot room and placed it in a plastic bag. The bag was sealed by tying it in a knot.

FF Baker's turnout gear and the air pack were taken to and secured in the records room at Headquarters along with other evidence relative to the investigation. This room contains the medical records for all members of the Department past and present, and is always locked. The only members of the Department who have keys to the Records Room are the Chief of Department, David Costa, the Assistant Chief of Department, Mark Pare and the Department Investigative/Safety Officer, Thomas Warren.

In the afternoon of March 24, 2006 Chief Warren contacted Mr. Joseph Martin at Shipman's Fire Equipment in Waterford Connecticut, explained what had occurred, and the need for cyanide testing of the air system. After discussing the options is was agreed that: (1) another set of routine air quality tests should be performed immediately and (2) an air test specific for cyanide needed to be performed.

Mr. Martin sent a representative from Shipman's to collect additional samples for testing on Saturday morning March 25, 2006. Mr. Martin did not want to use the samples collected by Chief Warren so as to ensure the quality of the testing results. Samples drawn by Shipman's for this testing included two samples from the air supply truck compressor, two samples from the air supply station compressor and a random bottle from the storage rack in the building. In addition six additional cylinders were taken in the event additional testing was needed.

It was determined that the samples collected by Chief Warren may be needed at a later date and would be kept locked in the records room in Fire Department Headquarters. Shipman's engaged Trace Analytics Inc. to conduct the routine air testing on the samples from the two compressors. Shipman's then sent the three remaining samples to St. Paul Travelers Laboratory in Winsor Connecticut, an AIHA Accredited Laboratory (# 100126) on March 27, 2006 for cyanide testing. The analysis was completed and a lab report was sent to the Providence Fire Department on March 28, 2006.

On March 24, 2006 Chief Warren contacted Mr. George Solitro from the Providence Water Supply Board to provide a copy of the latest testing for the water supply system. Mr. George Solitro indicated that the Water Supply Board routinely tests the drinking water quality and that the last sample taken was last February. Mr. Solitro sent a copy of the latest test results via fax to Chief Warren.

Also on March 24, 2006, Chief Warren requested the audio tapes of the radio transmissions of three fires that were recorded at the Bureau of Operation and Control. These tapes were delivered to Chief Warren on March 27, 2006 for the Cyanide Investigation Committee to review

On March 24, 2006, DAC Varone contacted Chief William Goldfedder, who maintains an email list of approximately 30,000 members of the fire service. An email was sent out soliciting information about cyanide exposures in the fire service. Chief Varone also made contact with also made with medical officers from the Phoenix Fire Department, (Dr. Tim England, MD), as well as Bob Halton, Editor of Fire Engineering Magazine, John Eversol, Steve Patrick, FBI Hazmat Response Team, and Dr. Tom Hales, from NIOSH. Local 799 President Paul Doughty contacted medical officers from the FDNY.

On Monday, March 27, 2006 Chief Costa formally appointed the investigative committee. The committee met, began formulating a plan, and responsibilities were delegated. Chief Costa and Local 799 Union President Paul Doughty agreed that immunity from departmental charges would be extended to all members who assisted the committee by providing information about the three fires. A meeting was held with Dr. Lee Okurowski, MD, MPH, at the Occupational and Health Center of Rhode Island, 410

South Main Street, Providence, RI 02903 to obtain some initial medical information on cyanide poisoning.

On Tuesday, March 28, 2006, Chief Warren made requests to NBC Channel 10, CBS Channel 12 and ABC Channel 6 news departments for video footage shot by the local news stations at the three fires. Video cassettes were made available by Channel 6 and 12 showing the three fire incidents. Channel 10 would not release their footage without a subpoena. A video cassette from Channel 12 was picked up by Chief Warren March 29, 2006. Lt. Kevin Jutras picked up a video cassette from Channel 6 on April 5, 2006.

On Tuesday, March 28, 2006, Lieutenant Kevin Jutras, Investigator Joseph Dorsey and Chief Warren went to the three fire scenes: 1197 Broad Street, 125 Knight Street and 70 Ralph Street. The members examined the scenes, collected evidence and took samples from each location. Lieutenant Jutras took extensive photographs of each location.

The first fire scene to be examined was The El Fogon Resturant at 1197 Broad St. A consent to search form was signed at the restaurant by the owner Rosa Rodriquez on 28 March 06 at 09:00 hrs. The fire scene was searched by team members, Battalion Chief Thomas Warren, Lt. Kevin Jutras, and Arson Investigator Joseph Dorsey. Arson Investigator Paul Colardo also assisted. Four samples of burnt items were seized at the scene for possible testing in the future. These items were marked as Items A through D:

A. Piece of the rubber membrane from the roof
B. Piece of burnt particle board from roof
C. Piece of burnt plywood backing from roof
D. Piece of rigid foam insulation from the underside of the metal roof

The second building searched was 70 Ralph St. The owner of 70 Ralph St., Georgeanne Famuyiro, had signed a consent at search at 08:45 hours on 28 Mar. 06 at 70 Ralph St. The team members examined the fire scene and seized some melted plastic from the 1st floor bathroom, marked as Item A. Arson Investigator Paul Colardo also assisted.

The third and final fire scene to be examined was 125 Knight St. The owner of the property, Gary Mariorenzi, signed the consent to search form on 28 March 06 at 06:30 hours at 125 Knight St. The fire scene was examined by the investigation team. Arson Investigator Paul Colardo also assisted. The team seized six items from the fire scene for future testing, marked as Items A through F.

A. Blue foam insulation from the exterior rear wall
B. Piece of vinyl siding from exterior rear wall
C. Piece of burnt carpet from rear bedroom
D. Piece of padding from under the rear bedroom carpet
E. Piece of carpeting from the living room
F. Piece of padding from under the carpeting in the living room

All the samples taken from the fire scenes were placed in unlined metal cans. The cans were sealed and were transported to 200 Chad Brown St. to be stored in the evidence room.

On Tuesday, March 28, 2006, DAC Varone created an MSAccess database to track various pieces of information relative to the investigation. All members who responded to any of the three fires were interviewed by members of the Cyanide Investigation Committee and the results were added into the database. Interviews began on Wednesday, March 29, 2006 and were primarily completed by Saturday, April 1, 2006 with the exception of a few members who were on vacation. Members were questioned about their activities and observations at the fires, and asked to sign a medical release that would allow the committee members to obtain the results of their blood tests for cyanide, lactic acid and carbon monoxide levels. A series of questions were used to direct members to estimate how long each member was exposed to smoke without their SCBA facepiece in place. The questions included: How long were you on scene at each fire, how long were you exposed to any type of smoke (heavy or light, and with or without your SCBA); how many SCBA bottles did you use; how long were you on air, and how long were you exposed to smoke without your facepiece on (including light or intermittent smoke). In answering the questions, members were encouraged to include any time they may have been exposed to smoke, even if they considered the exposure to be intermittent, minimal, or negligible.

On Monday, April 3, 2006, Chief Varone contacted Rhode Island Analytical Lab regarding the possible testing of FF Baker's turnout gear. Jim Gallagher, who is in charge on the Industrial Hygiene Group at Rhode Island Analytical, confirmed the ability of RI Analytical to perform testing on FF Bakers PPE, and recommended performing wipe tests. A Purchase Order was requested to allow the turnout gear to be wipe tested.

On April 4, 2006, Chief Varone and Lt. Jutras took FF Bakers turnout gear to Rhode Island Analytical Lab. The items were removed from the evidence room in Headquarters at 3:15 pm, and brought directly to RI Analytical. At 3:30 pm Chief Varone and Lt. Jutras met with Anthony E. Perrotti, President of RI Analytical, and James Mich, Vice-President of Operations. Upon further discussion the testing procedures and methodology it was agreed that wipe tests would be performed as follows:

Helmet – total cyanide present
Mask – total cyanide present
Jacket - cyanide per sq. inch
Pants - cyanide per sq. inch
Boots - total cyanide present
Gloves - total cyanide present

The items were turned over to RI Analytical, and a chain of custody record form was completed. After the conclusion of testing, BC Warren collected the evidence and returned it to the records room at Headquarters on April 17, 2006.

The committee gathered on Tuesday, April 4, 2006, Thursday, April 6, 2006, and Tuesday, April 11, 2006 to listen to the fireground radio audiotapes and watch the video tapes of the fires. By combining the information gathered during the interviews, the committee was able to develop incident time lines, and place personnel in certain locations on scene. This information was then combined with medical information to search for any trends among the members who tested high for cyanide poisoning.

A second survey was created to help understand and document the factors leading members to not wear their SCBA facepieces. This survey was given to all members who completed the initial interviews. See Appendix C

On Wednesday, April 12, 2006, Chief Warren provided Rhode Island Hospital with a request for the medical records of the members who had undergone testing for cyanide. On Friday, April 14, 2006, the lab results were released to the committee, and the data was entered into the database. The committee met on Friday, April 20, 2006 to analyze the final data and look for trends.

On April 27, 2006 the air pack and mask used by FF Baker at the Knight Street fire was examined and tested by Alan Moffat, Person-In-Charge of the Providence Fire Department Air Supply.

Between May 1 and May 4, doctors from NIOSH visited Providence to conduct a Health Hazard Evaluation relative to the cyanide exposures. Information was exchanged between the committee and the NIOSH investigators. In addition, meetings were held between NIOSH and Rhode Island Hospital at which committee members were permitted to attend.

During the course of the investigation, contact was made with the following:

Dr. William Bastan, PhD, Director of the Toxicology Lab at Rhode Island Hospital to answer question relative to the lab tests conducted;

Dr. Stephen Borron, MD, MPH, Clinical Professor and Director of Research, Emergency Medicine Division at University of Texas Health Science Center at San Antonio, an internationally noted expert on the medical toxicology of cyanide;

Jeff Emond, Senior Sensor Chemist, Biosystems

Dr. Thomas Hales, MD, MPH, NIOSH, Senior Medical Epidemiologist, Team Leader of the NIOSH Fire Fighter Fatality Investigation and Prevention Program – Cardiovascular, an occupational health specialist with expertise in firefighter health and safety;

Dr. John Halpin, MD, NIOSH, an occupational health resident;

Warner Haag, a chemist for Rae Systems

Dr. David G. Kern, MD, MPH, a former occupation health doctor with expertise in firefighter occupational safety and health issues;

Dr. Melissa Mcdiarmid, MD, MPH, an occupation health doctor with expertise in firefighter occupational safety and health issues;

Dr. James Mugyar, Professor of Chemistry, Rhode Island College, Providence, RI.

LIMITATIONS

The investigation committee acknowledges that our research and conclusions are based upon the information presently available to us. The committee does not have the expertise nor the resources to fully investigate all of the possible issues and sub-issues related to the subject at hand. In particular, we are unable to consider the effect that medication and underlying medical conditions may have had on the whole blood cyanide levels of members who were tested. It is hoped that NIOSH will conduct additional research to address the shortcomings of this report and further clarify our understanding of exactly what happened.

RESULTS

1. Results of Air Quality Testing of Air Supply

The laboratory tests conducted by Trace Analytics on March 28, 2006 on air from the Air Supply Station located at the Humbolt Avenue fire station and the mobile filling station located on the Air Supply Unit, were normal. See Appendix D.

The tests conducted by St. Paul Travelers Laboratory confirmed that the cyanide levels were within normal limits in all three sources, the Air Supply Station, the Air Supply Unit and the random bottle.[140] See Appendix E.

2. Results of Water Supply Board Tests

The most recent laboratory analysis of water from the Providence Water Supply Board indicated that cyanide levels were within normal limits. The test sample was collected on February 2, 2006 and testing was performed by the Rhode Island Department of Health. See Appendix F.

3. Results of Wipe Tests conducted on Firefighter Baker's Turnout Gear

The results of the wipe tests conducted on FF Baker's turnout gear are shown in Table 1, and show trace amounts of cyanide. See Appendix G for the complete report, including the methodology and testing procedures.

Table 1

Item	Wipe Area Sample	Cyanide Detected
Helmet	Entire outer surface	14 ug
Coat	4 ft^2 (back)	<0.5 ug/ft^2
Pants	1 ft^2 (left pant leg)	<2.0 ug/ft^2
Glove	Entire outer surface (left hand)	<0.5 ug
Mask	Entire outer surface	<0.5 ug
Boot	Entire outer surface (left boot)	0.5 ug

According to Dr. Stephen Borron, "The amounts that are reported appear very small (a toxic dose in man by ingestion is several milligrams and a lethal dose between 50-100 mg. At the microgram level, it seems unlikely that even if there were hand to mouth

[140] According to the laboratory, the abbreviations used are as follows: LT - Less Than; LOQ - Limit of Quantitation; ug – Micrograms; M is MG/m3---Milligram per cubic millimeter

transfer from the equipment that there would be the opportunity for poisoning by this route. I would not expect significant off-gassing nor skin absorption either."[141]

4. Results from FF Baker's SCBA

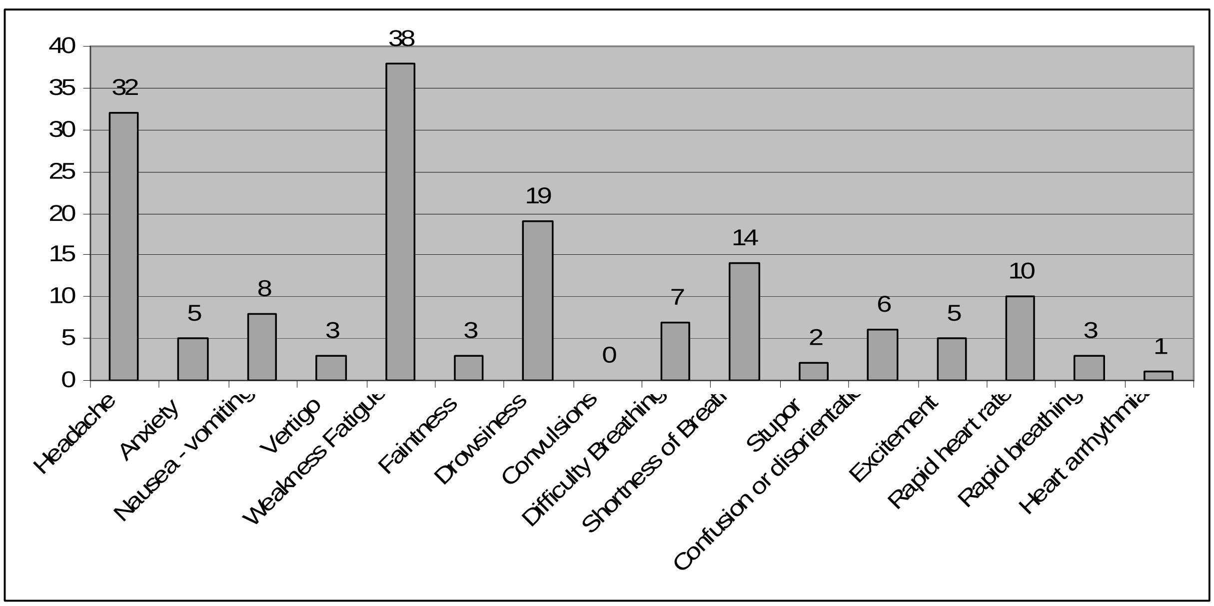
Tests performed on the air pack and facepiece used by FF Baker at the Knight Street fire showed the pack to be operating properly. See Appendix H. Copies of the most recent functional test for the air pack are also included.

5. Results from Firefighter Interviews and Blood Tests

A total of ninety-one firefighters responded to the three fires in question. Fifty-one responded to the Broad Street fire, forty-eight to Knight Street, and thirty-one to the Ralph Street fire. Four firefighters responded to all three incidents. None of those four members had cyanide levels of 20 ug/dL or higher.

Twenty-eight members sought medical attention as a result of the three fires. Twenty-seven members had their blood tested for cyanide. Twenty-six of those had their blood tested at Rhode Island Hospital, the other at St. Joseph's Hospital, Our Lady of Fatima Unit in North Providence. Table 1 shows the symptoms that members who responded to all three fires complained of.

