



DEPARTMENT OF HEALTH & HUMAN SERVICES

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Public Health Service

HE TAD File

Centers for Disease Control
National Institute for
Occupational Safety & Health
Robert A. Taft Laboratories
4676 Columbia Parkway
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November 1, 1990
HETA 90-205

Mr. Richard M. Duffy
International Association of Fire Fighters
1750 New York Avenue, NW
Washington, D.C. 20006

Dear Mr. Duffy:

On March 8, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Association of Fire Fighters to investigate conditions in a residential fire in Danville, Virginia. Two firefighters died in this fire, and previous investigators believed smoke inhalation did not adequately explain the deaths. On April 11-13, 1990, NIOSH investigators Dr. Scott Deitchman of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies, Mr. Dwayne Smith of the Injury Surveillance Branch, Division of Safety Research (DSR), and Mr. Samuel Terry from the Air Supplied Respirator Branch, DSR, conducted an investigation in Danville. This letter is the final report of our activities during that visit and our interpretation of the information we collected.

DESCRIPTION OF INCIDENT AND INVESTIGATION

On January 28, 1990 three professional firefighters combatting a residential fire became unconscious and were brought out of the structure in full cardiac arrest. One of the three was successfully resuscitated, while the remaining two firefighters failed to respond to all efforts to revive them. Because of unusual circumstances surrounding this incident, the International Association of Firefighters contacted NIOSH and requested assistance in determining what had caused these three firefighters to lose consciousness.

On April 11-13, 1990, a NIOSH field team consisting of a physician, a respirator specialist, and an occupational safety and health specialist conducted an investigation of this incident. NIOSH personnel reviewed the incident with the Chief of the Fire Department, an Assistant Fire Chief (the incident scene commander), the surviving firefighter, and all other firefighters who were on the scene. Also interviewed were responding rescue squad personnel, a police lieutenant who was on the scene, the emergency room physician who had been on duty the night of the incident, the two pulmonary physicians who had cared for the survivor, and the Assistant Chief Medical Examiner and the toxicologist who examined the deceased firefighters.

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On the evening of January 28, 1990, two engine companies with four firefighters each responded to a fire in a 1500 square foot, two level house. The first company on the scene found the residence full of smoke with a small amount of fire visible through the living room picture window. The engine company captain and two responding firefighters (the victims) stretched a 1 1/2" attack line to the front of the residence, broke out the picture window, and attacked the visible flame in the front room. In the NIOSH interview following this incident, the captain reported that large quantities of black smoke poured through this window and over the heads of all three involved firefighters.

The captain and the two firefighters then moved to the front door of the residence, forced open the door, donned the masks of their self-contained breathing apparatus (SCBAs) and entered the residence. At this time smoke reportedly was banked down near the floor. The crew conducted firefighting operations in the kitchen/living room area of the first floor of the residence. In the meantime, a second engine company arrived on the scene and began firefighting operations in the basement of the structure. Two additional off-duty firefighters arrived on the scene, donned SCBAs, and entered the structure through the front door to assist the crew operating on the first floor. These two firefighters discovered a hallway to their left as they entered the structure. All five men then proceeded down the hallway.

The last two firefighters on the scene located a small fire in one room, took the hoseline from the initial crew, extinguished this fire, and returned the hoseline to the initial crew. Witnesses report that the structure was still filled with smoke and that there was considerable heat within the structure at this time. Up to this point the captain had been in continual radio communication with the Assistant Fire Chief on the scene who was the incident commander.

At this time the last two firefighters to enter the structure separated from the initial crew. A few seconds later these two firefighters heard the members of the initial crew yelling, but were unable to understand what was being said. When they called out to the initial crew they received no response. One of the two firefighters reported detecting an unidentifiable "smell" and "taste" which he perceived even though he was wearing an SCBA, followed by an increase in temperature. At this point the two firefighters decided to exit the structure and left through a window.

Radio communication with the initial crew had been lost at this same time. (In a radio transmission, the crew's captain stated "We got a whole lot of heat in here, Chief." On the tape recording of this transmission the sound of the Captain's SCBA is clearly heard. Approximately two minutes later a transmission of "hey" was heard from the captain. This was approximately one minute after the other two

firefighters had exited the structure, and was the last transmission received from the initial crew.) At about this same time a basement door which led to the stairs failed, permitting a rush of heat and smoke from the intense fire in the basement to enter the upper floor of the structure.

