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TO: Director, National Institute for Occupational Safety and Health

FROM: Division of Safety Research, NIOSH

SUBJECT: Carbon Monoxide Kills Three Volunteer Firefighters Inside Well in Pennsylvania

SUMMARY

Three volunteer firefighters died inside a well after being exposed to carbon monoxide from the exhaust of a portable gasoline engine-powered pump. The incident occurred after four firefighters from a volunteer fire department responded to a request from a local resident to remove the remains of a dead animal from a 33-foot-deep water well. The firefighters decided to first pump the water out of the well (approximately 12 feet of water). One firefighter climbed down into the well on an aluminum ladder and built a wooden platform at the 15-foot level. A second firefighter climbed down into the well to help position a 9-horsepower gasoline engine-powered pump being lowered down to the platform. The two firefighters started the engine but were unable to prime the pump. Within a few minutes the first firefighter became dizzy and exited the well. The second firefighter remained in the well and became unconscious. In a rescue attempt the first firefighter climbed back down into the well, turned the engine off, and then collapsed unconscious over the engine. By this time, the engine had run for approximately 8 to 9 minutes. Within minutes several other volunteer firefighters responding to radio emergency calls arrived at the scene. Over the next 3 hours, eight volunteer firefighters entered the well in rescue attempts. Only two of the rescuing firefighters wore supplied-air respirators (SCBA type). The first firefighter was rescued and revived. The second firefighter and two other firefighters attempting rescue died. NIOSH investigators concluded that, in order to prevent future similar occurrences, volunteer fire departments should:

- develop and implement a confined space entry and rescue program
- develop and implement a respiratory protection program to protect volunteer firefighters from respiratory hazards
- ensure that firefighters are properly trained in the use of gasoline powered engines/pumps and the life-threatening hazards of carbon monoxide in a confined area

- develop and implement a general safety program to help volunteer firefighters recognize and control hazards affecting themselves.

INTRODUCTION

On May 1, 1990, a 39-year-old male volunteer firefighter died inside a 33-foot-deep water well in Pennsylvania while attempting to pump water out of the well. Also, two male volunteer firefighters (ages 40 and 20) died attempting rescue. On May 4, 1990, officials of the Water Pollution Control Federation (WPCF) notified the Division of Safety Research (DSR) of these deaths and requested technical assistance. On May 23 and May 30, 1990, two research industrial hygienists from DSR traveled to the incident site to conduct an investigation. The investigators spoke with volunteer fire department representatives and firefighters involved in the incident, and obtained reports from the police and coroner. Photographs of the incident were obtained during the investigation.

The three firefighters who died in this incident belonged to a volunteer fire department consisting of 170 members (30 of whom are active members) in a town with a population of 400. None of the members of the volunteer fire department receive pay for services performed. The initial firefighter victim (the second firefighter to enter the well) had 9 years' experience as an active volunteer firefighter. The other two firefighter victims had 3 and 4 years' experience, respectively, as active volunteer firefighters. The volunteer fire department has no written safety policy, no documented firefighter safety program, nor any confined space entry/rescue program or procedures. The three victims had received at least 8 hours' training on the emergency use of self-contained breathing apparatus (SCBA).

INVESTIGATION

Four voluteer firefighters responded to a request from a local resident to remove the remains of a dead animal from a 33-foot-deep well. The concrete well opening measured 18 inches by 22 inches and is located in the middle of a concrete porch at a private residence. The well shaft (from ground level down to a depth of 15 feet) is constructed of concrete and measures 5 feet by 7 feet. Below the 15 foot level, the well is an earthen hole 5 feet in diameter (see Figures 1 & 2). To remove the remains of the dead animal from the well, the firefighters decided to pump approximately 12 feet of water out of the well.