Table 1 – Totals for all three fires

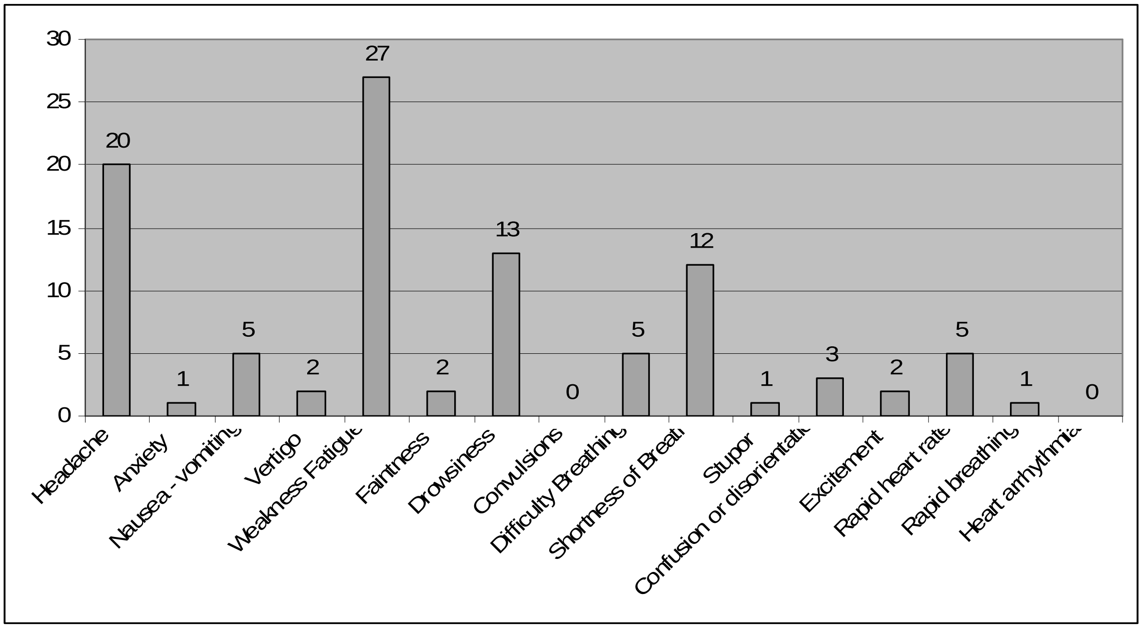


Of the fifty-one members who responded to the Broad Street fire, sixteen members (31.4%) sought medical attention, fifteen had their cyanide levels tested, and four had

[141] Email communication dated April 16, 2006.

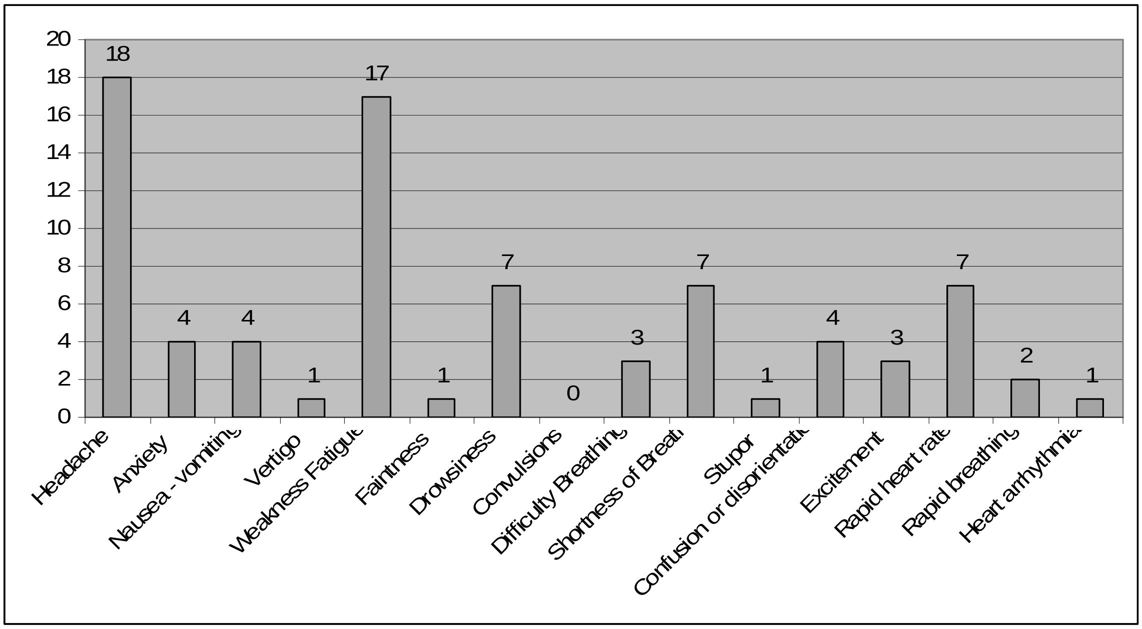
elevated cyanide readings above 20 ug/dL. Table 2 shows the symptoms reported by those responding to the Broad Street fire.

Table 2 – Broad Street



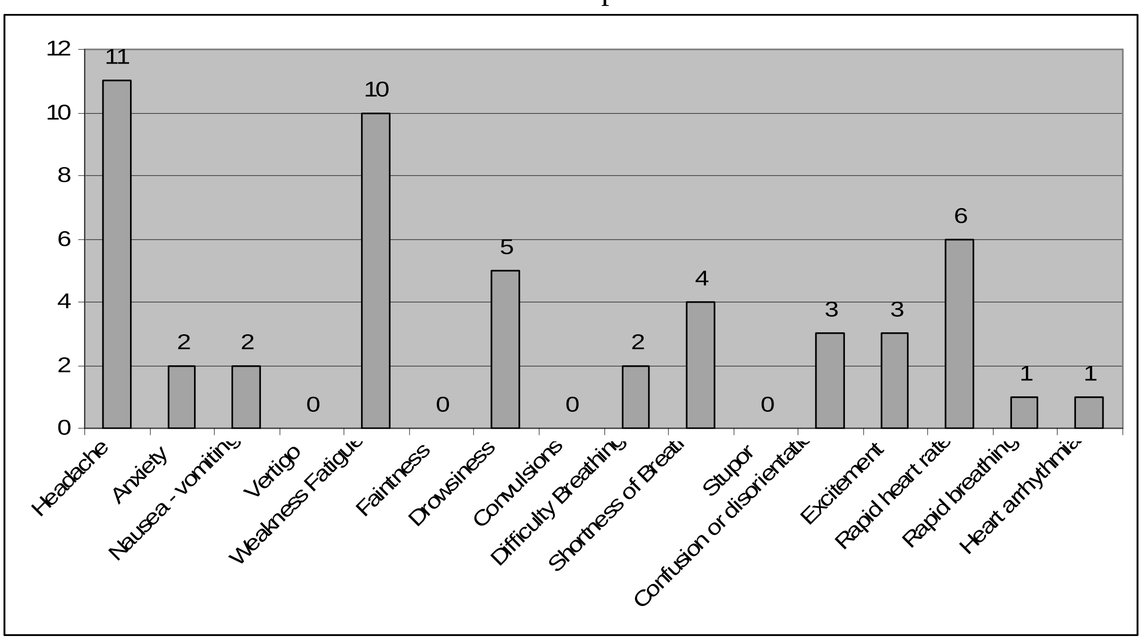
Of the forty-eight members who responded to the Knight Street fire, seventeen (35.4%) sought medical attention, all seventeen had their cyanide level checked, and five of the twelve had readings higher than 20 ug/dL. One of the complicating factors in understanding these results is that three of these five members also responded to the Ralph Street fire. In addition one of the remaining two members who had high levels of cyanide, is also one of the four members who had high levels after the Broad Street fire. Table 3 contains the symptoms reported by members who responded to the Knight Street fire.

Table 3 – Knight Street



A total of thirty-one members responded to the Ralph Street fire. Twelve members (39%) sought medical attention, but three of the twelve sought the medical attention prior to the Ralph Street fire due to their having been at the Broad Street fire. Of the nine remaining members, and all nine had their cyanide levels checked. Three of the nine had readings in excess of 20 ug/dL, and all three had previously been at the Knight Street fire. None of the three with high cyanide levels had been to the Broad Street fire. Table 4 contains the symptoms complained of by members who responded to Ralph Street.

Table 4 – Ralph Street



By querying the database, we found that only two members responded to the Ralph Street fire that had not responded to the Broad or Knight Street fires. One was a rescue technician who did not report a smoke exposure. The other was a fire lieutenant from Engine 6, the first due engine at the Ralph Street fire. Neither member reported any symptoms. The fire lieutenant reported a 5 to 10 minute exposure time without SCBA.

Table 5 lists the twenty-eight members who sought medical care, including the twenty-seven who had their cyanide levels tested, and which fires they responded to.

Table 5

ID	Rank	Regularly Assigned Company	Broad St.	Knight St.	Ralph St.	Cyanide Level ug/dL
1	Firefighter	L-2	X	X	X	17
2	Firefighter	SH	X			10
3	Firefighter	E-10	X			15
4	Firefighter	E-6		X		72
5	Firefighter	SH-1	X			22
6	Firefighter	E-11	X			10
7	Firefighter	E-15		X	X	16
8	Investigator	C-77		X	X	16
9	Firefighter	L-1	X			15
10	Firefighter	L-8	X	X		23
11	Captain	SH	X	X	X	19
12	Firefighter	E-3	X			57
13	Firefighter	E-6		X	X	66
14	Firefighter	L-6		X	X	51
15	Firefighter	E-6	X			54
16	Lieutenant	L6	X	X	X	16
17	Firefighter	E14		X		12
18	Lieutenant	E10	X			10
19	Firefighter	L1	X	X	X	14
20	Lieutenant	L5	X			12
21	Firefighter	L5	X			9
22	Firefighter	L-6		X	X	33
23	Firefighter	SH		X	X	7
24	Firefighter	SH	X			N/A
25	Firefighter	L-6		X	X	4
26	Firefighter	E-3	X	X		8
27	Captain	E-14		X	X	9
28	Firefighter	E-14		X	X	7

Table 6 shows a breakdown of twenty-eight members who sought medical attention with regards to (1) the total time each member was exposed to smoke at each incident, (2) the time each member worked in smoke without their facepiece in place, and (3) their whole blood cyanide level at the time of the test. The responses for time exposed to smoke and time without SCBA include total time members were exposed to intermittent smoke, as well as exposed to very light smoke.

Table 6

ID	Rank	Regularly Assigned Company	Broad St. Time Exposed	Broad St. Time W/O SCBA	Knight St. Time Exposed	Knight St. Time W/O SCBA	Ralph St. Time Exposed	Ralph St. Time W/O SCBA	Cyanide Level ug/dL
1	Firefighter	L-2	10 to 15 min.	10 to 15 min.	20 to 30 min.	10 to 15 min.	20 to 30 min.	5 to 10 min.	17
2	Firefighter	SH	20 to 30 min.	15 to 20 min.					10
3	Firefighter	E-10	45 to 60 min.	30 to 45 min.					15
4	Firefighter	E-6			45 to 60 min.	20 to 30 min.			72
5	Firefighter	SH-1	10 to 15 min.	10 to 15 min.					22
6	Firefighter	E-11	15 to 20 min.	10 to 15 min.					10
7	Firefighter	E-15			60 to 90 min.	45 to 60 min.	45 to 60 min.	30 to 45 min.	16
8	Investigator	C-77			60 to 90 min.	60 to 90 min.	45 to 60 min.	45 to 60 min.	16
9	Firefighter	L-1	30 to 45 min.	30 to 45 min.					15
10	Firefighter	L-8	30 to 45 min.	20 to 30 min.	0	0			23
11	Captain	SH	45 to 60 min.	30 to 45 min.	30 to 45 min.	15 to 20 min.	30 to 45 min.	10 to 15 min.	19
12	Firefighter	E-3	20 to 30 min.	10 to 15 min.					57
13	Firefighter	E-6			45 to 60 min.	30 to 45 min.	0	0	66
14	Firefighter	L-6			45 to 60 min.	45 to 60 min.	15 to 20 min.	15 to 20 min.	51
15	Firefighter	E-6	30 to 45 min.	15 to 20 min.					54
16	Lieutenant	L6	2 to 5 min.		60 to 90 min.	30 to 45 min.	45 to 60 min.	30 to 45 min.	16
17	Firefighter	E14			60 to 90 min.	10 to 15 min.	0	0	12
18	Lieutenant	E10	45 to 60 min.	15 to 20 min.					10
19	Firefighter	L1	30 to 45 min.	20 to 30 min.	15 to 20 min.	0	0	0	14
20	Lieutenant	L5	20 to 30 min.	15 to 20 min.					12
21	Firefighter	L5	15 to 20 min.	15 to 20 min.					12
22	Firefighter	L-6			30 to 45 min.	15 to 20 min.	20 to 30 min.	15 to 20 min.	33
23	Firefighter	SH			20 to 30	10 to 15	15 to 20	5 to 10	7

					min.	min.	min.	min.	
24	Firefighter	SH	5 to 10 min.	5 to 10 min.					N/A
25	Firefighter	L-6			20 to 30 min.	20 to 30 min.	15 to 20 min.	15 to 20 min.	4
26	Firefighter	E-3	45 to 60 min.	20 to 30 min.	30 to 45 min.	15 to 20 min.	0	0	8
27	Captain	E-14			30 to 45 min.	15 to 20 min.	5 to 10 min.	0 to 2 min.	9
28	Firefighter	E-14			45 to 60 min.	30 to 45 min.	5 to 10 min.	0 to 2 min.	7

Table 7 shows the cyanide levels of each member and the elapsed time between the blood draw and any of the fires that the member responded to. If a block is empty, it means the member did not respond to that particular fire.

Table 7

ID	Rank	Regularly Assigned Company	Broad St. Elapsed Time	Knight St. Elapsed Time	Ralph St. Elapsed Time	Cyanide Level ug/dL
1	Firefighter	L-2	9 hours	3 hours	* Note 1	17
2	Firefighter	SH	10 hours			10
3	Firefighter	E-10	13 hours			15
4	Firefighter	E-6		27 hours		72
5	Firefighter	SH-1	8 hours			22
6	Firefighter	E-11	10 hours			10
7	Firefighter	E-15		133 hours	125 hours	16
8	Investigator	C-77		133 hours	125 hours	16
9	Firefighter	L-1	10 hours			15
10	Firefighter	L-8	23 hours			23
11	Captain	SH	10 hours	4 hours	* Note 1	19
12	Firefighter	E-3	2 hours			57
13	Firefighter	E-6		8 hours	1 hour	66
14	Firefighter	L-6		11 hours	3 hours	51
15	Firefighter	E-6	8 hours			54

16	Lieutenant	L6	17 hours	11 hours	3 hours	16
17	Firefighter	E14		11 hours	3 hours	12
18	Lieutenant	E10	10 hours			10
19	Firefighter	L1	8 hours	3 hours	* Note 1	14
20	Lieutenant	L5	10 hours			12
21	Firefighter	L5	9 hours			12
22	Firefighter	L-6		11 hours	3 hours	33
23	Firefighter	SH		11 hours	3 hours	7
24	Firefighter	SH				N/A
25	Firefighter	L-6		11 hours	3 hours	4
26	Firefighter	E-3	16 hours	11 hours	3 hours	8
27	Captain	E-14		11 hours	3 hours	9
28	Firefighter	E-14		11 hours	3 hours	7

* Note 1 – member had blood tested between the Knight St. and Ralph St. fires.

Table 8 shows the results of the blood work on the members who were tested after the three fires, including whole blood cyanide, lactic acid and carboxyhemoglobin. Not all members were tested for lactic acid and carboxyhemoglobin.

Table 8

ID	Rank	Regularly Assigned Company	Cyanide Level ug/dL	Lactic Acid Level MEQ/L	CO Level %
1	Firefighter	L-2	17	2	
2	Firefighter	SH	10	1	
3	Firefighter	E-10	15	2	
4	Firefighter	E-6	72	1	
5	Firefighter	SH-1	22		
6	Firefighter	E-11	10		
7	Firefighter	E-15	16	1	
8	Investigator	C-77	16	2	
9	Firefighter	L-1	15	1	
10	Firefighter	L-8	23	3	
11	Captain	SH	19	1	
12	Firefighter	E-3	57	1	3

13	Firefighter	E-6	66	8.8	5
14	Firefighter	L-6	51	1	5
15	Firefighter	E-6	54	2	
16	Lieutenant	L6	16	1	
17	Firefighter	E14	12	1	3
18	Lieutenant	E10	10	1	
19	Firefighter	L1	14		
20	Lieutenant	L5	12	1	
21	Firefighter	L5	9		
22	Firefighter	L-6	33	2	5
23	Firefighter	SH	7	1	
24	Firefighter	SH	N/A		
25	Firefighter	L-6	4		
26	Firefighter	E-3	8		
27	Captain	E-14	9	1	3
28	Firefighter	E-14	7		

Table 9 shows the responses of all ninety-one members who responded to the three fires, listing their unit assignments for the fires, and the length of time they reportedly were exposed to smoke without their SCBA facepiece in place. The times that are listed include intermittent exposures and exposures to light smoke.

