FACE 88-01: Two Supervisors Die in Manhole in South Carolina

INTRODUCTION

On August 11, 1987, a city wastewater treatment plant supervisor (victim) entered a manhole that had an oxygen deficient atmosphere and collapsed. The victim's two supervisors entered the manhole in a rescue attempt. One of the victim's supervisors was soon overcome and also collapsed (rescuer victim). The other supervisor managed to climb back out and call for help. Both victims were pronounced dead at a local hospital.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a small municipality which has 208 employees. The victims worked for the public works department which has 36 employees. This department is mainly responsible for the city water system, sewer system, wastewater treatment plants, garbage collection, streets, and general city maintenance. The victims in this incident were the wastewater treatment plant supervisor and the public works director.

The city had a written safety policy and written confined space entry procedures at the time of the incident which, if followed, would have prevented the two fatalities. A monthly safety meeting is conducted among the public works department employees. The public works director and public utilities superintendent are both responsible for safety training. Safety training, which includes safe work practices for confined space entry, is well documented in the training that wastewater treatment plant operators received at a local technical college (in order to become certified as wastewater treatment plant operators). The wastewater treatment plant supervisor had received the highest level of certification possible (Class A certification). Some employees in the public works department had been trained in the use of self-contained breathing apparatus (SCBA's) one week prior to the incident. (The public utilities superintendent, however, had not received this training.) SCBA's are available at the wastewater treatment plants and ventilating fans and hydrogen sulfide direct reading detector tubes are available at the sewer system pump stations.

Since the incident, the city has been sponsoring regular training in confined space safety for public works employees at the local technical college.

SYNOPSIS OF EVENTS

Six days prior to the accident, the public works director met with the city manager to discuss problems with the effluent quality at one of the city's two wastewater treatment plants. Subsequent discussions with the city's consulting engineering firm, the public utilities superintendent and wastewater treatment plant supervisor led to a decision to collect a water sample from a horizontal pipe that connects two manholes located approximately 100 yards apart at a wastewater treatment plant. Between the manholes is a series of sand filtration beds. Both manholes are 8 feet deep, 5 feet in diameter and have a 24-inch-diameter covered "manway" opening at ground level.

On August 11, 1987, the director (age 38) met the plan supervisor (age 27) at the wastewater treatment plant. Although there were no eye witnesses of the events preceding the accident, information available suggests that the director entered the manhole at the north end of the filter beds while the plant supervisor stood by observing. While at the bottom of the manhole, using a sampling jar attached to the end of a sewer rod, the director fished far into the pipe to a probable distance of 50 to 100 feet. While performing this task, the director observed an accumulation of sand in the pipe. Upon exiting the manhole the director called for the sewer vacuum truck to come to the plant to clean the sand from the pipe. The superintendent, (who was away from the plant at the time) hearing the call on his radio and thinking that he was being summoned, drove to the plant.

After the superintendent arrived at the plant the three men drove to the manhole at the south end of the sand filtration beds. A decision was made to enter that manhole in order to determine if there was also

sand at that end of the pipe. The manhole cover was removed and remained off for several minutes. Then the plant supervisor entered the manhole with a flashlight to look into the horizontal pipe at the bottom. At that time the director and the superintendent heard a splash, so they looked down into the manhole and saw that the plant supervisor had collapsed. The director said, "Quick, we need to get down there and get him out." The two men descended into the manhole, grabbed the plant supervisor and lifted his head out of approximately 6 inches of water. Within seconds the director shouted, "Get out, get out quick!" The superintendent managed to ascend the manhole ladder rungs and as he reached the top felt slightly light-headed. He looked back and saw that the director had also collapsed.