Repeated attempts to contact the initial crew via radio failed to elicit any response. The Fire Chief had arrived on the scene by this time, as had other off-duty firefighters. After being unable to establish contact with the initial attack crew either via radio or in response to the department's "evacuation" signal, the Fire Chief ordered a rescue team into the structure. The first two men to enter the structure in a rescue effort followed the 1 1/2" hose which the initial attack crew had brought into the structure with them. These two men encountered intense heat and heavy fire in the kitchen/dining room area and were forced to withdraw. They then pulled the 1 1/2" attack line that was already in the house back to themselves (at the front door) and reentered the structure, knocking down the fire as they advanced the hose line.

After searching the living room and kitchen/dining room area they found the hallway. As the first of these two men started down the hallway he observed a light in the hallway, which proved to be a flashlight carried by one of the missing firefighters. The missing firefighter was lying face down in the floor of the hallway. The rescuing firefighter carried the unconscious firefighter toward the door where he was met by other Fire Department personnel, who then took the unconscious firefighter outside. The rescue firefighter returned to the hall, and in the first room he encountered the second firefighter of the initial crew. This individual was also lying face down on the floor. He was removed in a manner similar to the first victim. The rescue firefighter then returned down the hall and found the remaining victim (the Engine Company Captain) in the second room on the left (a bathroom) lying face down in the bath tub. As he was carrying the Captain down the hall he encountered two firefighters who took the Captain outside. In the meantime the rescue firefighter's SCBA had ran out of air. The firefighter removed the mask from his SCBA and crawled along the floor to the front door where he exited the structure.

All three of the victims (the Captain and the two firefighters) were in cardiac arrest when removed from the structure. Each victim was removed from the structure within approximately 10 minutes from the time radio communication was lost.

Cardiopulmonary resuscitation (CPR) and advanced cardiac life support (ACLS) were immediately begun on all three victims. Neither of the two firefighters, both of whom were in their 30's and reportedly in good health, responded to continued resuscitation efforts. Although resuscitative efforts were continued during transport and at the local hospital, both men were pronounced dead approximately 2 hours after they were removed from the structure.

The Engine Company Captain, who was 20 years older than the two firefighters and was in the structure longer than either of the other two, responded to CPR almost immediately and survived the incident.

RELEVANT INFORMATION CONCERNING THIS CASE

1. The residence involved in this incident had been under Police observation for some time as a result of suspected illegal drug activity. The resident and his son had both been shot and injured at the residence a few days prior to the fire, reportedly by rivals in the drug business. However inspection of the residence after the fire failed to discover the presence of any illegal drugs, or chemicals or apparatus used to manufacture illegal drugs.
2. The cause of the fire was determined by law enforcement and fire personnel to be arson. Flame "trails" were readily observable through the structure. Samples of various materials taken from the structure and analyzed by The Bureau of Alcohol, Tobacco, and Firearms (ATF) labs revealed the presence of typical accelerants used in arson fires (gasoline & kerosene). Gasoline had been poured on the carpet down the center of the hallway, burned through the carpet to the floor, and had self-extinguished. It was reported that carpet samples taken from the area smelled strongly of gasoline. The carpet also had burned and then self-extinguished, possibly indicating an oxygen deficient/carbon dioxide and/or carbon monoxide rich atmosphere within the structure prior to "opening" of the building by fire department personnel.
3. According to personnel from both the Fire and Police Departments, the Captain and the two firefighters were wearing their SCBA when they were removed from the structure. A police department detective who removed the Captain's face mask reported that this mask was tightly fitted, and that the mask on one of the other firefighters appeared to fit properly. This officer did not see the other firefighter's face mask before it was removed. No one else was able to verify that the masks to these units were properly secured on the faces of the victims. In the last radio transmission received from the Captain, one can clearly hear his SCBA operating while he speaks.

One of the involved SCBAs was reportedly removed from one of the deceased firefighters, donned by another firefighter, and worn back into the structure without problems. The other unit was sent to NIOSH, DSR for examination. No problems with operation of the unit were observed by DSR staff. When the victims were removed from the fire structure, all three SCBA were operational, with air remaining in the supply tanks.