Table 9

				Time Exposed to Smoke without SCBA		
Rank	BroadCompany	KnightCompany	RalphCompany	Broad St.	Knight St.	Ralph St.
Battalion Chief	B-2	B-2		5 to 10 minutes	0 to 2 minutes	
Battalion Chief	B-3			0		
Firefighter	D-1			15 to 20 minutes		
Dep. Asst. Chief	D-1			5 to 10 minutes		
Lieutenant	E-10	E-7		20 to 30 minutes	0	
Firefighter	E-10			15 to 20 minutes		
Firefighter	E-10			15 to 20 minutes		
Firefighter	E-10			30 to 45 minutes		
Firefighter	E-11			15 to 20 minutes		
Firefighter	E-11			10 to 15 minutes		
Captain	E-11			20 to 30 minutes		
Firefighter	E-13			0 to 2 minutes		

Lieutenant	E-13			10 to 15 minutes		
Firefighter	E-13			20 to 30 minutes		
Firefighter	E-13			30 to 45 minutes		
Firefighter	E-3	L-1	L-1	20 to 30 minutes	15 to 20 minutes	0
Firefighter	E-3			20 to 30 minutes		
Lieutenant	E-3			30 to 45 minutes		
Firefighter	E-3			10 to 15 minutes		
Lieutenant	E-5			0		
Firefighter	E-5			30 to 45 minutes		
Firefighter	E-5	AS1		0	0	
Firefighter	E-5	AS1		0	0	
Firefighter	E-8			0 to 2 minutes		
Lieutenant	E-8			15 to 20 minutes		
Firefighter	E-8			20 to 30 minutes		
Firefighter	E-8	E-7		20 to 30 minutes	0	
Investigator	FPB			45 to 60 minutes		
Investigator	FPB			45 to 60 minutes		
Battalion Chief	HQ			5 to 10 minutes		
Lieutenant	L-1			30 to 45 minutes		
Firefighter	L-1			20 to 30 minutes		
Firefighter	L-1	L-1	L-1	20 to 30 minutes	0 to 2 minutes	0
Firefighter	L-1			30 to 45 minutes		
Firefighter	L-2			5 to 10 minutes		
Firefighter	L-2	L-2	L-2	10 to 15 minutes	10 to 15 minutes	5 to 10 minutes
Lieutenant	L-2			15 to 20 minutes		
Firefighter	L-2			20 to 30 minutes		
Lieutenant	L-4	L-6	L-6		30 to 45 minutes	30 to 45 minutes
Firefighter	L-4			2 to 5		

				minutes		
Firefighter	L-4			2 to 5 minutes		
Firefighter	L-4	L-4		5 to 10 minutes	0	
Firefighter	L-5			15 to 20 minutes		
Lieutenant	L-5			15 to 20 minutes		
Firefighter	L-5			15 to 20 minutes		
Firefighter	L-5			20 to 30 minutes		
Rescue Lt.	R-1		R-1	0		0
Firefighter	R-1		R-5	0		0
Firefighter	SH1			5 to 10 minutes		
Firefighter	SH1			10 to 15 minutes		
Firefighter	SH1			15 to 20 minutes		
Captain	SH1	L-2	L-2	30 to 45 minutes	15 to 20 minutes	10 to 15 minutes
Lieutenant		SH1	SH1		2 to 5 minutes	2 to 5 minutes
Firefighter		SH1	SH1		5 to 10 minutes	2 to 5 minutes
Firefighter		SH1	SH1		10 to 15 minutes	5 to 10 minutes
Firefighter		SH1	SH1		10 to 15 minutes	5 to 10 minutes
Captain		R-2	R-2		0 to 2 minutes	2 to 5 minutes
Firefighter		R-2	R-2		0 to 2 minutes	0 to 2 minutes
Firefighter		L-6	L-6		45 to 60 minutes	15 to 20 minutes
Firefighter		L-6	L-6		20 to 30 minutes	15 to 20 minutes
Firefighter		L-6	L-6			15 to 20 minutes
Firefighter		L-4			0	
Captain		L-4			0	
Firefighter		L-4			0	
Firefighter		L-2	L-2		2 to 5 minutes	5 to 10 minutes
Firefighter		L-2	L-2		5 to 10 minutes	15 to 20 minutes
Captain		L-1	L-1		2 to 5 minutes	0

Firefighter		L-1	L-1		5 to 10 minutes	0
Investigator		FPB	FPB		60 to 90 minutes	45 to 60 minutes
Firefighter		E-8	E-8		10 to 15 minutes	5 to 10 minutes
Firefighter		E-8	E-8		5 to 10 minutes	5 to 10 minutes
Lieutenant		E-8	E-8		2 to 5 minutes	0 to 2 minutes
Firefighter		E-8	E-8		5 to 10 minutes	2 to 5 minutes
Firefighter		E-7			0	
Firefighter		E-6	E-6		45 to 60 minutes	30 to 45 minutes
Firefighter		E-6			20 to 30 minutes	
Firefighter		E-6	E-6		30 to 45 minutes	0
Firefighter		E-3			30 to 45 minutes	
Lieutenant		E-3			10 to 15 minutes	
Firefighter		E-3			20 to 30 minutes	
Firefighter		E-3			20 to 30 minutes	
Firefighter		E-14	E-14		0	10 to 15 minutes
Firefighter		E-14	E-14		10 to 15 minutes	0 to 2 minutes
Captain		E-14	E-14		15 to 20 minutes	0 to 2 minutes
Firefighter		E-14	E-14		30 to 45 minutes	0 to 2 minutes
Deputy Assistant Chief		D-1			0	
Firefighter		B-2	B-2		0	0
Battalion Chief		B-2	B-2		0	0
Lieutenant		AS1			0	
Lieutenant			E-6			5 to 10 minutes
Firefighter			R-1			0

6. Fire Scene Analysis

The investigation team located fuels at all three fire scenes that are known to give off hydrogen cyanide in a fire.[142] At the Broad Street fire, rigid foam insulation panels were located in the ceiling and roof assembly. In addition, the roof consisted of a rubber outer membrane that was sealed with a black tar like adhesive. Portions of the roof contained asphalt shingles. The interior of the restaurant contained a significant quantity of fiber reinforced plastic (FRP).

At the Knight Street fire, among the burning contents were a crib mattress, plastic bags of clothing, plastic toys, electronic devices (television, stereo) the exterior of which were made of plastic, a mattress and box spring. Also the fire area was carpeted and had a foam padding beneath the carpet.

At Ralph Street, the fire was confined to the bathroom that contained a fiberglass tub that melted, and numerous plastic items. Heat from the fire was sufficient to melt plastic items in the adjacent kitchen area, as evidenced in Photo 11 and 12.

These fuels were among the most obvious sources of cyanide generating fuels present at the fire scenes. It was not possible to identify all of the cyanide containing fuels as some items were consumed by the fire, and others had been disposed of prior to the investigators examining the fire scenes. In addition there may have been some less obvious sources of cyanide.

7. Coordination of Fireground Activities in Relation to Member's Cyanide Levels

Figure 4 is a floor plan of the Broad Street fire, showing the approximate locations that four members with high cyanide levels reported to be working. The members all report having worked in other areas of the building as well, but Figure 4 reflects the areas where their areas of operation overlap. As is evident from Figure 4, all members with high cyanide levels at the Broad Street fire operated on Sides 2 and 3 of the building, which was the direction of the prevailing winds. In addition, three of the four reported having worked inside the structure as well.

Figure 5 is a floor plan of the Knight Street fire showing the approximate locations that the four members with high cyanide levels reported to be working. As was the case in Figure 4, members reported having worked in several locations at various times. Figure 5 shows the area of overlap. All four members who had high cyanide levels operated inside the fire room on the first floor.

[142] Samples from each location have been seized and remain in the custody of the Providence Fire Department. In light of the scientific data available concerning the presence of cyanide in various fuels, the investigation committee did not feel it was necessary to have the samples tested. The samples will remain in the evidence locker in the event that testing at a future date is warranted.

Figure 6 is a floor plan of the Ralph Street fire, showing the approximate locations of the three members with high cyanide levels. There appears to be no obvious correlation of high levels of cyanide to location of operation at the Ralph Street fire.

8. Symptoms and Work Locations

Thirty-eight of the ninety-one firefighters (41.8%) who responded to the three fires complained of weakness and fatigue, while thirty-two (35.2%) complained of headaches. These symptoms were the most common symptoms reported. Breaking these numbers down by incident allows us to look at symptoms and compare them to locations where members operated.

Table 10 shows the members who were at the Broad Street fire, and who complained of weakness or fatigue and/or headache, together with the locations in which they worked at the scene, and the length of time they were exposed to smoke without their SCBA. Members who had their blood levels checked for cyanide are identified by their ID number, and their cyanide levels are shown.

Table 10 – Broad Street

Rank	Company	Location 1	Location 2	Location 3	Headache	Weakness Fatigue	Time w/o SCBA
Deputy Assistant Chief	D-1	Outside Side 1	Outside Side 4		X	X	5 to 10 minutes
Firefighter	D-1	Outside Side 2	Outside Side 4	Inside Floor 1	X	X	15 to 20 minutes
(#3 CN = 15) Firefighter	E-10	Outside Side 2	Outside Side 2		X	X	30 to 45 minutes
Lieutenant	E-10	Inside Floor 1	Outside Side 2			X	20 to 30 minutes
(#21 CN = 9) Firefighter	E-10	Outside Side 2	Outside Side 2	Outside Side 1	X	X	15 to 20 minutes
(#6 CN = 10) Firefighter	E-11	Outside Side 3	Roof	Outside Side 3		X	10 to 15 minutes
Captain	E-11	Roof – Side 3	Outside Side 3	Outside Other		X	20 to 30 minutes
(#15 CN = 54) Firefighter	E-11	Roof – Side 3				X	15 to 20 minutes
(#12 CN = 57) Firefighter	E-3	Outside Side 4, 1, 2	Inside 1st Floor Side 3	Outside Side 2	X	X	10 to 15 minutes
(#26 CN = 8) Firefighter	E-3	Inside Floor 1	Outside Side 2	Inside Floor 1	X	X	20 to 30 minutes
Firefighter	E-3	Inside Floor 1	Outside Side 2	Inside Floor 1	X	X	20 to 30 minutes
Firefighter	E-8	Inside Floor 1	Outside Side 2		X	X	20 to 30 minutes

(#10 CN = 23) Firefighter	E-8	Inside Floor 1 toward rear	Inside Floor 1	Side 2	X	X	20 to 30 minutes
(#18 CN = 10) Lieutenant	E-8	Inside Floor 1	Inside Floor 1	Inside Floor 1	X	X	15 to 20 minutes
(#9 CN = 15) Firefighter	L-1	Outside Side 4, 2, 1	Inside Floor 1	Outside Side 1, 3	X	X	30 to 45 minutes
Lieutenant	L-1	Outside Side 2	Inside Floor 1	Outside Side 2		X	30 to 45 minutes
Firefighter	L-1	Inside Floor 1	Outside Side 3	Roof		X	20 to 30 minutes
(#19 CN = 14) Firefighter	L-1	Inside Floor 1	Inside Floor 1	Outside Side 3	X	X	20 to 30 minutes
Lieutenant	L-1	Outside Side 2	Inside Floor 1	Outside Side 2	X		30 to 45 minutes
(#1 CN = 17) Firefighter	L-2	Outside Side 2	Outside Side 4		X	X	0 to 2 minutes
(#16 CN = 16) Lieutenant	L-4	Outside Side 4	Outside Other	Outside Side 4	X	X	0 to 2 minutes
Firefighter	L-5	Inside Floor 1	Outside Side 2	Outside Side 2		X	15 to 20 minutes
Firefighter	L-5	Roof	Roof			X	20 to 30 minutes
Firefighter	L-5	Roof	Outside Side 4	Outside Side 2		X	15 to 20 minutes
(#20 CN = 12) Lieutenant	L-5	Inside Floor 1	Outside Side 2	Outside Side 3	X	X	15 to 20 minutes
(#2 CN = 10) Firefighter	SH1	Outside Side 1, 2	Inside Floor 1	Outside Side 1, and 4	X	X	15 to 20 minutes
(#24 CN - NA) Firefighter	SH1	Outside Side 3	Roof	Outside Side 1	X	X	5 to 10 minutes
(#5 CN = 22) Firefighter	SH1	Inside Floor 1	Outside Side 1 and 2	Outside Side 2 and 4	X	X	10 to 15 minutes
(#11 CN = 19) Captain	SH1	Outside Side 1	Roof		X		30 to 45 minutes

As is evident from Table 10, 16 of the 20 members (75%) who complained of headaches after the Broad Street fire operated on Sides 2 or 3, while 23 of the 27 members (85%) who complained of weakness and fatigue also worked on Sides 2 and 3.

Table 11 shows the members who responded to the Knight Street and Ralph Street fires that complained of weakness or fatigue and/or headache, together with the locations in which they worked, and the length of time they were exposed to smoke without their SCBA. Again, members who had their blood levels checked for cyanide are identified by their ID number, and their cyanide levels are shown.

Table 11

Rank	Knight Street	Ralph Street	Knight St. Co.	Knight Location1	Knight Location 2	Knight Location 3	Knight Time w/o SCBA	Ralph St. Co.	Ralph St. Time w/o SCBA	Ralph St. Location1	Ralph St. Location 2	Ralph St. Location 3	Headache	Weakness -Fatigue
#17 CN=12 Firefighter	X		E-14	Inside Floor 1	Inside Floor 1	Inside Floor 1	10 to 15 min.	E-14	0 to 2 min.	O/S Side 4	O/S Side 4	O/S Other	X	
#27 CN=9 Captain	X	X	E-14	Inside Floor 1	Inside Floor 1	Inside Floor 1	15 to 20 min.	E-14	0 to 2 min.	Inside Floor 1	O/S Side 1		X	
#28 CN=7 Firefighter	X		E-14	Inside Floor 1	Inside Floor 1	Inside Floor 1	30 to 45 min.	E-14	0 to 2 min.	O/S Side 4 - Inside Floor 1	O/S Side 1		X	X
Firefighter	X		E-3	O/S Side 4	Inside Floor 2	Inside Floor 2	30 to 45 min.						X	X
Lieutenant	X		E-3	Inside Floor 2	Inside Floor 2	O/S Side 2	10 to 15 min.							X
Firefighter	X		E-3	Inside Floor 2	Inside Floor 2	O/S Other	20 to 30 min.						X	
#4 CN=72 Firefighter	X		E-6	Inside Floor 1	Inside Floor 3		20 to 30 min.						X	X
#7 CN=16 Firefighter	X	X	E-6	Inside Floor 1	Inside Floor 1	O/S Other	45 to 60 min.	E-6	30 to 45 min.	Inside Floor 1	Inside Floor 1	O/S Other		X
#10 CN=23 Firefighter	X		E-7	O/S Other			0						X	X
(Resp. to Broad St.) Lieutenant	X		E-7	O/S Side 1	O/S Side 1	O/S Side 1	0							X

Firefighter	X	X	E-8	Inside Floor 2	Inside Floor 2	Inside Floor 2	5 to 10 min.	E-8	5 to 10 min.	Inside Floor 1	Inside Floor 2		X	
Firefighter	X	X	E-8	Inside Floor 2	Inside Floor 2	O/S Side 4	5 to 10 min.	E-8	2 to 5 min.	Inside Floor 1	Inside Floor 2		X	
#8 CN=16 Investigator	X	X	FPB	Inside Floor 1	Inside Floor 1	O/S Side 3	60 to 90 min.	FPB	45 to 60 min.	O/S Side 1	Inside Floor 1		X	X
Captain	X	X	L-1	Inside Floor 2	Inside Floor 3	Inside Floor 2	2 to 5 min.	L-1	0	O/S Other				X
#26 CN=8 Firefighter	X		L-1	Inside Floor 1	Inside Floor 1	Inside Floor 1	15 to 20 min.	L-1	0 to 2 min.	O/S Side 1	O/S Side 1	O/S Side 1	X	X
#19 CN=14 Firefighter	X	X	L-1	Inside Floor 2	Inside Floor 1	Inside Floor 2	0 to 2 min.	L-1	0 to 2 min.	O/S Side 1	O/S Side 1	O/S Side 1	X	X
#1 CN=17 Firefighter	X	X	L-2	Inside Floor 1	Inside Floor 1		10 to 15 min.	L-2	5 to 10 min.	Inside Floor 1	Inside Floor 1		X	X
#11 CN=19 Captain	X	X	L-2	Inside Floor 2			15 to 20 min.	L-2	10 to 15 min.	Inside Floor 1	Inside Floor 2		X	
#14 CN=51 Firefighter	X	X	L-6	Roof	Inside Floor 1		45 to 60 min.	L-6	15 to 20 min.	Roof			X	X
#25 CN=4 Firefighter	X	X	L-6	Roof	Inside Floor 1		20 to 30 min.	L-6	15 to 20 min.	Roof				X
#16 CN=16 Lieutenant	X	X	L-6	Inside Floor 1	Inside Floor 1	Inside Floor 1	30 to 45 min.	L-6	30 to 45 min.	Inside Floor 1	Inside Floor 1	Inside Floor 2	X	X

#22 CN=33 Firefighter	X	X	L-6	Inside Floor 1	O/S Side 3	Inside Floor 1		L-6	15 to 20 min.	Inside Floor 1	Inside Floor 1	Inside Floor 1		X
#23 CN=7 Firefighter	X	X	SH1	Inside Floor 2 and 3rd floor	Inside Floor 2 - sides 1 and 2		10 to 15 min.	SH1	5 to 10 min.	Inside Floor 2			X	
Firefighter	X	X	SH1	Inside Floor 2	Inside Floor 2	Inside Floor 2	5 to 10 min.	SH1	2 to 5 min.	Inside Floor 2	Inside Floor 2	Inside Floor 2	X	
Firefighter Note: O/S = Outside	X	X	SH1	Inside Floor 1	Inside Floor 1	Inside Floor 1	10 to 15 min.	SH1	5 to 10 min.	Inside Floor 1	Inside Floor 2	Inside Floor 2		X

Table 11 indicates that 10 of the 18 members (56%) who complained of headache at either the Knight or Ralph Street fires operated at the Knight Street fire in the first floor (fire apartment), while 13 of 17 members (76%) who complained of weakness and fatigue operated in the fire apartment at Knight Street. Interestingly enough, two members from Engine 8 and two members from Special Hazards who operated above the fire apartment on the second floor, complained of headaches. Counting these four members, 14 of 18 (78%) of the members complaining of headaches operated in or immediately above the fire apartment at the Knight Street fire.