The day before the incident, the firefighters tried to pump the water out of the well by lowering the hoses on two different fire trucks into the well water. However, the truck pumps were not capable of pulling water up 30 feet. The following day, the

firefighters decided to pump the well out using a 9-horsepower gasoline-powered engine pump. As a result of this decision the following sequence of events occurred:

- Firefighters lowered two aluminum ladders (tied end to end) into the well.
- A firefighter (first firefighter) climbed 15 feet down into the well on the ladder and wedged two boards across the well shaft to set the pump on.
- Another firefighter (second firefighter) climbed down into the well to help position the gasoline pump.
- The gasoline pump was lowered down to the platform, and the two firefighters started the engine but were unable to prime the pump.
- Within a few minutes, the first firefighter became dizzy, exited the well, and collapsed on the ground near the well opening.
- Firefighters, who remained outside the well noted that the second firefighter in a crouching position on the platform next to the pump was unresponsive.
- The first firefighter regained consciousness and, in a rescue attempt, climbed back down into the well, turned the gasoline engine off (the pump engine had run for approximately 8 to 9 minutes), and collapsed unconscious over the pump engine.
- The second firefighter then apparently fell off the platform face down into the water (6 feet below the platform).
- A third firefighter climbed down into the well in a rescue attempt, but was unable to lift the first firefighter and climbed back out.
- A fourth firefighter called for help on the truck radio, then climbed down into the well with one end of a rope. He tied the rope around the first firefighter's torso, and collapsed unconscious, falling facedown into the water.
- By this time, other volunteer firefighters arrived at the scene in response to the radio emergency call, and began pulling on the rope that was attached to the first firefighter. They were unable to lift him.
- A fifth firefighter climbed down into the well, placed the first firefighter on his shoulder and hoisted him out of the well with the help of firefighters pulling on the rope

at the well opening.

- Firefighters began cardiopulmonary resuscitation (CPR) on the first firefighter, who regained consciousness. (Up to this time, none of the firefighters who entered the well wore any type of respiratory protective equipment.)

- A sixth firefighter donned an SCBA and started down into the well in a rescue attempt, followed by the fifth firefighter who was not wearing any respiratory protective equipment.

- Within a minute the fifth and sixth firefighters climbed back out of the well. The sixth firefighter complained that he was having difficulty wearing the SCBA because of the cramped conditions in the well, and the fifth firefighter complained of dizziness.

- The sixth firefighter then removed the SCBA and climbed back down into the well with the end of a rope.

- Upon reaching the platform the sixth firefighter yelled that he needed help.

- A seventh firefighter who was not wearing any respiratory protective equipment climbed down to the platform and observed the second, fourth, and sixth firefighters all floating face down in the water.

- Feeling dizzy, the seventh firefighter climbed back out of the well and collapsed unconscious on the ground near the well opening.

- An eighth firefighter donned an SCBA, climbed down into the well, tied the end of a rope around the torso of the sixth firefighter, and, with the help of firefighters pulling on the rope at the well opening, began hoisting the sixth firefighter out of the well. Using this method, they managed to hoist him a few feet above the platform but the rope became entangled in the ladder.

- At this time, the alarm to the SCBA worn by the eighth firefighter sounded, so the eighth firefighter climbed out of the well.

- The fifth firefighter reentered the well (without any respiratory protective equipment), climbed down to where the sixth firefighter was hanging, untangled the rope from the ladder, placed the sixth firefighter on his shoulder, and, with the help of firefighters pulling on the rope at the well opening, hoisted the sixth firefighter out of the well.

- Emergency medical service (EMS) personnel (who had arrived at the scene approximately 20 minutes after hearing the radio call for help) administered CPR to the sixth firefighter at the site and en route to a local hospital. Efforts to resuscitate the sixth firefighter were unsuccessful and he was pronounced dead in the hospital emergency room.

- A ninth firefighter climbed down into the well (without wearing any respiratory protective equipment) in a rescue attempt, but felt dizzy after reaching the platform so he climbed back out of the well.

- A tenth firefighter donned an SCBA, climbed down the ladder into the well to the water level, tied the end of a rope around the torso of the fourth firefighter and began hoisting the firefighter out of the well using the same technique as before. Again, the rope became entangled in the ladder when the fourth firefighter was a few feet above the platform.

- After several minutes, the tenth firefighter was able to free the entangled rope and the fourth firefighter was finally removed from the well just as the alarm on the tenth firefighter's SCBA sounded.

- An EMS rescuer then donned an SCBA, climbed down into the well, and hoisted the second firefighter out of the well using the same hoisting technique as immediately before. (By this time, approximately 3 hours had elapsed from the time that the rescue of the second firefighter had initially begun.)

- EMS personnel administered CPR to both the fourth and second firefighters immediately after they were removed from the well and while en route to the local hospital. Both were pronounced dead on arrival by the attending physician.