The superintendent called the city fire department rescue squad and then summoned two plant operators (operators #1 and #2 who were working nearby at the plant) to come help. The superintendent directed operator #1 to retrieve an SCBA located at the plant chemical building. Upon arrival at the manhole, the superintendent and operator #2 helped operator #1 put on the SCBA and enter the manhole. While operator #1 descended into the 24-inch-diameter "manway" opening, the air hose on the SCBA was somehow damaged and, as a result, when he reached the bottom, the air hose disconnected from the air tank. Because of the damaged hose, operator #1 climbed back out and the three of them (the superintendent and operators #1 and #2) waited until fire department personnel arrived, which was approximately 5 minutes after the director collapsed. Upon arrival, two fire department rescuers donned SCBA's and entered the manhole. Using ropes and harnesses the fire department rescuers removed the director and plant supervisor (victims) from the manhole and began administering cardiopulmonary resuscitation (CPR). County EMS personnel then arrived and continued CPR for approximately 10 minutes at the accident site. The victims were transported to a local hospital where the plant supervisor was pronounced dead on arrival and the director was pronounced dead 1 hour later by the attending physician.

The following day while conducting an investigation of the incident (and also several days later), personnel from the State OSHA tested the atmospheres inside both manholes for oxygen (O_2), hydrogen sulfide (H_2S), and flammable atmosphere, and obtained the following results:

North Manhole / South Manhole

(Tested several days after incident / Site of Fatalities, tested one day after incident

O_2	12.8% / 11%
H_2S	Negative / Negative
Flammable atmosphere	Negative / Negative

CAUSE OF DEATH

The coroner listed the cause of death for both victims as asphyxiation.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should implement a comprehensive safety review program of the existing safety policy and procedures.

Discussion: Although the municipality had a written safety policy and written confined space entry procedures, they were not followed. The fact that three supervisors (the public works director, the public utilities superintendent, and the wastewater treatment plant supervisor) entered a manhole (resulting in the death of the public works director and wastewater treatment plant supervisor) without regard to basic confined space safe work practices underscores the importance of assuring that workers and supervisors who are engaged in the operation and maintenance of sewer systems and wastewater treatment plants are trained sufficiently in the recognition and awareness of confined space hazards they may encounter in

the daily performance of their duties. One paragraph from the municipality's confined space entry procedures states:

"In all confined spaces the atmosphere shall be tested with the gas monitor prior to anyone descending into the confined space. Do not descend into the confined space unless you get a clean test."

However, State OSHA interviews with public utility personnel revealed a common belief in a false notion that regular manholes are not a problem because of the sewer vent pipes provided at each home and building in the city. An effective training program directed at dispelling such dangerous misconceptions is imperative in order to promote worker safety. The established written safety policy and procedures were sufficient to have prevented the incident if they had been followed, but they were not fully implemented and practiced. Implementation of a program for confined space safety should minimally include the following:

1. Posting of confined spaces and confined space procedures where they will be noticed by employees.

2. Regularly scheduled safety policy meetings (bi-weekly or monthly) to reinforce the safety policy and confined space entry procedures.

3. Review process for allowing employees to make recommendations or improving written policies and procedures.

4. Employer monitoring of tasks assigned to employees to assure the implementation of safety policies.

5. Emergency rescue procedures.

6. Availability, storage and maintenance of emergency rescue equipment.

Recommendation #2: Employers should enforce safety procedures.

Discussion: Supervisors in the Public Works Department of this municipality did not routinely follow the established confined space entry procedures. Employers must enforce established procedures and continuously monitor work practices. Minimally, employers should insure that the following confined space safe work practices are not only addressed in the company safety policy, but also implemented on the job:

1. Is confined space entry necessary? Can the task be completed from the outside?

2. Has a company safe entry permit been issued?

3. If entry is to be made, has the air quality in the confined space been tested?

   - Oxygen supply at least 19.5%
   - Flammable range less than 10% of the lower flammable limit
   - Absence of toxic air contaminants

4. Have employees and supervisors been trained in selection and use of personal protective equipment and clothing?

   - Protective clothing
   - Respiratory protection
   - Hard hats
   - Eye protection
   - Gloves

- Life lines
- Emergency rescue equipment

5. Have employees been trained for confined space entry?

6. Have employees been trained in confined space rescue procedures?

7. If ventilation equipment is needed, is it available and/or used?

8. Is the air quality tested when the ventilation system is operating?

The two fatalities would have been prevented if these recommendations had been followed. Specific recommendations regarding safe work practices in confined spaces can be found in NIOSH publications 80-106, "Working In Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces."