9. Kenneth Bakers activities over the week prior to the Ralph Street fire.

Table 12 shows the days that FF Baker worked during the month preceding the Ralph Street fire, and includes a listing of all incidents to which he responded. Table 13 lists Firefighter Baker's activities for the week prior to the Ralph Street fire. FF Baker did not have a second job. His hobbies included bowling, riding motorcycles and hunting.

Firefighter Baker was witnessed collapsing at the scene of a building fire at 70 Ralph Street while operating the pump of Engine 6. The first member to reach him found him to be unresponsive and ashen. He was immediately moved to Rescue 2 which was standing by at the building fire. Members of Rescue 2 and Engine 14 began treating FF Baker for a cardiac arrest. FF Baker was found to be in ventricular fibrillation, and was defibrillated twice while in Rescue 2. An IV was started and a breathing tube inserted. CPR was continued during rapid transport to Rhode Island Hospital Emergency Department. The time from when the witness collapse occurred to the time he was transferred to RI Hospital trauma staff was approximately ten minutes.

FF Baker was given cardiac medications by protocol, defibrillated again in the Emergency Department at Rhode Island Hospital, and responded to treatment. The primary diagnosis was a non-ST elevated myocardial infarction with a secondary diagnosis of cyanide toxicity.

FF Baker was substituting for another member of Engine 6 at the time he had the heart attack. According to the members of Engine 6 that worked the night shift of March 23-24, 2006, Firefighter Baker did not complain of any symptoms after the Knight Street fire. The members had dinner, did some chores around the station, and responded to one additional incident between the Knight Street fire and the Ralph Street fire. This incident was a Still Box at 9 Armington Avenue at 2018 hours that turned out to be food on the stove. The incident was handled by Engine 15 and Ladder 6, and Engine 6 was cancelled while enroute. It is reported that between 20:00 and 21:00 hours FF Baker smoked a cigar. FF Baker has not smoked cigarettes in over 20 years but on rare occasions may smoke a cigar. At the time FF Baker appeared normal and coherent. According to FF Baker's wife, Patricia Baker, she spoke to FF Baker at about 21:00 hours. He mentioned the Knight Street fire but did not complain of any symptoms.

The radio tapes of the Ralph Street fire indicate that the officer of Engine 6 had to request that Engine 6's line be charged at least three times over the radio. However, all of these requests were unintelligible on the recording. Some members who were at the scene at Ralph Street reported that FF Baker seemed confused prior to him collapsing, while others stated they saw no such confusion. The Lieutenant of Engine 6 reported that FF Baker reported to the truck promptly for the alarm and did not need assistance in locating Ralph Street.

Table 12 – FF Baker's Work Activities

FF Kenneth Baker's A-Group Shift and Callbacks

1- 28 Feb. 06 Eng. 14

1-Still @ 1857	465 Pl. Valley Pkwy.	EMS
2-Still @ 1958	Vinton St	EMS
3-Still @ 2331	114 Almy St	Auto Lockout
4-Box @ 0206	1688 Westminster	Def. Det. E-8

2- 09 Mar.06 Eng. 6

1-Still @ 2029	564 Plainfield St	EMS/R-5

3- 10 Mar.06 Ladder 2

1-Box @ 1817	861 Broad St	False
2-Still @ 2010	140 Bellevue Ave	EMS/R-3
3-Box @ 0123	Plainfield/Alverson	False

4- 11 Mar.06 Eng.6

1-St. Box @ 2043

5- 16 Mar.06 Eng. 6

1-Box @ 1045	1655 Westminster St.	E-8's
2-Still @ 1352	381 Plainfield St.	EMS/R-1
3-Still @ 1635	49 Mercy Unfounded	EMS/R-2

6- 17 Mar.06 Eng. 6

1-Still @ 1209	39 Daniel Ave.	Cranston/R-2

2-Still @ 1353 & 1422 370 Plainfield St.

The Fire Marshall and building inspector's office responded at Lt. Williams request to investigate a possible illegal body shop at this location. There was a strong odor that smelled like spray paint. Workers stated that the odor was petroleum solvent they were using to clean an engine.

7- 17 Mar.06 Eng 14

1-Box @ 1948	Amherst/Putnam	False
2-Box @ 2000	235 Promenade St.	False E-7
3-Still @ 2155	73 Prescott St.	EMS
4-Box @ 2305	235 Eaton	False L-3
5-S/Box @ 2312	86 Hawkins St	Garage Fire E-14

- Minimal damage to building, all exterior work
- Extinguished with booster line, no air packs required. "Confined to exterior wall"

8- 18 Mar.06 Eng. 6

1-Still @ 1816	335 Hartford Ave.	EMS/R-6
2-Still @ 2044	153 Whittier Ave.	EMS/R-2

9- 19 Mar.06 Eng. 6

1-Still @ 0910	152 Merino St.	EMS/R-2
2-Still @ 1010	91 Laurel Hill Ave.	Water Emergency
3-Still @ 1234	20 Kelly St.	Defective Alarm
4-Box @ 1254	Silver Lake/Murray	False
5-Still @ 2109	279 Killingly St.	EMS/R-2

10- 20 Mar.06 Eng.6

1-Still @ 0210	39 Glenbridge Ave.	RMS/R-6

11- 23 Mar.06 Eng. 6

1-S/Box 1736	125 Knight St.	Bldg. Fire
2-S/Box 2021	9 Armington Ave	Food on Stove
3-S/Box 0207	70 Ralph St.	Bldg. Fire

Table 13 – FF Baker's Activities

FF Bakers activities during the week prior to March 24, 2006:

March 23, 2006

Spent the day at home.

Went into work at 4:45 pm to sub for Carmine Vita

March 22, 2006

AM - Cleaned and waxed his motorcycle

Went to lunch with a friend

Spent the afternoon at home

Bowled from 7-9:30

Returned home

March 21, 2006

Spent the morning at home

Had his haircut at 1:00 pm

Bowled from 6-9:30

Returned home

March 20, 2006

Spent day at home

Worked on motorcycle, changed oil

Bowled from 6-9:30

Returned home

March 19, 2006

Spent day at home

Worked in E-6 at night

March 18, 2006

Spent day at home

Worked in E-6 at night

March 17, 2006

Worked in E-6 (day)

Worked a callback in E-14 (night)

March 16, 2006

Worked in E-6 (day)

Spent the evening at home

10. SCBA USAGE

Table 14 shows the results of the second survey on SCBA usage. The second survey was given to all 91 members who responded to the three fires, but the results as shown were limited to members of crews that actually operated in a tactical fireground assignment at one or more of the three fires. Chief officers, rescue (EMS) personnel, members assigned to FAST Companies, and members who's units remained in staging were not included because their reasons for not wearing SCBA differed significantly from those of the units operating inside, on top of, and adjacent to the fire buildings. A total of 68 surveys were utilized to generate Table 14.

Table 14 – Why Air Pack Was Not Worn at All Times

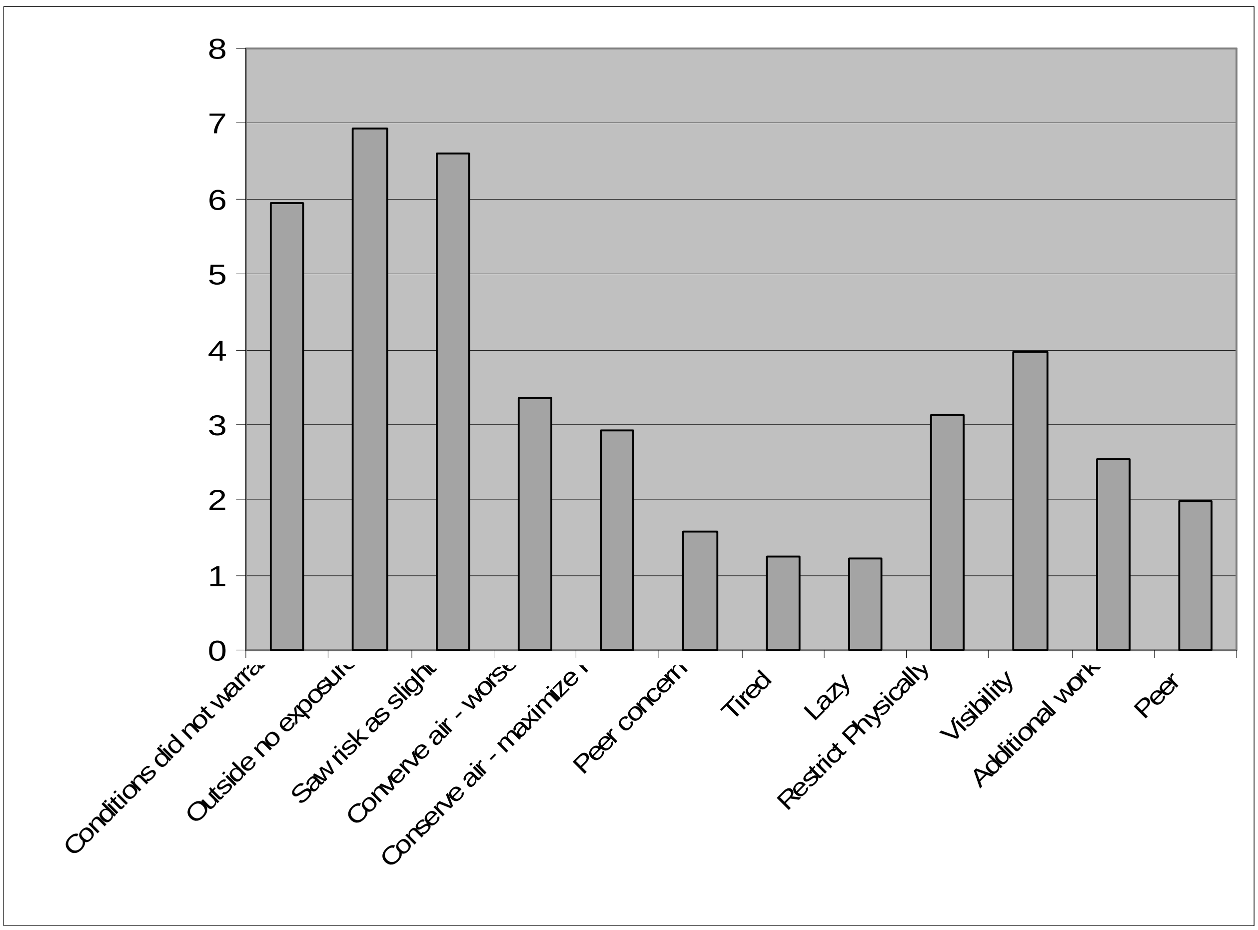


Table 14 Categories

Conditions did not warrant SCBA
I was outside & did not believe I was exposed
Saw risk as slight
Conserving air in case conditions worsened
Conserving air to maximize time fighting fire
Others had their packs off (peer concern)
Too tired to wear pack
Too lazy to wear pack
SCBA too physically restricting
SCBA restricts ability to see
SCBA was empty but there was more work to be done
Did not want to leave crew (peer)

DISCUSSION

On the afternoon of March 23, 2006, when a Providence firefighter who responded to a building fire at 1197 Broad Street tested positive for toxic levels of cyanide in his blood, the sense amongst members of the department was that this was an isolated and highly unusual situation. Later in the day when additional members who operated at the Broad Street fire tested positive for cyanide, the sense was that there was something unusual at the Broad Street fire that led to cyanide being present. However, after two more fires over the next fourteen hours resulted in several additional members who were not at the Broad Street fire testing positive for cyanide, including one who suffered a heart attack, it became obvious that something more significant was occurring.

Determining the source of the cyanide became a major focus of the department over the following days. The air quality tests performed by Trace Analytics and St. Paul Traveler's Laboratory on March 28 established that the source of the cyanide was not the compressed breathing air from the member's air packs. Test results from the Providence Water Supply Board established that the public water supply did not appear to be contaminated.

At the same time the department became aware of research by Dr. Debra Wallace, Dr. Marc Eckstein, Dr. Stephen Borron, and numerous others cited previously, that established convincingly that hydrogen cyanide is produced in significant quantities at fires involving materials that are commonly present in modern buildings, such as plastics, synthetics and nitriles. Much of the literature talked about the fact that both the fire service and the medical communities had overlooked hydrogen cyanide as playing a major role in smoke inhalation deaths.[143]

In the aftermath of the three fires, a total of eight members of the department had whole blood cyanide levels of 20 ug/dL or higher, including FF Kenneth Baker who suffered a heart attack at the Ralph Street fire. While subject to considerable debate among cyanide toxicologists, 20 ug/dL of cyanide appears to be accepted as the upper range of normal for whole blood cyanide tests. The delineation between normal levels and toxic levels is more uncertain as many experts feel that levels of 50 ug/dL should be considered toxic, as opposed to any level over 20 ug/dL. Levels between 250 to 300 ug/dL are considered to be lethal, although some evidence exists to suggest that levels as low as 100 ug/dL may be lethal. The reality is that there is a great deal of uncertainty inherent in understanding and treating cyanide poisoning.

Table 5 shows that four of the eight members with cyanide levels over 20 ug/dL responded to the Broad Street fire. One of these four also responded to the Knight Street fire. However, that member was assigned to Engine 7 at the Knight Street fire, and

[143] Eckstein M and Maniscalco PM, *Focus on Smoke Inhalation - The Most Common Cause of Acute Cyanide Poisoning*, Prehospital and Disaster Medicine http://pdm.medicine.wisc.edu Vol. 21,No. 2, (Mar-Apr, 2006)

Engine 7s crew remained in staging for the duration of the fire. The member in question reported that he was never was exposed to any smoke at the Knight Street fire.

The four members with high cyanide levels after the Broad Street fire were regularly assigned to four different companies in three different stations: Special Hazards 1 from the Washington Street station; Engine 3 from the Washington Street station; Engine 6 from the Hartford Avenue station; and Ladder 8 from the Brook Street station. In addition, the four members were working on March 23, 2006 in four different companies at the fire: Special Hazards (regular assignment), Engine 3 (regular assignment), Engine 8 (callback) from the Messer Street station, and Engine 11 (callback) from the Reservoir Avenue station. The fact that the members came from different companies, different stations, and different shifts seemed to rule out an accidental or intentional ingestion or exposure occurring in the fire stations prior to the Broad Street fire as a possible cause of the cyanide poisonings.