4. An air sample of the breathing air used to fill the involved SCBAs was taken the morning after the incident and sent to a lab for analysis of oxygen, carbon monoxide, carbon dioxide, condensed hydrocarbons, and water. This air proved to be of higher quality than is required for SCBA use.
5. A hazardous materials team from the Roanoke County Fire and Rescue Department was called to the site and arrived approximately three hours after this incident. A sweep through the structure by these individuals failed to reveal any hazardous material. However, the windows of the structure had been broken out during the fire, and the structure had been ventilated both by the fire department and naturally prior to the arrival of the hazardous materials team. No samples which would indicate actual atmospheric conditions within the structure during the fire were taken.
6. Arterial blood gas samples from both deceased firefighters were taken after their arrival at the hospital and showed carboxyhemoglobin levels of 17% and 38%. Both firefighters were cigarette smokers, but this alone probably does not account for the measured carboxyhemoglobin levels, since carboxyhemoglobin levels in smokers are generally in the 2%-10% range (depending on the number of cigarettes/day).¹ The time the samples were taken is not indicated, but the firefighters were admitted to the emergency room at 2250 and 2251 Eastern Standard Time (EST). The highest carboxyhemoglobin level recorded for the surviving firefighter (the Captain) was 32%. The time indicated on this specimen was at 2251 EST. It appears likely that the specimens from the two deceased firefighters were also taken at about this same time. Since arterial blood samples for blood gas analysis were not drawn at the time of the firefighters' rescue, and since no time is given for the initial blood gas samples, it is impossible to determine what blood CO levels were present when the firefighters collapsed.

When the firefighters were brought out of the burning house they were found to be unresponsive and apneic (not breathing), and resuscitation was begun which included ventilation with 100% oxygen. Records reviewed during the investigation failed to reveal the time at which resuscitation was begun, but a footnote to the printed log of fire department radio transmissions indicates that the first firefighter was brought out of the house between 2210 and 2218 EST. It therefore would seem likely that the firefighters had been ventilated with 100% oxygen for approximately 30 minutes before the blood gas samples were drawn (assuming they were drawn on arrival at the emergency room). The elimination half-life of carbon monoxide in the blood during breathing of 100% oxygen is approximately 60 minutes.² This is

for persons spontaneously breathing; because respiration during CPR is less efficient than spontaneous breathing, elimination of carbon monoxide could take longer. Still, it is likely that the carboxyhemoglobin levels of the affected firefighters were higher when they were removed from the building than when the samples were taken at the hospital. Carboxyhemoglobin levels above 40% are usually associated with unconsciousness, while levels over 60% are usually fatal.¹

Tests conducted the following day by the Medical Examiner's office failed to detect any carboxyhemoglobin in the victim's blood. However, the lower limit of detection of the test performed there is 20% carboxyhemoglobin, which is well above normal limits.³ An outside medical examiner we consulted reported that carboxyhemoglobin is very stable in a cadaver, so the negative result is not due to breakdown of the carboxyhemoglobin. The medical records of both deceased firefighters indicate they received resuscitation efforts (with intubation and artificial ventilation) for about 40 minutes after arrival in the emergency room; in the consulting medical examiner's experience, it is quite possible for aggressive CPR and ventilation to reduce a patient's carboxyhemoglobin to normal levels.⁴ This most likely accounts for the difference in the carboxyhemoglobin levels determined by the two labs. (The medical records of the firefighters appear to show progressive declines in the carboxyhemoglobin levels during resuscitation, but because many of the blood gas reports do not have times indicated, their complete sequence can not be determined).

Cyanide is often generated by combustion of synthetics found in homes, such as urea-formaldehyde or polyurethane foams, polyamide (nylon), or fabrics and upholstery made with polyacrylonitrile.⁵ Postmortem tests of blood cyanide levels performed on the two deceased firefighters were negative (the sensitivity of the test at the Bureau of Forensic Sciences laboratory is 0.5 mg/l). The blood specimens for cyanide analysis were received by the Bureau of Forensic Sciences laboratory on January 30, the second day after the deaths occurred. As blood cyanide levels in cadavers have been reported to decline after a day, it is possible that levels of cyanide above the measured values existed in the blood of the deceased firefighters at the time of death.⁶ In the absence of any detectible cyanide, however, any previous level was likely to have been low.

7. The Medical Examiner's office gave the cause of death for both firefighters as smoke inhalation, based on the observation that "There is an abundance of soot in the lower trachea and large mainstem bronchi" and "Soot present in the smaller bronchiolar radicles." Soot was also observed in the airways on bronchoscopic examination of the survivor.

One could speculate that if the firefighters had incurred enough smoke exposure and soot deposition while outside the house, they would have been incapacitated and therefore been unable to continue their work and enter the house; this would lead to the conclusion that the smoke exposure must have occurred while they were inside the house. Unfortunately there is no definition of the amount of soot an individual inhaling smoke can have deposited in their airways and still be able to function. All witnesses present state that a dense, black smoke was present not only within the structure, but also on the grounds around the building. One Emergency Medical Technician (EMT) trying to work on an injured firefighter (who was lying on the ground) moved him to the inside of a rescue vehicle located away from the fire scene to avoid this dense smoke. With heavy smoke conditions such as this, it seems possible that all those on the fire scene would have had some amount of soot in their airways.