FACE 88-36: Three Construction Supervisors Die from Asphyxiation in Manhole

INTRODUCTION

On August 19, 1988, a 31-year-old male assistant construction supervisor (victim) entered an oxygen-deficient manhole to close a valve and collapsed at the bottom. In a rescue attempt a labor foreman (male, age 34) and the victim's supervisor (male, age 36) entered the manhole and also collapsed. All three workers were pronounced dead at the scene by the county coroner.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer, a construction company with 225 employees, employs approximately 145 laborers and 80 supervisory and clerical employees. The company is the prime contractor on large construction projects and subcontracts most of the excavation, concrete, and paving work.

The company has a written safety program but does not have any policy or procedures on confined space entry. New employees receive a brief orientation on the company safety program from the foremen. Construction superintendents are required to conduct weekly safety "tool box" meetings with workers.

SYNOPSIS OF EVENTS

The company had been contracted to construct an industrial park consisting of an office complex and decorative landscaping with a large plastic-lined pond. The pond was designed so that the water level in the pond could be controlled by opening or closing a gate valve in a 12-inch-diameter drain pipe. The drain pipe with the gate valve was installed on a concrete pad at the bottom of a manhole near the edge of the pond. The manhole, measuring 24 feet deep with an inside diameter of 4 feet and a 24-inch opening, was completed in January 1988.

By early July 1988, the company had almost completed construction of the industrial park; however, some general clean-up and repair work continued until August 19, 1988, which was to be the company employee's last day at the construction site.

At approximately noon on the day of the incident a laborer working on the pond heard the construction supervisor tell the victim to enter the manhole and close the gate valve in preparation for filling the pond. The laborer noticed the labor foreman standing above the manhole as the victim entered. The manhole atmosphere had not been tested or ventilated before entry. Shortly after reaching the bottom the victim collapsed in about 12 inches of water. As observed by the laborer, the labor foreman yelled to the superintendent (who was about 100 feet away) that something was wrong with the assistant superintendent (victim), and that he (the labor foreman) was going down into the manhole. The labor foreman entered the manhole and was followed into the manhole by the superintendent who had rushed over to help. Presumably, some time after entering both the labor foreman and superintendent also collapsed.

The laborer who had witnessed the supervisors enter the manhole continued working inside the pond until about 40 minutes later when he became concerned and went to the manhole. When he looked into the manhole he saw the three men collapsed at the bottom.

The police and fire departments were immediately notified and a rescue squad arrived within approximately 15 minutes. Fire fighters, wearing self-contained breathing apparatus (SCBA), entered the manhole and removed the workers. The three workers were later pronounced dead at the scene by the county coroner.

Four hours after the incident, the manhole atmosphere was tested by a private analytical laboratory. Results of the tests showed oxygen levels from 18.5 percent to 20 percent and methane at 300 to 600 parts per million (ppm) at depths from 12 to 15 feet. Decomposing organic material in the water at the bottom of the manhole may account for the methane production and oxygen consumption.

On September 1, 1988, (after the manhole had been closed for 8 days) the manhole atmosphere was tested for oxygen (O_2), hydrogen sulfide (H_2S), and combustible gases (percent of the lower explosive limit or percent LEL) during the investigation by the DSR industrial hygienist. Results of these tests are as follows:

Depth	O_2	H_2S%	LEL
10 feet	18.4%	negative	negative
14 feet	16.7%	negative	negative
18 feet	16.1%	negative	negative
22 feet	15.2%	negative	negative

CAUSE OF DEATH

The medical examiner listed the cause of death for all three workers as asphyxiation due to lack of oxygen. The initial victim (assistant construction superintendent) and the first rescuer victim (labor foreman) showed signs of being submerged in water.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should develop and implement specific procedures for confined space entry.