Further analysis of the data collected from the members during the interviews revealed that all four members had worked outside the building at 1197 Broad Street on either Side 2 or Side 3. See Table 10 as well as Figure 4. Three of the four members also reported having operated inside the building early in the fire.

All four members reported that they engaged in heavy exertion at the Broad Street fire. All four members complained of weakness and fatigue after the fire. Three of the four reported a headache and three of the four reported shortness of breath. All four reported that they were exposed to smoke intermittently for at least 10 to 15 minutes without their SCBA facepieces in place.

Information from Table 10 shows that 75% of the members complaining of headaches and 85% of the members complaining of weakness and fatigue after the Broad Street fire operated on Sides 2 and 3. According to information provided to the investigation committee by Channel 12 meteorologist Tony Patrarca, the winds at the time of the fire were out of the north at 15 to 20 miles per hour, which would have pushed the smoke toward sides 2 and 3. The wind direction and effect on the smoke was confirmed by watching the video footage of the fire, looking at still photos of the fire, and witness interviews with the members who operated at the scene.

The scene examination at the Broad Street fire confirmed the presence of cyanide containing fuels among the building components and contents that burned, including foam insulation, rubber roof membrane, tar and fiber reinforced plastic.

Table 5 also shows that the four other members with high cyanide levels responded to the Knight Street fire. Two of these four members were assigned to Engine 6 (from the Hartford Avenue station), and two were assigned to Ladder 6 (from the Atwells Avenue station). Three of these members also responded to the Ralph Street fire. However, it was not until after FF Baker had suffered a heart attack at the Ralph Street fire, that anyone who had been to the Knight Street fire was tested for cyanide poisoning.[144]

All four members who had high cyanide levels after the Knight Street fire worked on the first floor inside the fire apartment. See Figure 5. Three of the four complained of weakness and fatigue, and two complained of a headache after the fire.[145] Two members described their workload as heavy and one described it as moderate.

The results contained in Table 11 show that 56% of the members complaining of headaches and 76% of those complaining of weakness and fatigue at the Knight Street fire operated in the fire apartment. In addition 78% of those complaining of headache operated in or immediately above the fire apartment. As was the case at the Broad Street fire, there was an abundance of cyanide producing fuels involved in the fire. All four members with high cyanide levels after the Knight Street fire acknowledge that they did not wear their SCBA for at least 15 to 20 minutes when exposed to smoke.

Three of the members with high cyanide levels operated at the Ralph Street fire, namely FF Baker and the two members of Ladder Co. 6. All three of these members had previously operated at the Knight Street fire. FF Baker remained outside at the Ralph Street fire operating Engine 6's pump. One member who had high levels of cyanide operated on the roof, while the other operated inside on the first floor. See Figure 6. The scene examination at Ralph Street disclosed the presence of cyanide containing fuels in the room of origin and adjacent areas.

Based upon the above information, the investigation committee has concluded that the cyanide exposures that occurred on March 23 and 24, 2006 were the result of an accidental exposure to hydrogen cyanide that was generated from the burning fuels at two and possibly all three of the incidents.

Although three of the four members who had high cyanide levels after the Knight Street fire also went to the Ralph Street fire, there are two factors that lead us to conclude that it is more likely that a high level of hydrogen cyanide present at Knight Street accounted for the high cyanide level of FF Baker and the other two members with high levels after the Ralph Street fire. First of all, the Acting Lieutenant of Engine 6 at the Knight Street fire had the highest cyanide reading of anyone at any of the three fires, at 72 ug/dL. This member did not go to the Ralph Street fire. Thus his exposure appears to have been solely from the Knight Street fire. The Acting Lieutenant's witness statements indicate that he worked side-by-side with FF Baker for most of the Knight Street fire.

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144 Three members who had operated at both the Broad Street fire and Knight Street fire, went for testing after the Knight Street fire, (and before the Ralph Street fire) but this was due to symptoms experienced after the Broad Street fire. None of these members tested above 20 ug/dL.

145 FF Baker was one of the four members who worked on the first floor at Knight Street and had elevated cyanide readings. Unfortunately FF Baker has no recollection of the incident, therefore we do not know if he experienced any of these symptoms. Interviews with his co-workers indicate he did not complain of any symptoms after the Knight Street fire. This was confirmed by his wife who spoke to him at 9:00 pm on March 23, 2006 who said he mentioned the fire but complained of no symptoms.

Secondly, FF Baker, who also worked in Engine 6 at the Knight Street fire, had the second highest cyanide reading at 66 ug/dL. Members who operated at the Ralph Street fire were extensively questioned about FF Baker's activities on the scene at Ralph Street. By all accounts FF Baker remained outside of the building and out of smoke at the Ralph Street fire. As a result, the conclusion of the investigation committee is that the exposure that led to high cyanide levels in FF Baker probably occurred at the Knight Street fire.

There are three important problems that have combined to make understanding the cyanide exposure issue difficult. The first involves the short half-life of cyanide in the blood. The second involves the nature of the presently available blood tests for cyanide. The third involves understanding and interpreting the results of the blood tests.

1. HALF-LIFE ISSUE

The best information that the committee has available concludes that hydrogen cyanide that is inhaled gets into the blood stream in a matter of seconds, and has a half-life in the blood of approximately one hour.[146] In other words, if a member has a blood cyanide level of 100 ug/dL immediately after an exposure, one hour later the level should be 50 ug/dL, two hours later it should be 25 ug/dL, and three hours later it should be 12.5 ug/dL. Most of the firefighters tested for cyanide after any of the three fires, were tested between three and ten hours after the exposure. As a consequence, the results of the blood tests performed on Providence Firefighters hours and in some cases days after the fires would seem to yield an inaccurate picture of the members' actual exposure to cyanide. A delay of even an hour to two hours in administering the blood tests could have resulted in cyanide levels having returned to normal for members who had elevated cyanide levels immediately after the fires.[147]

However, as is evident from Table 7, several members had blood cyanide levels that were still elevated several hours after the exposure occurred. One member's cyanide levels remained elevated twenty-seven hours after the exposure. Extrapolating back from the time of the blood draw to the time of the fire based on a one hour half-life would yield a super-lethal dose. This fact would seemingly call into question the validity of the one-hour half-life figure. As will be discussed below, a better understanding of the complexity of the whole blood cyanide test explains why a high cyanide level may occur even after an extended elapsed time.

Nevertheless, the one hour half-life of cyanide in the blood has no doubt contributed to the difficulty in understanding the extent of the cyanide problem amongst firefighters.

2. BLOOD TEST ISSUES

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[146] Dr. Stephen Borron; Baud F, Barriot P, Toffis V, *et al*: Elevated blood cyanide concentrations in victims of smoke inhalation. *N Engl J Med* 1991;325:1761–1766.
[147] Eckstein M and Maniscalco PM, (2006), p. 50.

Blood tests for cyanide have been criticized as being subject to variation due to laboratory procedures and handling of the samples.[148] There are two primary whole blood tests for cyanide. One test takes approximately two hours to complete, and the other takes approximately five days to complete.[149] The lack of a readily returnable cyanide test has been cited in the literature as impairing the ability of doctors to diagnose and treat patients within the time frames needed to treat a patient with acute cyanide poisoning.[150]

Further compounding the problem is that not all hospitals and laboratories have the capability to perform cyanide tests. A survey of major hospitals in New England disclosed that no hospitals besides Rhode Island Hospital perform cyanide tests in house, and only eight laboratories in the country that perform whole blood cyanide tests.[151] Hospitals that do not perform such a test in-house would have to send the blood out by courier to be tested by one of the eight labs that do perform such a test. As a result doctors in hospitals without such in-house testing capability may have to wait up to a week for the results of blood cyanide tests to be returned.[152]

A diagnostic test which takes a week, or even a day, to come back has limited clinical value to a doctor treating a critically ill patient possibly poisoned by a chemical with a half-life of one hour. The apparent result has been that doctors do not routinely perform cyanide tests on smoke inhalation patients, including firefighters.

3. UNDERSTANDING AND INTERPRETING THE RESULTS

Even more problematic is the fact that the whole blood cyanide test does not differentiate between the toxic forms of cyanide in the blood, and some of the detoxified forms of cyanide that are in the process of being removed from the body by one of the metabolic pathways by which the body naturally removes cyanide.[153]

The whole blood cyanide test presently used by Rhode Island Hospital is a state of the art test, using the Conway Diffusion Method and spectrophotometry. See Appendix I for the full methodology. The test measures the level of cyanide in the blood, as well as cyanide that is bound to methemoglobin and thiocyanate.[154] Cyanide has a strong affinity for

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[148] Moriya F, Hashimoto Y: Potential for error when assessing blood cyanide concentrations in fire victims. *J Forensic Sci* 2001;46:1421–1425.

[149] Dr. William Bastan, May 3, 2006

[150] Hall AH, Rumack BH, Clinical Toxicology of Cyanide, Ann Emerg Med, 1986 Sep; 15 (9): 1067-1074; Hamilton HE, Street EW, Beckman-Royder M Adams K, Cyanide and thiocyanate by microdiffusion and spectrophotometry, Selected Methods of Emergency Toxicology, Vol. 11, 1986, p. 57-62.

[151] Hospitals surveyed include UMass Medical Center at Worcester, Brigham and Women’s Hospital, Mass General, and Beth Israel Deaconess Medical Center. Survey conducted by Dr. William Bastan.

[152] Dr. William Bastan, Director, Toxicology Lab, RI Hospital, 24 April 2006. In addition, the blood test for the member who went to Fatima Hospital was sent by Fatima Hospital to the Mayo Clinic in Rochester, Minnesota and took over 24 hours to come back.

[153] Eckstein M and Maniscalco PM, (2006), p. 50.

[154] Dr. Bastan, 24 April 2006, and 3 May 2006, and Dr. Borron, May 12, 2006. Not all authorities agree on what is measured by the whole blood cyanide test, and in particular what forms of cyanide are yielded by the Conway Diffusion Method. The best information available at the present time suggests that the whole

methemoglobin, and once it is bound to methemoglobin is not toxic. The Conway Diffusion Method cannot differentiate between toxic cyanide and non-toxic cyanmethemoglobin. According to Dr. Stephen Borron:

> *Smoke exposure can cause elevated methemoglobin (oxidized hemoglobin) in variable amounts. Methemoglobin (unlike hemoglobin) is a very potent binding protein for cyanide. Moriya from Japan has reported that methemoglobin levels in fatal fire victims were up to 5% and were capable of scavenging blood cyanide up to 11.4 mg/l (4 x a lethal level), so smaller amounts of methemoglobin in a living firefighter could explain the smaller blood cyanide concentrations reported here. Cyanide bound to methemoglobin does not pose a risk to the patient unless it is released back into the blood stream. In general, as cyanmethemoglobin "gives up" its cyanide in the blood, it is scavenged by rhodanese (a naturally occurring enzyme) and eliminated in the urine. In other words, methemoglobin bound to cyanide would give the impression of higher blood concentrations of cyanide than are truly available to cause poisoning. So the levels appear high, but really aren't. In my mind, this is a likely cause of the elevated blood cyanides in your firefighters.*[155]

According to Dr. Borron, the Conway Diffusion Method will also yield cyanide that is in the blood as thiocyanate.[156] Thiocyanate is a non-toxic compound that is a part of the normal detoxification process for the elimination of cyanide from the body. Eighty percent of the cyanide that enters the body will be eliminated via thiocyanate. The half-life of thiocyanate in the body is approximately thirty hours, considerably longer than the half-life of cyanide in the blood, which would explain why several members had high levels of whole blood cyanide many hours after the exposure.

It is important to understand that high blood cyanide levels detected hours after an exposure is evidence that a patient may at one time have had high levels of cyanide in their blood. However, the tests alone do not indicate that the patient is presently at a toxic level for cyanide. Rather, doctors must consider the whole blood cyanide test results in light of the patient's symptoms and lactic acid levels to determine the effect that cyanide is having on the patient.

WHAT DOES THIS MEAN

The ramifications of these three problems in light of what has occurred in Providence are startling. Many of the firefighters who tested normal for cyanide, may have had high levels of cyanide at the fire scenes and immediately thereafter, but due to the short half-life of cyanide and the length of time between the exposures and the blood draw, their cyanide levels returned back to normal. Many other firefighters who did not go for testing, but experienced symptoms of weakness, fatigue and headaches after the fires may

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blood cyanide tests do not include cyanide that is in the blood as Vitamin B12, but does include cyanide that is bound to methemoglobin (Bastan and Borron) and thiocyanate (Borron).

[155] Email communication, April 9, 2006

[156] Telephone communication 12 May 2006

well have had toxic levels of cyanide immediately after the fire. Tables 1 through 4 show the symptoms of members who responded to the three fires.

Due to the fact that doctors do not routinely order cyanide tests on injured firefighters after fires, the number of firefighters who are routinely being exposed to cyanide could be gravely underestimated. The committee is compelled to concur with the growing list of experts who have concluded that hydrogen cyanide poses a much more significant problem to firefighters than previously believed. The committee also concludes that the lack of ordering such tests routinely on smoke inhalation victims and firefighters may have contributed to the cyanide problem going unnoticed for as long as it has.[157] It would appear that the Providence Fire Department and Rhode Island Hospital may have run into the tip of a very large iceberg.

HEART ATTACK ISSUES AMONG FIREFIGHTERS

On March 24, 2006 FF Kenneth Baker suffered a heart attack. While the connection between FF Baker's cyanide level and his heart attack are beyond the ability of this committee to address, several very important issues are raised. First of all, cyanide can cause heart arrhythmias.[158] While the committee is not able to conclude that a cyanide related heart arrhythmia led to FF Bakers heart attack we can say with certainly that FF Baker had elevated levels of cyanide in his blood at the time he suffered the heart attack.

Secondly, heart attack deaths account for approximately 50 firefighter fatalities each year.[159] Fortunately Ken Baker will not be counted as one of those fifty firefighters for 2006, but he very well could have been had it not been for the outstanding advanced life support (ALS) care he received on the scene by members of the Providence Fire Department, and again at the trauma center at Rhode Island Hospital.

How many other Ken Baker's are there out there, who operate at a fire scene (whether exposed to high levels of cyanide in fire smoke or not) have a heart attack, are treated immediately by EMS personnel, transported to definitive care promptly, and survive? According to the National Fire Protection Association, between 200 and 300 firefighters a year suffer non-fatal heart attacks at fire scenes.[160] These figures do not include the

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[157] Eckstein M and Maniscalco PM, (2006). It should be pointed out that not everyone was surprised by these results. Numerous toxicologists with whom the committee has had contact were fully aware of the problem, and expressed surprise that the problem was not more widely known by firefighters and medical practitioners.

[158] http://www.inchem.org/documents/pims/chemical/pimg003.htm; Baskan SI; Zoltani CK,. Platoff GE, and Baskin SI, Simulation Studies of Cyanide-Caused Cardiac Toxicity, ARL-TR-3443 (March 2005); ATSDR (2004), p. 20, 39, 104. This issue will be discussed below at length.

[159] Fatalities among volunteer and career firefighters, United States 1994-2004, CDC, MMWR, http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5516a3.htm. According to data at the US Fire administration web site, an average of 12 firefighters per year die from heart attacks at fire scenes. See http://www.usfa.fema.gov/applications/ffmem/index.jsp.

[160] Karter, MJ, Molis, JL, 2004 U.S. Firefighter Injuries, NFPA Journal, National Fire Protection Association, (November 2005).

firefighters who suffer a heart attack hours or days after a fire as a result of having fought the fire.

How many of these 200 to 300 fire-scene heart attacks remain non-fatal due to the outstanding ALS care provided by firefighters and paramedics at fire scenes, combined with outstanding treatment in our nation's trauma centers? Very few professions operate with ALS units standing by when they work. Had 200 to 300 work-place heart attacks per year been occurring among miners while they are mines, among commercial fisherman while they are at sea, or timber loggers while in the woods, a significant number of those heart attacks could be expected to be fatal due to the lag time of securing ALS care. This reality strikes the committee: is the fire service severely under-estimating the gravity of the risk of heart attack by focusing only on fatalities? Could the presence and outstanding ability of these on-scene ALS units be masking a problem that is much more serious than the currently cited statistic of fifty heart related firefighter fatalities per year would otherwise reflect? And what role does cyanide play in these heart attacks?