8. A large quantity of "household" chemicals, including numerous aerosol cans, was present in the basement room near the stairs which lead to the first floor. These containers and their contents were effectively destroyed during the fire. It is possible that some unknown substance (or substances) were vaporized at this time and were carried upstairs in the smoke and heat when the basement door failed.
9. The involved Fire Department has standard operating procedures requiring the use of SCBAs when entering a structure on fire. The Department reports that, because of this policy, they have had no problems with smoke inhalation within the past several years. EMTs and hospital emergency room personnel also reported that they do not typically treat members of this Fire Department for smoke inhalation problems. This supports the Fire Department's contention that their personnel utilize SCBA.
10. One firefighter (one of the two who exited the residence via a window at the time of the incident) reported a "smell" and a "taste" that was like "being hit with a glass of cold water, I couldn't breathe". The firefighter who located the three victims, and who ran out of air himself while bringing out the Captain, reported being dizzy and nauseous. These sensations reportedly left when he received oxygen at the hospital and returned when oxygen was discontinued. The Fire Chief, who entered the structure's living room without an SCBA to help carry the victims out of the structure reported feeling "dizzy, almost like I was drunk". Other individuals at the scene reported no unusual odors, sensations, or observations.
11. Tissue samples of both deceased firefighters have been retained by the State Medical Examiner's office. Additional testing would therefore be possible.

12. An investigation of this incident was conducted by the State Fire Chief's Association. Citing a lack of sufficient evidence, this investigation disagreed with the Medical Examiner, supported the involved Fire Department's performance during the incident, and stated that "a toxin above and beyond the ordinary was in that atmosphere" while admitting that the exact substance may never be known.

CONCLUSIONS

Due to numerous factors, including the time delay prior to this investigation, lack of environmental sampling at the time of the incident, and failure to record times on blood gas readings taken following the incident, it is not possible at this time to make a definitive determination as to the actual cause of the firefighters deaths. In trying to explain the cause of this incident, two questions arise:

- 1) What agent caused the firefighters' collapse?
- 2) By what route were they exposed?

We present several hypotheses to account for the available evidence; although none of them are completely satisfactory, they can be discussed in order of likely probability.

- 1) What agent caused the firefighter's collapse?

The agent causing the death of the firefighters was likely a product of combustion of some material in the house. Speculation as to the identity of this agent has included carbon monoxide, cyanide, or an unknown toxin generated by the fire. Although it is impossible to state the cause of death with certainty, the available evidence of the soot in the airways of all three firefighters strongly suggests they incurred significant smoke exposure. The carboxyhemoglobin levels measured in two of the firefighters at the time of admission approach levels associated with incapacitation; if levels were higher at the time the firefighters collapsed, carbon monoxide may have been the cause. Carbon monoxide intoxication can result after short exposures to high levels. The amount of carbon monoxide produced in fires ranges from 0.1% to 75%; for example, breathing at a ventilation rate of 30 l/min for 30 seconds in an atmosphere of 10% carbon monoxide would produce a carboxyhemoglobin level of 75%.⁷ In addition, the combustion which generates oxides also consumes oxygen and may produce a rapidly progressive oxygen-deficient atmosphere, which would potentiate the anoxic effect of carbon monoxide poisoning.⁵

Although cyanide is often produced in structural fires, no cyanide was detected in the blood of the deceased firefighters. The lower limit of detection of the test used by the Bureau of Forensic Sciences in Roanoke is 0.5 milligrams of cyanide per liter of sample (mg/L).⁸ The

lowest whole blood concentration of cyanide compatible with death from acute poisoning is 1-2 mg/L.⁶ In cases where there is a marked excess of carbon monoxide relative to that of cyanide, it has been suggested that the carboxyhemoglobin levels indicate the cause of death.⁹ Thus it is less likely that cyanide was the cause of death.