CAUSE OF DEATH:

The coroner listed the causes of death for the second firefighter and sixth firefighter as carbon monoxide inhalation, and the cause of death for the fourth firefighter as drowning, with loss of function due to carbon monoxide inhalation.

RECOMMENDATIONS/DISCUSSION

Recommendation # 1: Volunteer fire departments should develop and implement a confined space entry and

rescue program.

Discussion: Volunteer firefighters may be required to enter confined spaces to perform either non-emergency tasks or emergency rescue. Therefore, volunteer fire departments should develop confined space entry and rescue programs, that include emergency rescue guidelines and provide procedures for entering confined spaces. A confined space program, as outlined in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces," should be implemented. At a minimum, the following items should be addressed:

1. Is entry necessary? Can the task be completed from the outside? For example, many fire departments use an underwater search and rescue device which consists of several sections of metal tubing connected together with a hook on the end. Such a device can be used to fish the dead animal remains or other objects out of a well without the need for entry. Also, some fire departments in rural areas use water jet pumps, water siphon booster pumps, or high pressure ejector pumps to pump water at depths greater than 15 feet. This type of pump could have been lowered into the well to pump the water out without the need for anyone to enter the well. Measures that eliminate the need for firefighters to enter confined spaces should be carefully evaluated and implemented if at all possible before considering human entry into confined spaces to perform non-emergency tasks.

2. Has a confined space entry permit for non-emergency entry been issued by the fire department?

3. If entry is to be made, has the air quality in the confined space been tested for safety based on the following:

   - Oxygen supply at least 19.5%
   - Flammable range for all explosive gases less than 10% of the lower explosive limit
   - Absence of toxic air contaminants?

4. Is ventilation equipment available and/or used?

5. Is appropriate rescue equipment available?

6. Are firefighters and firefighter supervisors being continuously trained in the selection and use of appropriate rescue equipment such as:

   - SCBA's
   - lifelines
   - human hoist systems offering mechanical advantage

- o protective clothing?

7. Are firefighters being properly trained in confined space entry procedures?

8. Are confined space safe work practices discussed in safety meetings?

9. Are firefighters trained in confined space rescue procedures?

10. Is the air quality monitored when the ventilation equipment is operating?

The American National Standards Institute (ANSI) Standard Z117.1-1989 (Safety Requirements for Confined Spaces), 3.2 and 3.2.1 state, "Hazards shall be identified for each confined space. The hazard identification process shall include, ... the past and current uses of the confined space which may adversely affect the atmosphere of the confined space;... The hazard identification process should consider items such as... the operation of engine powered equipment in the confined space." An evaluation and identification of the hazards of a non-emergency confined space task is imperative so that supervisors can determine if the fire department has the proper equipment and personnel with the appropriate training to enter a confined space. Volunteer fire departments without the appropriate training and/or equipment should not attempt non-emergency confined space tasks.

Recommendation #2: Volunteer fire departments should develop and implement a respiratory protection program designed to protect firefighters from respiratory hazards.

Discussion: National Fire Protection Association (NFPA) Standard 1404 3-1.2 and 3-1.3 (Standard For a Fire Department Self-Contained Breathing Apparatus Program) state, "Respiratory protection shall be used by all personnel who are exposed to respiratory hazards or who may be exposed to such hazards without warning... Respiratory protection equipment shall be used by all personnel operating in confined spaces, below ground level, or where the possibility of a contaminated or oxygen deficient atmosphere exists until or unless it can be established by monitoring and continuous sampling that the atmosphere is not contaminated or oxygen deficient." Volunteer fire departments should develop and implement a respiratory protection program which includes training in the proper selection and use of respiratory protective equipment according to NIOSH Publications "Respirator Decision Logic" (Publication #87-108) and "Guide to Industrial Respiratory Protection"

(Publication #87-116).

Recommendation #3: Volunteer firefighters should be trained in the use and limitations of gasoline-powered pumps and the hazards of carbon monoxide in a confined area.