SCBA USAGE

The information contained in Table 6 shows that members at each of the fires in question, exposed themselves to smoke for varying periods of time without their SCBA facepiece in place. It would seem elementary that the wearing of SCBA at appropriate times would theoretically eliminate the possibility of exposure to hydrogen cyanide as well as a host of other toxic byproducts. However, after thoroughly examining this issue (including watching videotapes from the fire scene) the Committee does not feel the lack of wearing of SCBA at the three incidents is a procedural compliance issue nor should it be treated as a disciplinary issue. Furthermore, characterizing the problem as a procedural compliance or disciplinary issue ignores the complexity of the problem.

The Providence fire Department has had a mandatory mask regulation that dates back to 1980. This regulation is credited with dramatically reducing the number of smoke inhalation injuries. By and large, Providence Firefighters have complied with spirit and letter of the mandatory mask regulation, and utilize their SCBA in a manner consistent with most fire departments in the region and the United States.

According to the interviews and the data from the second survey (Table 14), the primary reasons that firefighters did not wear their SCBAs at the three fires in question had to do with trained, seasoned firefighters misperceiving the risk, and making a calculated risk-benefit analysis on the fireground without all of the pertinent information.

Firefighters are expected to make the decision to wear or not wear their SCBA at a variety of incidents, not just building fires. From investigating false or accidental alarms, to investigating strange odors or the smell of smoke, to operating at brush fires, rubbish fires and car fires, to determining at what moment at a building fire the mask should go on, firefighters rely upon their skill, judgment and experience in determining when to mask up.

A member's air supply is a precious but limited resource at a fire. Once the air supply is exhausted the member and his/her entire crew must exit the fire area, and another crew must be brought in. The ability of a crew to accomplish a tactical assignment is limited by the air consumption of the member who uses up his/her air supply first. The unnecessary consumption of air in non-contaminated areas reduces the work that the company can perform, and that unit's effectiveness.

When viewed on a more global scale, the wearing of SCBA implicates issues of how many companies/personnel are needed by a fire department, the number of resources and personnel that are needed on scene, accountability procedures for tracking of crews into and out of the building, comprehensive air management, as well as cultural/peer pressure issues that exert a heavy influence on a firefighters' decisionmaking. As a consequence firefighters are culturally conditioned to go on air as late as possible, and once their air is exhausted, to remain in the fire area if the atmosphere is believed to be tolerable. In making these decisions firefighters utilize their experience, which as this report has concluded, may be leading them to falsely conclude that an atmosphere is safe when it is not. Given the steep dose-effect curve of cyanide, it is likely that firefighters are routinely being exposed to dangerous levels of cyanide at fires without realizing it. Had it not been for Dr. William's instruction to the attending physicians to test the chauffeur of Engine 3 for cyanide on March 23, 2006, the member's symptoms would probably have been dismissed as carbon-monoxide or flu related, the members who were suffering headaches and/or weakness and fatigue would have felt better the following day, FF Baker's heart attack would have been considered an unavoidable tragedy, and nothing would have changed in the Providence Fire Department.

The Committee believes the solution to the problem is not simply to issue an admonition to firefighters to wear their air packs during overhaul, nor is it disciplining members who fail to comply with existing mandatory mask regulations. In fact there is credible research that establishes that cyanide may be present outside the area commonly associated with visible smoke through a process known as quantitative decomposition.[161]

The solution involves better education of the firefighters about the risks, and better instrumentation to assist firefighters in making the determination about when SCBA is needed and when it is not. Instrumentation is presently available that will allow a firefighter to determine instantly whether or not a toxic product such a hydrogen cyanide, hydrogen chlorine, and carbon monoxide is present in the area. It is inconceivable to the committee that members would knowingly expose themselves to cyanide or any other toxic gas that is known to be there, but it is just as obvious that firefighters will continue to expose themselves when they are expected to guess when a toxic gas is or is not present.

The committee unanimously agrees that the focus in preventing a recurrence of such an event should be on an engineering solution as opposed to the institution of administrative or disciplinary solutions. The committee envisions the day when firefighters are issued

[161] Wallace, Deborah, "In the mouth of the Dragon: toxic fires in the age of plastics", 1990

detection equipment (possibly integrated into the SCBA) that is capable of providing a warning that a hazardous atmosphere exists.

DERMAL EXPOSURE TO CYANIDE

The results of the wipe test performed on FF Baker's turnout gear by Rhode Island Analytical Laboratory confirms what has been written regarding the fact that hydrogen cyanide is primarily an inhalatory hazard to firefighters. Only trace amounts of cyanide were found on FF Baker's turnout gear. It is possible for hydrogen cyanide gas to adhere to smoke particulates and become imbedded in turnout gear, but the overall risk of dermal absorption from this route appears to be minimal. Specifically the committee does not believe that FF Baker re-exposed himself to cyanide when he donned the same turnout gear that he wore to the Knight Street fire, at the scene of the Ralph Street fire.

This is not to say that firefighters should ignore the risk of re-exposure associated with contaminants on their turnout gear. Firefighters should be encouraged to treat their turnout gear after a fire as a potential source of a wide variety of toxins and take appropriate steps to decon and clean their gear and themselves.

UNUSUAL AND UNEXPLAINED FINDINGS

Two members from Ladder 6, designated as Firefighter #14 and Firefighter #25, responded to both the Knight Street and Ralph Street fires. According to interviews with both members, they worked side by side at both incidents the entire time they were on scene. At Knight Street, they performed roof ventilation together, and then proceeded to the fire room on the first floor to rejoin their company. At the Ralph Street fire they performed roof ventilation. Both members reported that they did not wear their air packs at either fire. The details of the interviews of each member were confirmed by watching the videotapes from the news stations, and interviews with other members.

Both members went to Rhode Island Hospital at approximately 05:00 hours on 24 March 2006 for testing. FF #14 had a cyanide level of 51 ug/dL. FF #25 had a cyanide level of 4 ug/dL. Consistent with these readings FF #14 complained of headache, weakness and fatigue, drowsiness and nausea. FF #25 had no symptoms.

Rhode Island Hospital contacted FF #14 later in the morning on 24 March 2006, and requested that he return for additional testing. A second blood test drawn at 09:30 hours showed FF #14 was at 54 ug/dL.

None of the doctors or experts with whom the committee spoke with can conclusively explain the reason for the difference between FF #14 and FF #25's cyanide levels, nor why FF #14's cyanide level appeared to have gone up over the course of four and one half hours. The committee's best guess in regards to why FF #14's cyanide level increased is that the difference was within the normal variation of the test.[162] Our assumption is that most of the cyanide in FF #14's system was bound up as thiocyanate and cyanomethemoglobin. The committee's best guess as to why the two members had such widely different blood cyanide levels is that the release of cyanide from a burning fuel may be a localized event whereby a member standing next to a burning object may receive a different dose than someone standing a few feet away. However, medical and/or physiological differences between the two members cannot be ruled out.

RELATIONSHIP OF CYNAIDE TO PRE-EXISTING HEALTH ISSUES OF PROVIDENCE FIREFIGHTERS

The long term effects of exposure to cyanide are not well understood nor studied. [163] Nothing in the literature suggests a mechanism by which cyanide exposure could account for an excess of sarcoidosis in firefighters who may be chronically exposed to cyanide.

According to the ATSDR, cyanide is known to cause macular degeneration and optic atrophy. [164] Cyanide has also been associated with eye irritation and slight peripheral vision loss.[165] Some studies have associated cyanide with retrobulbar neuritis.[166] While no documentation could be found that conclusively connects cyanide exposure to the 1990 eye problem in Providence, the issue certainly warrants more investigation.

Cyanide poisoning is known to cause cardiac abnormalities.[167] The mechanism by which cyanide causes cardiac abnormalities has been the subject of research by the US Army and others concerned about the use of cyanide as a weapon.[168] The exact mechanisms by which cyanide causes these cardiac abnormalities is beyond the expertise of these investigators and the scope of this investigation. However, what is clear is that cyanide can cause a variety of cardiac related issues. Consider the following from the International Programme on Chemical Safety (IPCS):

9.4.1 Cardiovascular

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[162] FF #14 and FF #25 responded to one incident between the Knight Street and Ralph Street fires. The run was a still box to 9 Armington Avenue, which turned out to be food on the stove. The crew of Ladder 6 assisted in ventilating the building. According to witness statements, FF #14 and FF #25 remained together side-by-side throughout that incident. The company was on the scene for approximately 15 minutes and members were inside the structure for approximately 5 minutes in very light smoke from burnt food. The building was well ventilated at the time they entered.

[163] CICAD 61

[164] ATSDR (2004) p. 67

[165] ATSDR (2004) p. 41; see also Carelli V, Ross-Cisneros FN, Sadun AA. 2002. Optic nerve degeneration and mitochondrial dysfunction: Genetic and acquired optic neuropathies. Neurochem Int 40:573-584.

[166] CICAD 61

[167] CICAD 61; Dr. Stephen W. Borron, article on emedicine.com, available on the web at http://www.emedicine.com/EMERG/topic118.htm#section~clinical

[168] Zoltani CK,. Platoff GE, and Baskin SI, Simulation Studies of Cyanide-Caused Cardiac Toxicity, ARL-TR-3443 (March 2005)

> *Cyanide has at least two cardiac effects: 1. an initial effect on the Beta-adrenergic receptors, either directly or indirectly, and 2. reduction of myocardial contractility through inhibition of cytochrome oxidase (Baskin et a1., l987).*
>
> *Early electrocardiographic changes include atrial fibrillation, ectopic ventricular beats, abnormal QRS complex, sinus bradycardia.*
>
> *Cyanide has a marked effect on the systemic blood pressure (Klimmek et a1., l982) as a result of a direct effect on blood vessels and on the autonomic nerve supply to the cardiovascular system (Vick & Froelich, l985). Cardiovascular collapse may occur especially in cases of massive poisoning (Heijst et a1., l987).*[169]

Furthermore, cyanide can cause cellular changes to cardiac tissue, such as swelling and hemorrhaging, as well as lactic acidosis, the production of catecholamines, calcium overload, and the development of ischemic changes, all of which set the stage for cardiac arrhythmias.[170] There is also evidence which suggests that death from cyanide poisoning may occur up to eight days after the exposure. [171] NIOSH has recognized that electrocardiogram changes can be observed 2-3 weeks after a fire related cyanide exposure. [172]

Collectively, this information raises grave concerns to the investigators, particularly in light of the heart attack problem among firefighters previously discussed. 200 to 300 firefighters suffer heart attacks at fire scenes every year. However, the cardiac abnormalities induced by cyanide are not limited to immediate on-scene affects, and may be causing some of the more than 800 to 900 heart attacks that firefighters sustain each year in the line of duty. [173] Given the fact that cardiac abnormalities may not present immediately, many off-duty heart attacks (for which numbers do not exist) may also be related to cyanide exposures occurring at fires.

In light of this information, the investigation committee believes the connection between the cardiac/atrial fibrillation problem among Providence Firefighters and exposure to cyanide warrants further investigation.

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[169] http://www.inchem.org/documents/pims/chemical/pimg003.htm
[170] Zoltani CK, et al (2005) p. 1-2.
[171] Baskin and Brewer (1997) p. 276 citing Paulet G, Chary R, Bocquet P. The comparative value of sodium nitrite and cobalt chelates in the treatment of cyanide intoxication in non-anesthetized animals. *Arch Int Pharmacodyn.* 1969;127:104–117; and Haymaker W, Ginzler AM, Ferguson RL. Residual neuropathological effects of cyanide poisoning in dogs: A study of the central nervous system of 23 dogs exposed to cyanide compounds. *Mil Surg.* 1952;3:231–246.
[172] NIOSH Health Hazard Evaluation Report, HETA 81-276-1100 (1981)
[173] Karter, MJ, Molis, JL, 2004 U.S. Firefighter Injuries, NFPA Journal, National Fire Protection Association, (November 2005). Information was also from a data-analysis performed on the NFPA database by Michael Karter on 12 May 2006.

RECOMMENDATIONS

Based upon the information gathered during the course of the investigation, the investigation committee recommends the following:

Recommendation 1. TRAINING AND EQUIPMENT. The Providence Fire Department should immediately embark on a two pronged approach to ensure that a repeat of this incident does not occur. Prong 1 is to develop and institute a training program that focuses on making members aware of the hazard posed by hydrogen cyanide at fires. This program needs to include an explanation about why the cyanide problem is more significant today than ever before, the chemistry of cyanide, identification of cyanide containing fuels, the toxicology of cyanide including the steep dose-effect curve, the medical concerns of cyanide, and why firefighters cannot merely rely on their past experience to determine whether or not a particular atmosphere is safe. This training should be delivered to all members at the earliest possible time, and thereafter be incorporated into recruit training, company officer training, and chief officer training programs.

The second prong is to investigate, acquire and deploy cyanide detection equipment into the field for use at fires. There are a number of options in this regard that must be considered (for example – should we purchase multi-gas detectors, or single gas detectors; which manufacturer provides the best detector; should we have one detector per battalion/incident, one per company, or one per member). As best we can determine, there are no detectors presently available that can withstand daily use in a fire environment. BioSystems, from Middletown, CT has been approached and is willing to partner with the Providence Fire Department to take existing cyanide detection technology and develop detection equipment that can operate in a fire environment.

Recommendation 2. COMPLIANCE. There needs to be enhanced compliance with the existing mandatory mask regulation. It is hoped and believed that through adoption of Recommendation No. 1 above, that Recommendation No. 2 will be that much easier to implement. Enhanced compliance will require a cultural change on the part of firefighters. Company officers must focus on the protection of their members, and ensure that SCBA are utilized when necessary. Chief officers must focus on ensuring that an adequate number of personnel are on scene; that air consumption is anticipated and planned for; that crews are rotated in and out of buildings at intervals based on estimated air usage (whether the crews desire to be rotated or not); and that accountability for all personnel is maintained. It is envisioned that the increased usage of SCBA will result in the need for more personnel on the fire ground, and more movement of personnel into and out of the fire building. In this regard the investigation committee recommends that the department form a committee to develop new deployment models and new structure fire standard operating procedures. By way of example only, FDNY assigns 5 to 6 members to an engine company, and expects that rotation into and out of the contaminated environment will be accomplished at the company level, supervised by the company officer. An alternative that may work for the Providence Fire Department may be to assign a second engine company to each attack hoseline, and have the two company officers organize the rotation so that no member has to remove their mask in a contaminated or unknown atmosphere. Whatever deployment model the department chooses to adopt, it will result in a new method of operating on the fireground.

This new committee should address the issue of progressive air management. [174] Progressive air management includes considerations about how SCBA air is to be managed, when a company/member should be removed from the hazardous area so as to ensure the member is outside of the contaminated area before removing their facepiece, how much reserve air should be left when the member exits to allow for emergencies, who is responsible for managing air use, and who will be responsible to monitor compliance.

The committee should also address fireground accountability, tracking resources, and consideration of new tactics in the Providence Fire Department, including the use of positive pressure ventilation.

Recommendation 3. SCBA TRAINING FOR DIFFICULT OPERATIONS. All personnel need physical training with SCBA to enhance the comfort level of members when engaged in difficult operations such as climbing ladders, operating on roofs, operating in confined spaces, and communicating while on air. During the course of the investigation, many members stated that they did not feel comfortable operating on roofs, climbing ladders or talking over the radio with SCBA on. Members should be required to drill with SCBA until they feel comfortable wearing SCBA in all commonly encountered situations. At the present time the committee does not believe the use of SCBA on roofs should be made mandatory provided adequate detection equipment is available to assure the safety of the atmosphere on the roof. In the absence of such detection equipment, SCBA (with facepiece in place) should be utilized on roofs when the toxicity of the atmosphere is not known.

Recommendation 4. AIR SUPPLY UNIT. The Air Supply Unit should be dispatched to all Code Reds as a fill in company. This practice will help ensure that an adequate supply of extra air cylinders is available at fire scenes. A new SOP is needed to address operation of the Air Supply unit on scene, including operation of the on-board compressor system, and limitations on its use. All members assigned to Engine 5 and the Air Supply unit must be familiar with the operation and limitations of the compressors and fill stations.

Recommendation 5. COMMAND SUPPORT. The Incident Commander bears ultimate responsible to ensure proper air management at a fire scene. In order for the Incident Commander to manage resources, oversee tactical operations, ensure fireground accountability, manage radio communications, maintain the written command matrix, ensure scene safety, and now ensure proper air management, additional command support personnel are required. A command aide (or command technician) would allow the Incident Commander to effectively manage all of the responsibilities, and lessen the likelihood that he/she will become overwhelmed. In addition, a command aide would

[174] Gagliano, et al, (2006)

allow the Incident Commander to utilize the available command software, which is capable of tracking and managing air usage by companies.