The suggestion that an unknown toxin was present in the house and caused the death of the firefighters apparently began as a result of the belief that an illicit drug laboratory was present in the house. The emergency room physician's note for one of the firefighters, dictated on the night of the fire, states that "according to firemen, patient was in a burning building with the presence of many pounds of 'cocaine.'" Similar statements appear in the Medical Examiner's reports; the narrative summary in the report on one firefighter states "Abundant cocaine as well as other unidentified chemicals were found around the house," while the narrative summary in the report on the other states "Abundant chemicals are said to have been found in the premises." Finally, a committee of Virginia fire chiefs concluded that a toxin "above and beyond the ordinary was in the atmosphere" in the house and caused the death of the firefighters.¹⁰

In contrast, the report of the Roanoke County Hazardous Materials Team states "No detection of anything unusual throughout the house except for a trailor [sic] upstairs [presumably referring to the trail left by the accelerant used by the arsonist]" and "Nothing chemical or lab related was detected." This was confirmed by Lt. T.A. Smith of the Danville Police Department, who told us that examinations of the house by representatives of the Drug Enforcement Agency and the Bureau of Alcohol, Tobacco and Firearms found nothing in the house to indicate drug activities of any kind. It is possible that an unknown toxin was present, perhaps having dissipated by the time the investigations were conducted. However, in the absence of any evidence to support its presence, this hypothesis should be assigned a relatively low probability.

2) By what route were the firefighters exposed?

If the firefighters died from the inhalation of combustion products, one could suggest they received their exposure before they donned their SCBA and entered the house. While we do not know the exact time when the three firefighters entered the house, according to the radio transmission log, at 2153 EST the Deputy Chief called the Captain by the callsign "Interior," and the Captain responded. This strongly suggests the three firefighters were in the house at that time. The Captain continued to report as late as 2159.08, with his last transmission at 2201. This suggests that the firefighters were actively working in the house for at least 6-8 minutes before they collapsed. If it is assumed both that the firefighters incurred their smoke and carbon monoxide exposure before they donned SCBA, and that the exposure was enough to produce carboxyhemoglobin levels greater than 38% (the level recorded in one firefighter after half an hour of

resuscitation), it is difficult to believe they would have been able to function for 6 minutes or more after that exposure. It therefore seems more likely that the firefighters sustained the bulk of their carbon monoxide exposure while in the building.

It has also been suggested that the firefighters could have succumbed to an unknown toxin that either penetrated their SCBA and was inhaled, or penetrated their turnout gear and was absorbed through the skin. Fire smoke is an extremely complex mixture of substances. When unidentified compounds are combined in the high temperatures of a fire, the potential exists for the formation of a wide variety of chemical combinations. Because of this, it is not possible to conclusively disprove the hypothesis of an unknown toxin; however, no concrete evidence exists to support it. If such a penetrating and lethal toxin had been present in the structure, one would expect that other firefighters entering the same areas would have been at risk of being overcome. Although some firefighters reported unusual sensations or symptoms, none were overcome and no unusual signs were seen in those who were examined in the emergency room. Other firefighters on the scene reported nothing out of the ordinary.

This leaves the possibility that for some reason the firefighters' SCBA units were, at some point, not delivering air to the exclusion of outside air. Perhaps the three firefighters, for unknown reasons (e.g., to conserve their air supply, to ease communications, etc.), may have loosened their facepieces resulting in exposure to high carbon monoxide or carbon dioxide levels, oxygen deficiency, and/or an unknown toxin which caused them to collapse. This, however, contradicts all the evidence that firefighters in this department scrupulously adhered to the existing SCBA policy; it is doubtful that all three firefighters would have performed this action without some reason, one which we cannot guess in retrospect. Yet the high carboxyhemoglobin levels suggest that somehow the firefighters were exposed to environmental air in the home. As explained in item #7, above, the findings of soot in the airway are not specific enough to suggest an explanation.

RECOMMENDATIONS

In similar situations in the future, all possible efforts should be made to obtain a "grab sample" of the atmosphere within the area by using a gas-tight bag. Analysis of the atmosphere could reveal atmospheric conditions at the fire scene at the time of the incident such as CO levels, oxygen levels, and the presence of contaminants not typically found in fire smoke (or typical fire smoke contaminants in atypical concentrations). Additionally, blood samples of the victims of such incidents should be taken as soon as possible, and the time properly recorded in order that these samples may be studied at a later time. Blood samples taken during hospital treatment, and the reports of the laboratory results, should also be labeled with the time they were drawn. Finally, investigations of this type should

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involve a team on site as soon as possible after the incident, preferably within 24 hours. This team should include an industrial hygienist with equipment to take samples of any and all suspect materials found at the scene.

This letter comprises our final report on this incident. If you have any questions, please feel free to contact us by telephone at (513) 841-4386 (Dr. Deitchman), (304) 291-4804 (Mr. Smith), or (304) 291-4333 (Mr. Terry). In the meantime, we wish to thank all those who generously showed us their willingness to help us address in our investigation.

Sincerely yours,



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