Discussion: The firefighters in this incident operated a gasoline-powered pump while inside a confined space without providing any exhaust ventilation. According to interviews with the firefighters involved, they were unaware of the hazards that this would create. Noting the gasoline engine size and type, how long the engine had been running, and the atmosphere volume of the well, the carbon monoxide concentration was estimated to be approximately 20,500 parts per million (PPM) (Appendix). For carbon monoxide, this is more than 13 times the "immediately dangerous to life and health" (IDLH) concentration, which is 1500 PPM (according to the NIOSH Pocket Guide to Chemical Hazards).

Recommendation #4: Volunteer fire departments should develop and implement a general safety program designed to help firefighters recognize, understand, and control hazards affecting them.

Discussion: NFPA standard 1500, 3-1.1 states that "The fire department shall establish and maintain a training and education program with the goal of preventing occupational accidents, deaths, injuries, and illnesses." NFPA standard 1500, 3-1.4 states that "The fire department shall provide training and education for all members to ensure that they are able to perform their assigned duties in a safe manner that does not present a hazard to themselves or to other members." Firefighters are often requested by residents to perform non-emergency tasks that can endanger the firefighter's life. As part of the safety program, fire departments should carefully evaluate each task to identify all potential hazards, (e.g., falls, electrocutions, burns, etc.) and implement appropriate control measures.

REFERENCES

1. National Institute for Occupational Safety and Health, Criteria for a Recommended Standard ... Working in Confined Spaces. DHHS (NIOSH) Publication Number 80-106, December 1979.

2. National Institute for Occupational Safety and Health, A Guide to Safety in Confined Spaces. DHHS (NIOSH) Publication Number 87-113, July 1987.

3. National Fire Protection Association (NFPA), Fire Department Self-Contained Breathing Apparatus Program. NFPA 1404, 3-1, 1989.

4. National Fire Protection Association (NFPA), Fire Department Occupational Safety and Health Program. NFPA 1500, 3-1, 1987.

5. American National Standards Institute, Inc. (ANSI), Safety Requirements for Confined Spaces. ANSI Z117.1-1989.

6. National Institute for Occupational Safety and Health, Respiratory Decision Locic. DHHS (NIOSH) Publication Number 87-108, May 1987.

7. National Institute for Occupational Safety and Health, A Guide to Industrial Respiratory Protection. DHHS (NIOSH) Publication Number 87-116, September 1987.

8. National Institute for Occupational Safety and Health, Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication Number 85-114, September 1985.

Appendix

CALCULATION OF ESTIMATED CARBON MONOXIDE CONCENTRATION:

Engine size and type: 377 cc, 3600 RPM, 4-stroke, exhaust emission approximately 7% carbon monoxide

Engine running time: Assume engine running in well 8 minutes
Well atmosphere: 643 cubic feet [(5' X 7' X 15' = 525 cubic feet) + (3.14 X 6.25 X 6' = 118 cubic feet)] = 643 cubic feet

$$\text{Therefore: } \frac{377 \text{ cc}}{\text{R}} \times \frac{3600 \text{ R}}{\text{Min.}} \times \frac{1}{2} \times \frac{0.06 \text{ cu. in.}}{1 \text{ cc}} \times \frac{1 \text{ cu. ft.}}{1728 \text{ cu. in.}}$$

$$= \frac{23.56 \text{ cu. ft. exhaust}}{\text{Min.}}$$

$$\text{Carbon monoxide} = 7\% : \frac{23.56 \text{ cu. ft.}}{\text{Min.}} \times \frac{0.07 \text{ CO}}{1}$$

$$= \frac{1.65 \text{ cu. ft. CO}}{\text{Min.}}$$

$$\text{Total carbon monoxide: } \frac{1.65 \text{ cu. ft.}}{\text{Min.}} \times 8 \text{ Min.} = 13.19 \text{ cu. ft.}$$

$$\text{Total carbon monoxide concentration: } \frac{13.19 \text{ cu. ft. CO}}{643 \text{ cu. ft. air}}$$

= 2.05% carbon monoxide = 20,500 PPM carbon monoxide

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Fatal Accident Circumstances and Epidemiology (FACE) Project

The National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research (DSR), performs Fatal Accident Circumstances and Epidemiology (FACE) investigations when a participating state reports an occupational fatality and requests technical assistance. The goal of these evaluations is to prevent fatal work injuries in the future by studying the working environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in fatal injury, and the role of management in controlling how these factors interact.

States participating in this study: Georgia, Indiana, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia.

Additional information regarding this report is available from:

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