Because the assignment of command aides will necessitate a change in the collective bargaining agreement, the Committee recommends as an interim measure the assignment of a command/safety company to every Code Red. Personnel from this company can be utilized to assist the incident commander. In some cases it may be feasible to utilize the officer of the command/safety company as a safety officer to perform air monitoring.

The draw backs to utilizing the command/safety company in this way are several. First, members of the command/safety company may lack the requisite training, experience and perspective to effectively assist the Incident Commander. Second, use of the command software requires extensive familiarization and practice. It is unlikely that the command software can be effectively utilized by personnel who may be called upon to use it sporadically.[175] Third, the command/safety company will not be present during the critical first few minutes of the fire to assist the Incident Commander with size-up and scene organization. Lastly, assigning an entire company to accomplish a task that one person can accomplish is wasteful. It ties up a key tactical unit that may be needed elsewhere on the fire scene or elsewhere in the city.

Recommendation 6. POST-FIRE DECONTAMINATION. Firefighters should wash their turnout gear after every fire. In addition, firefighters should shower and change their cloths after every fire. Both of these steps will help to reduce the risk of exposure to toxins in fire smoke. The department should consider expanding the number of washing machine extractors to better facilitate the laundering and decontamination after fires. Ideally each station should have its own extractor and each member should be issued a second set of turnout gear to allow for prompt decontamination. In light of the city's financial situation, perhaps a grant could be sought to fund the acquisition of the needed extractors and turnout gear.

Recommendation 7. MEDICAL COMMUNITY. The medical community needs to be educated about the presence of cyanide in modern day fire smoke. Smoke inhalation patients should be routinely tested for cyanide, and cyanide poisoning should be at the top of the list of conditions to rule out when smoke inhalations patients are brought into an emergency room. It is hoped that through close contacts with the Rhode Island Department of Health and area hospitals, a formalized training program can be developed and implemented.

Recommendation 8. MEDICAL RESEARCH. Additional medical and toxicological research is needed to better understand:

- the effects of hydrogen cyanide on humans;
- the levels at which cyanide is toxic;
- the levels of cyanide in firefighters immediately after fighting fires

[175] The command software was purchased in 2001 in anticipation of the assignment of fire captains as command aides. After the contract proposal that included this proposal was rejected in August, 2001, and a change of city administrations, the matter was never given serious consideration again.

- the interplay between the half-life of cyanide in blood, with thiocyanate and methemoglobin so as to allow doctors to better interpret whole blood cyanide levels;
- the relationship between cyanide and cardiac arrhythmias (including atrial fibrillation), and firefighter heart attacks
- the relationship between cyanide and macular degeneration, optic neuritis and other eye problems among firefighters
- the effects of medications and underlying medical conditions on cyanide uptake, retention, detoxification and blood levels

Additional research will help the medical community and the fire service better understand the dynamic interaction between cyanide, thiocyanate, methemoglobin and the whole blood tests. Research is also needed to develop a new blood test for cyanide that can return a result within a diagnostically useful period of time,

Recommendation 9. NEW CYANIDE ANTIDOTE. The development and approval of new cyanide antidotes, such as hydroxocobalamin, needs to be expedited. Hydroxocobalamin has been used in France to treat victims of smoke inhalation for over ten years with remarkable results. Given the harmful side effects of current cyanide antidotes, and the experience of firefighters and medical personnel in Europe with hydroxocobalamin, fast track status for this antidote is clearly warranted. If the information provided by doctors such as Dr. Borron, Dr. Eckstein, Dr. Alcorta, and Dr. Fortin is accurate, many lives could be saved each year, including the lives of firefighters.[176]

Recommendation 10. FIRE RESEARCH. Additional chemical and thermodynamic research is needed to better understand:

- how much cyanide is being generated at fire scenes
- what conditions yield higher versus lower concentrations of cyanide
- whether cyanide that is released in a fire remains localized (in a localized area around the fuel that is off gassing) or does it spreads out throughout the building
- is the cyanide localized in the smoke or is it extending beyond the visible smoke cloud
- is cyanide released only under certain fire conditions or is it released more commonly whenever a cyanide containing product burns

It is hoped the answers to these questions may provide an explanation for why one member of Ladder 6 had high readings and was symptomatic for cyanide poisoning, while another member of Ladder 6 who accompanied that member throughout two fires, had low cyanide levels and no symptoms. The committee is left a lingering question: Is it

[176] In the interim, consideration should be given to the use of hydroxocobalamin to revive pets that are overcome by smoke. According to the literature the same metabolic pathways would be involved and the additional research data may help shed some light of the use of hydroxocobalamin in humans.

possible that one firefighter standing adjacent to a smoldering television set, may receive a toxic dose of cyanide while another firefighter standing three feet away does not? Nothing in the literature can answer this question.

This research will also help firefighters to understand and be able to predict at what types of incidents besides working structure fires, that cyanide might be present, including when investigating smells of smoke and light smoke conditions.

Recommendation 11. DATA MANAGEMENT. The fire department should develop a better data management system to track exposures. Some members submit exposure reports after every fire that they respond to. The problem with this practice is that it tends to minimize or obscure the significance of an actual exposure when it occurs. Other members do not submit exposure reports no matter how significant the conditions. As a result it is difficult to rely on the data to make determinations.

There also needs to be greater trust and cooperation between the fire department administration, the union, and the union members with the emphasis on protecting the safety, health and well being of members. Most medical conditions that members experience are diagnosed by private physicians, and an occupation connection is never made. It is only by looking at the medical conditions of the entire workforce that connections can be made between illnesses and occupational exposures. Without accurate information on the health problems that members are experiencing, it is impossible to draw connections between occupational exposures and illnesses. However, in the absence of trust, the sharing of confidential health information will not occur.

Recommendation 12. IMPROVEMENTS TO SCBA. Additional research is needed to further refine and improve existing SCBA. A reoccurring statement from firefighters who were interviewed, as well as from data from the second survey, was that many members removed their face piece to improve visibility. See Table 14. Facepieces with improved visibility would help address these concerns. Longer duration packs that are lighter and ergonomically designed to better facilitate operations on ladders and roofs would also help address the concerns of many firefighters.

Company officers indicated that they removed their face piece to communicate over the radio. The department should investigate the availability of better communication devices to allow firefighters to communicate clearly while the SCBA face piece is donned. However, training and education about proper methods of radio use with the face piece in place (Recommendation 3), may address some of these concerns.

Recommendation 13. PUBLIC EDUCATION. The general public, the media and legislators need to be educated about the dangers of smoldering and burning plastics and other cyanide containing fuels. The public needs to know that the dangers associated with cyanide may be present before the presence of any flames and that it is possible to be incapacitated by the invisible gases during the incipient stage of a fire which could prevent them from escaping. Fire codes commonly take into account combustibility of various finishes and furnishings, but fail to consider the toxic smoke generated by the decomposition or burning of such items. Those responsible for adopting fire codes should incorporate some consideration of the toxicity inherent in products such as plastics and polyacrylonitriles to the same extent they consider flame spread.

Recommendation 14. EXECUTIVE FIRE OFFICER RESEARCH. Additional research is needed to analyze the data collected by the investigation team, possibly combining that data with information from the NIOSH investigation. It is possible there are correlations between high cyanide levels and other factors that a more in depth analysis may reveal. It is recommended that Chief Officers of the Providence Fire Department currently enrolled in the Executive Fire Officers Program at the National Fire Academy select this topic for further study as an applied research project.

Recommendation 15. REQUEST TO NIOSH. Additional research by NIOSH is needed to confirm the conclusions of the investigation committee, and further investigate other cyanide related issues including:

- the relationship between member's cyanide levels and medical conditions
- the relationship between member's cyanide levels and smoking
- the relationship between cyanide exposure and the cardiac issues experienced by Providence Firefighters
- the relationship between cyanide exposure and the 1990 eye problems experienced by members of B-Group

Research is also needed to better understand and document the role that on-scene ALS care is having on firefighter fatalities. Improvements in ALS care and better availability of ALS units at fire scenes may be masking serious trends in firefighter fatalities. For example, if firefighter fatalities on the fireground due to heart attack remain relatively constant from year to year, or even decline slightly, but improvements in ALS care result in a better survival rate for those suffering a heart attack, the overall risk of heart attack to firefighters may actually be going up each year. By looking solely at fatality statistics, we may completely miss the fact that the risk has gone up.

Recommendation 16. AWARENESS. The fire service needs to be made aware of the problem posed by hydrogen cyanide. Copies of this report should be disseminated and made available to all fire departments, the United States Fire Administration, National Fire Academy, IAFF, IAFC, and the NFPA to make as many firefighters as possible aware of what occurred. Many of the fire service related recommendations made in this report should be considered for adoption by other fire departments.

Figure 1

Broad Street Fire

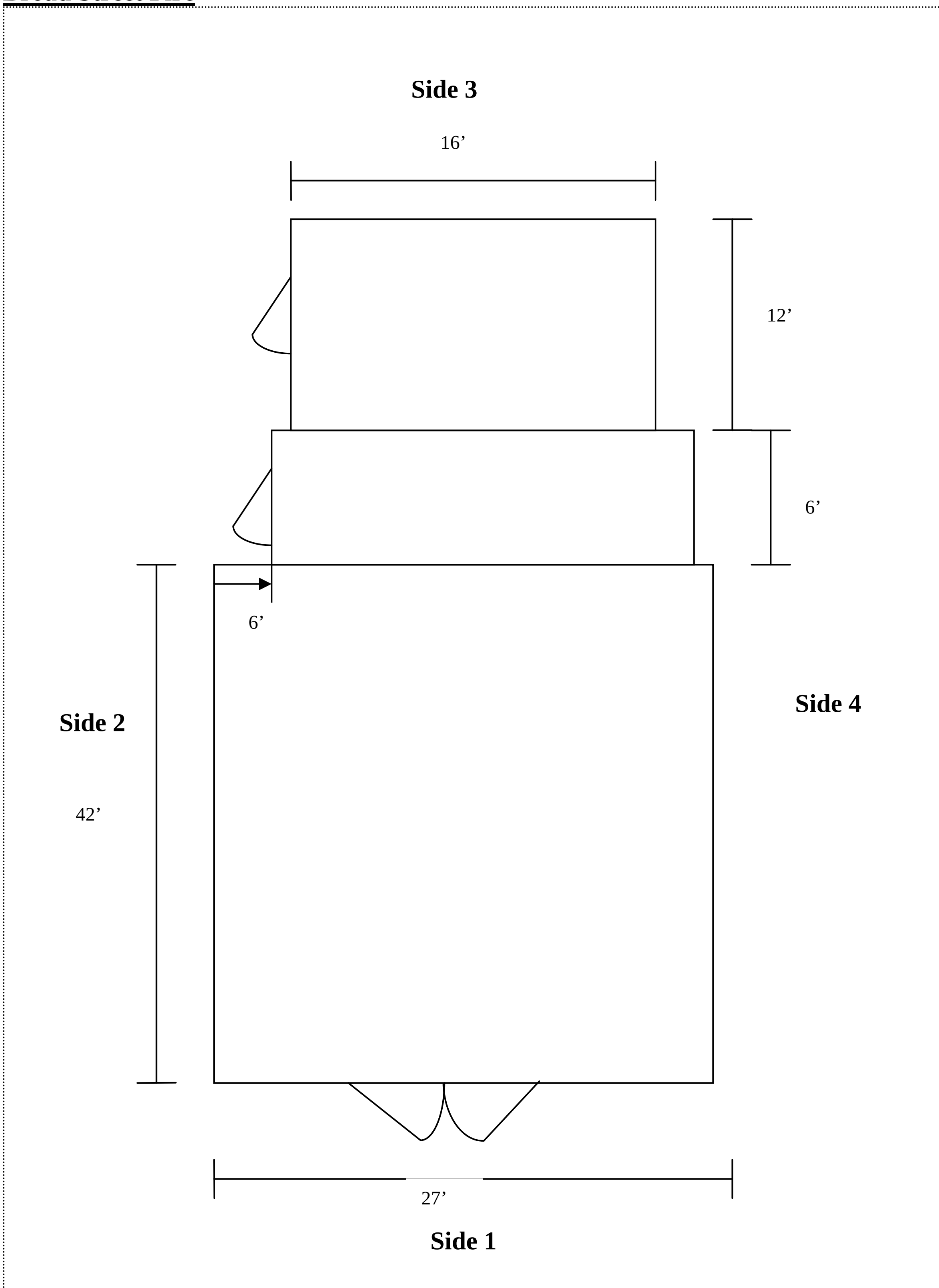


Figure 2

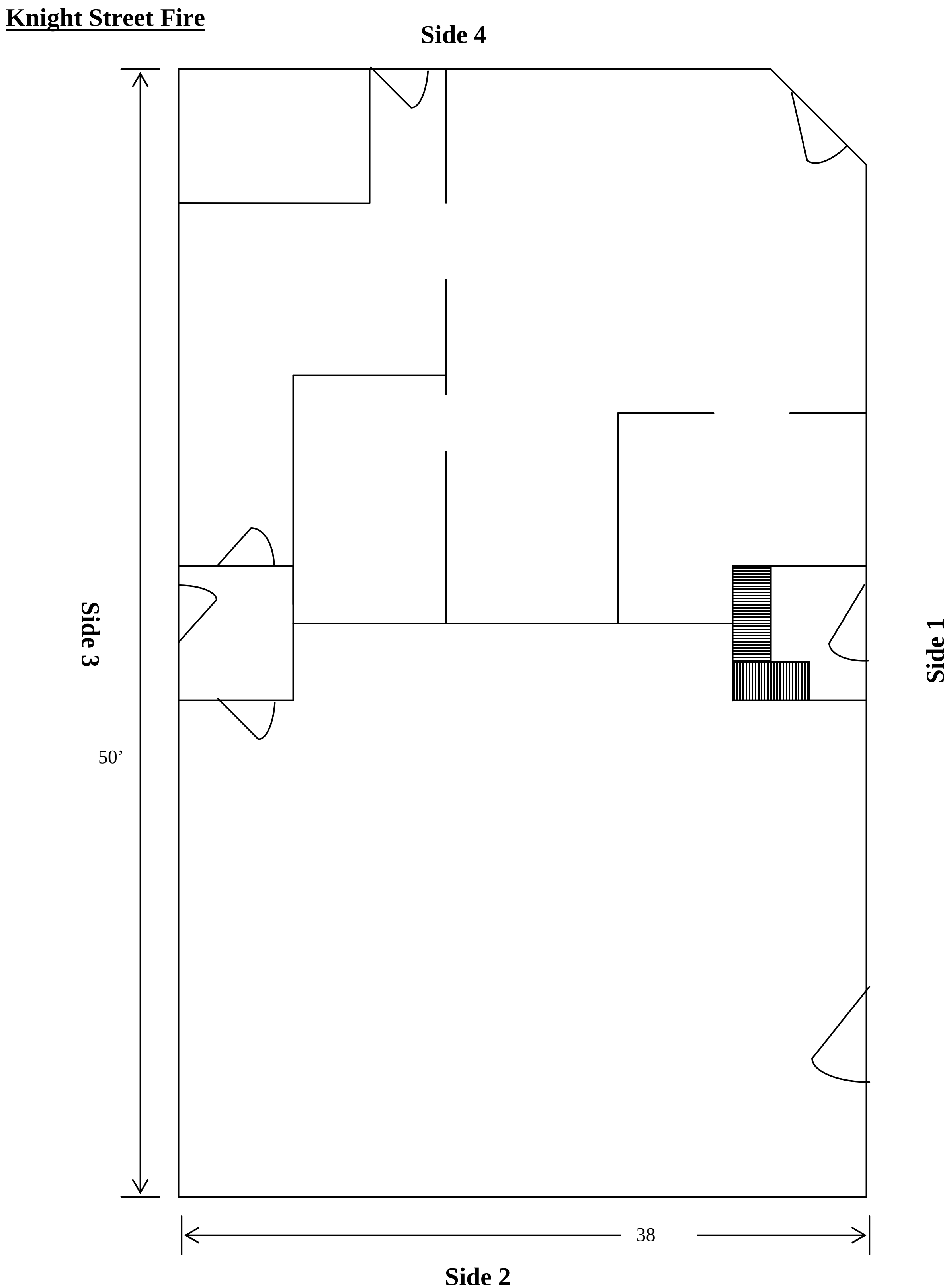


Figure 6

Figure 3

Ralph Street Fire

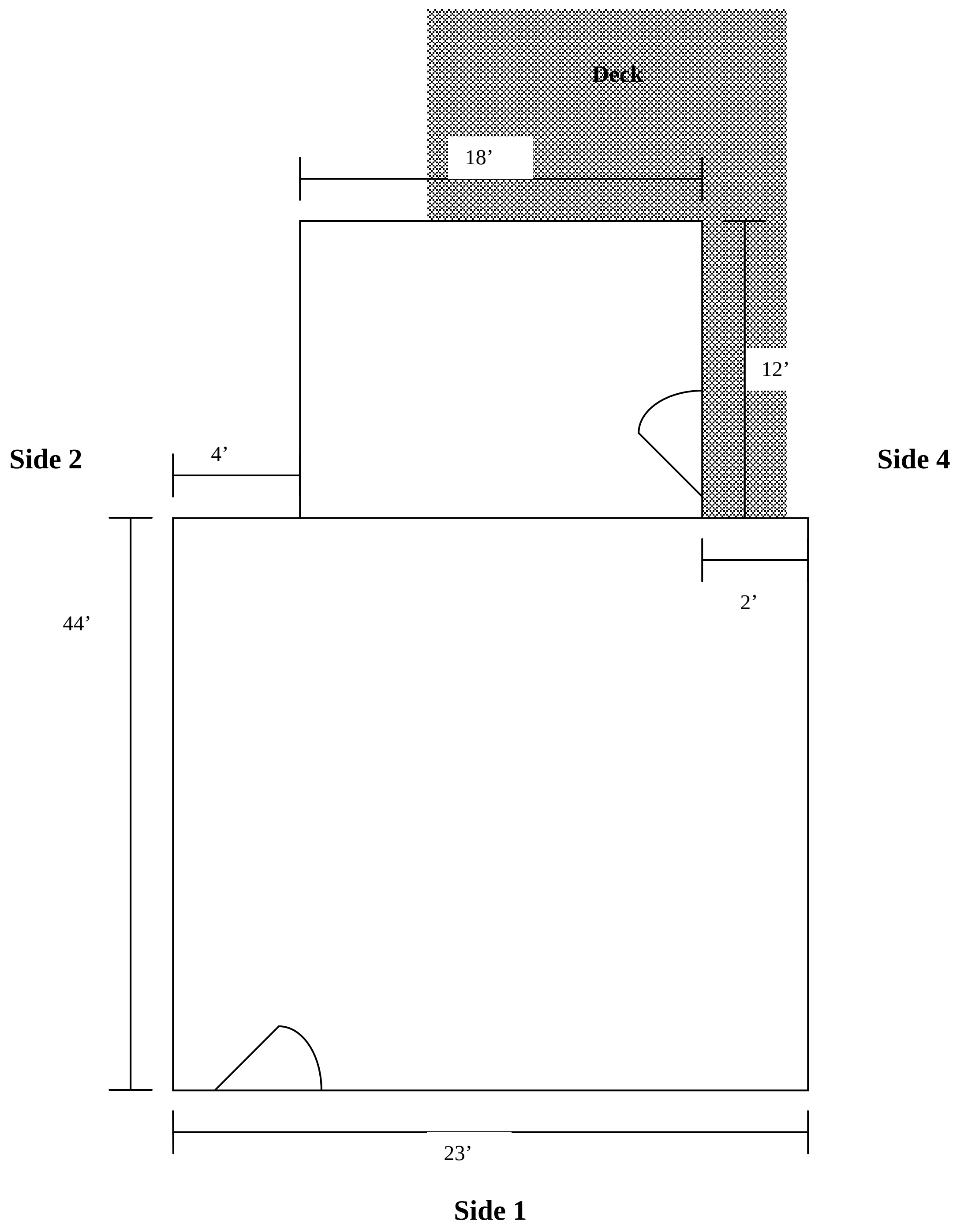


Figure 4

Broad Street Fire

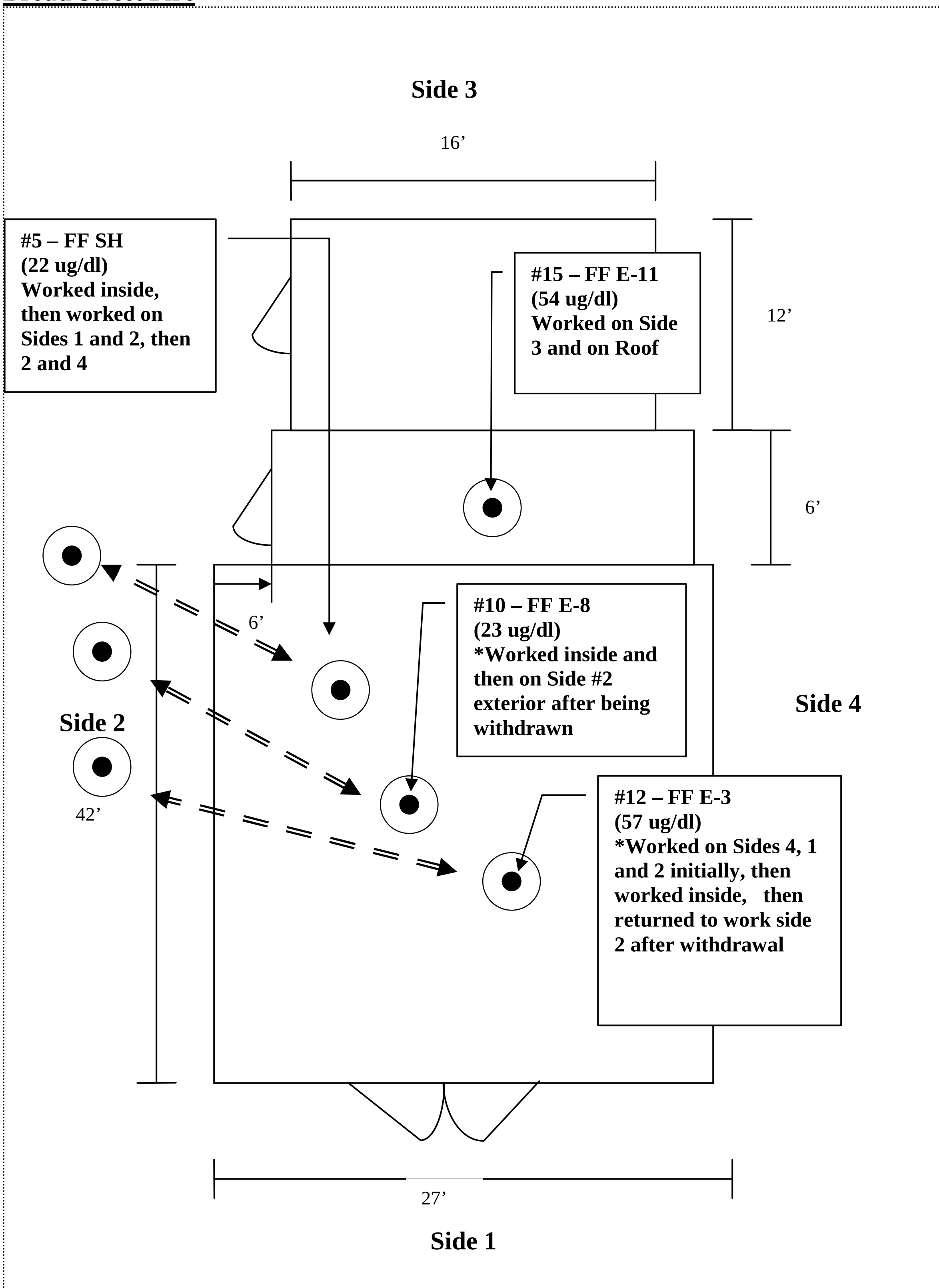


Figure 5

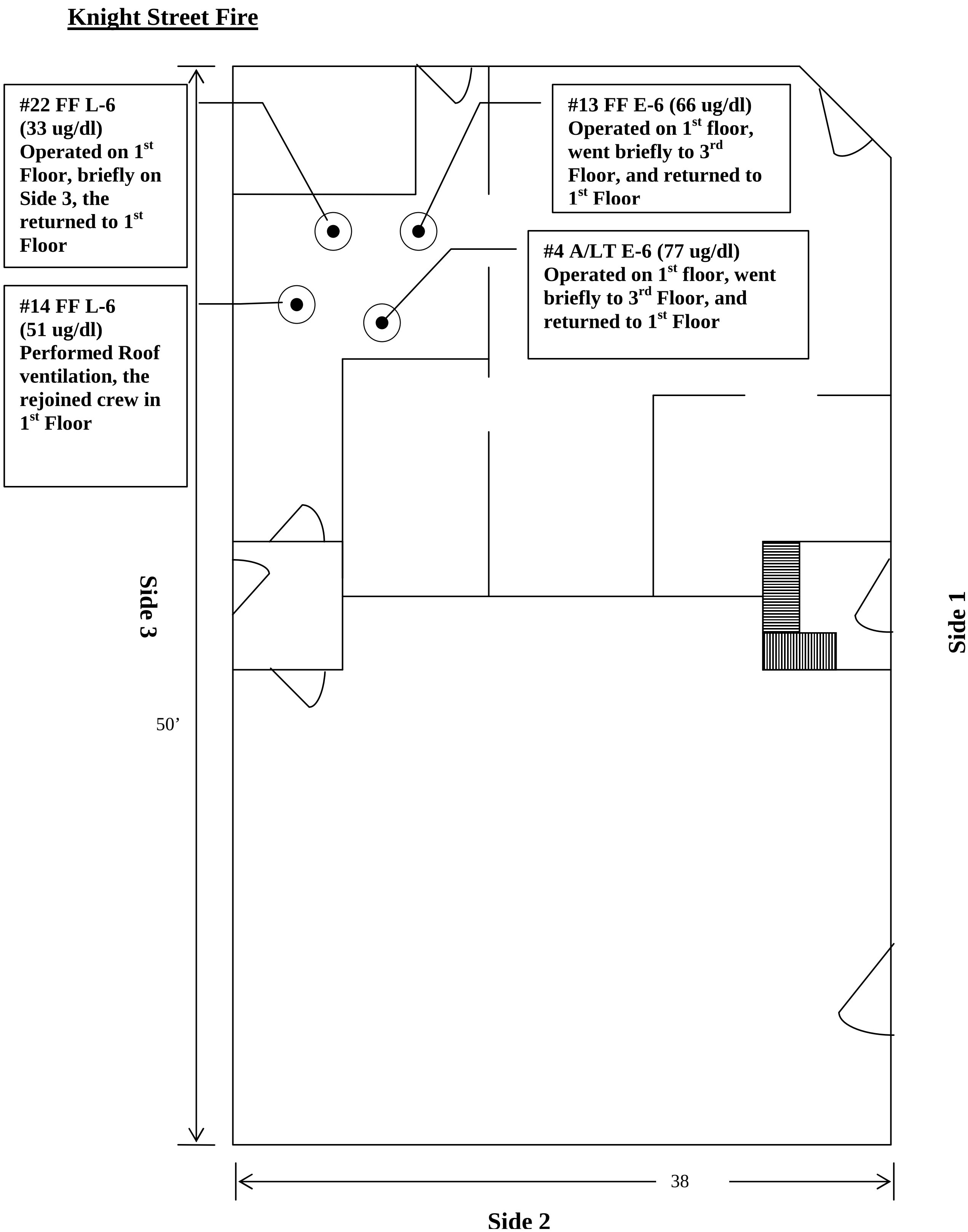
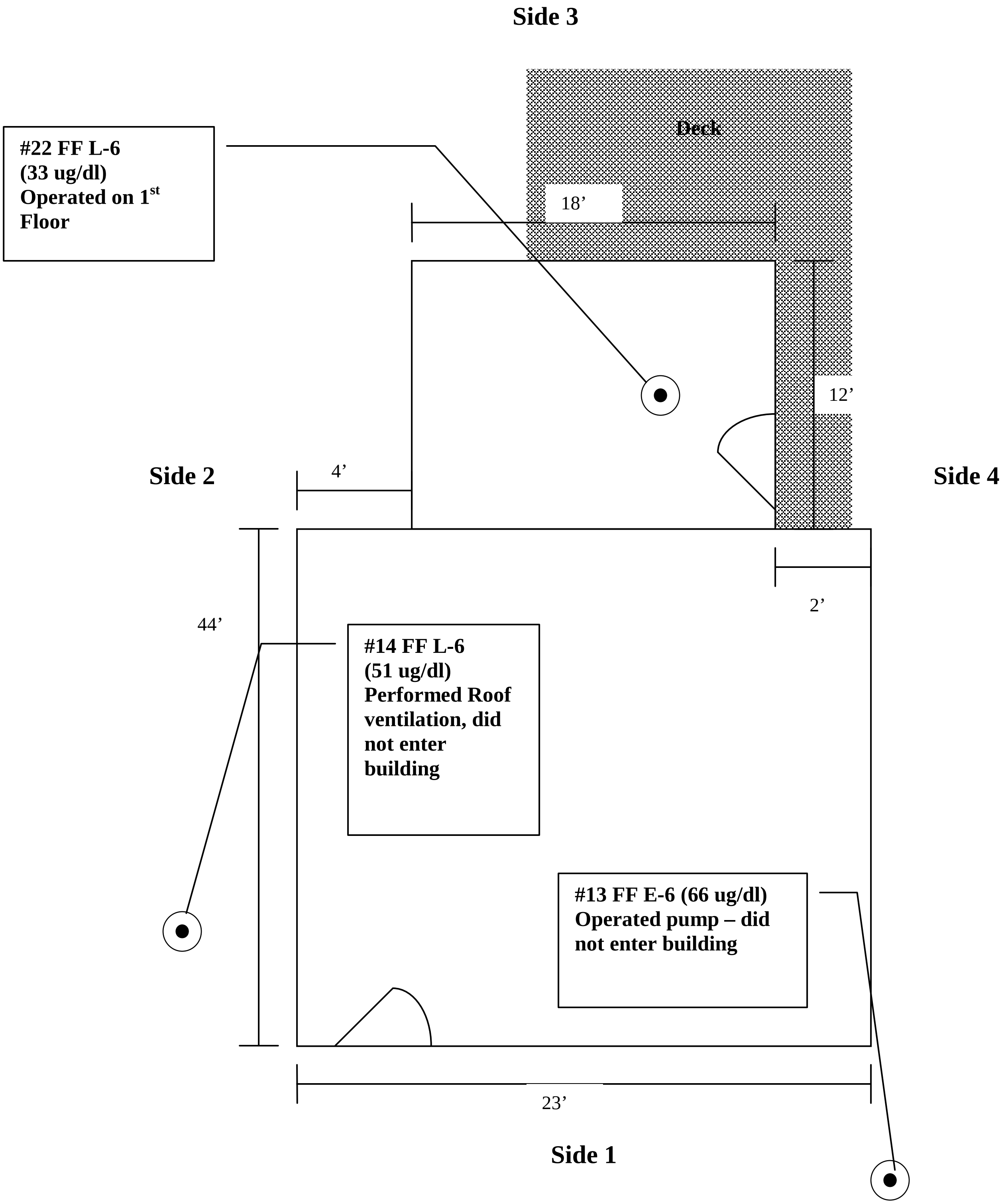

Knight Street Fire
#22 FF L-6 (33 ug/dl) Operated on 1st Floor, briefly on Side 3, the returned to 1st Floor
#14 FF L-6 (51 ug/dl) Performed Roof ventilation, the rejoined crew in 1st Floor
#13 FF E-6 (66 ug/dl) Operated on 1st floor, went briefly to 3rd Floor, and returned to 1st Floor
#4 A/LT E-6 (77 ug/dl) Operated on 1st floor, went briefly to 3rd Floor, and returned to 1st Floor
Side 3
50'
Side 1
38
Side 2

Figure 6

Ralph Street Fire



Appendix A – Joint Memorandum

Appendix B – Optic Neuritis Info

Appendix C – Follow Up Survey

Appendix D - Trace Analytics Lab Results

Appendix E – St. Paul Traveler's Lab Results

Appendix F – Rhode Island Department of Health Water Quality Lab Report

Appendix G – Rhode Island Analytical Lab report on FF Baker's Turnout Gear wipe tests

Appendix H – Tests on FF Baker's SCBA and mask

Appendix I - Rhode Island Hospital Lab Procedures for whole blood cyanide testing