Discussion: According to the employer, company employees are not usually required to enter manholes. However, as illustrated in this incident, the assistant construction superintendent did enter a manhole under the direction of his supervisor. In addition to manholes, it is reasonable to expect that the employer could encounter other types of confined spaces in the construction business. The company should therefore develop and implement a confined space entry program as outlined in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A guide to Safety in Confined Spaces." Minimally, the following items should be addressed:

1. Is confined space entry necessary? Can the assigned task be completed from the outside?

2. Has a confined space safe entry permit been issued by the company?

3. Are confined spaces and confined space procedures posted where they will be noticed by employees?

4. If entry is to be made, has the air quality in the confined space been tested for safety?

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

5. Have employees and supervisors been trained in the selection and use of personal protective equipment and clothing?

   - Protective clothing
   - Respiratory protection
   - Hard hats
   - Eye protection
   - Gloves
   - Life lines
   - Emergency rescue equipment

6. Have employees been trained for confined space entry?

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

8. Have employees been trained in confined space rescue procedures?

9. If ventilation equipment is needed, is it available and/or used?

10. Is the air quality tested when the ventilation system is operating?

Three company supervisors entered a manhole without regard to basic confined space safe work practices. As a result, all three died. This underscores the importance of ensuring that supervisors as well as laborers engaged in the construction, operation, and maintenance of manholes and other confined spaces are adequately trained. This training should focus on the recognition and awareness of confined space hazards that construction workers may encounter, as well as confined space safe work practices. The three fatalities could have been prevented if these recommendations had been followed.

FACE 88-44: Construction Sub-Contractor Asphyxiated in Manhole

INTRODUCTION

On August 20, 1988, a 26-year-old male construction worker died when he entered a manhole containing an oxygen deficient atmosphere and was asphyxiated.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim in this incident was self-employed as a construction sub-contractor and had no formal safety program. The victim had 8 years of experience in construction and had previously worked for the same prime contractor on projects similar to the one he was involved in at the time of his death.

SYNOPSIS OF EVENTS

On the day of the incident the victim was involved in the construction of a new sewer system. Construction on this system had been underway for many months; however, the sewer system had not yet been connected to the existing system. The sewer lines being installed were 18-inch lines, with 4-foot-diameter concrete manholes, providing access to these lines, located at intervals along the sewer right-of-way. Ground water had been seeping into the sewer lines and small amounts of this water was present in both the lines and the manholes.

At the time of the incident the victim had been working as a sub-contractor in various manholes on this system for slightly over 4 hours. He told a co-worker that he was going to install a plug in the lines leading to the manhole where the incident occurred (to keep out the ground water) and that he would then meet the worker for lunch. The victim planned to pump the water out of the manhole after lunch and then construct a baffle in the manhole.

This manhole contained approximately 1 foot of water and 2 to 3 inches of mud at the bottom. A wooden ladder had been left in the manhole since the time of construction but the manhole had not been opened since it was installed 6 months prior to the incident.

The victim parked his truck at the side of the manhole and left the door open and the motor running. He then removed the cover from the manhole and climbed down the ladder to install the plug. His co-worker, driving a tractor, arrived on the scene a few minutes later and saw the victim lying at the bottom of the manhole. The co-worker ran to a nearby home and telephoned for help.

The local fire department responded to the call and four fire fighters were on the scene within 4 minutes. One of the fire fighters immediately descended the ladder to check the victim for vital signs. As he reached the victim, he said he felt as though "someone had put a piece of cellophane over my face." The fire fighter began climbing the ladder to escape from the manhole but he was extremely dizzy and had to be pulled from the manhole by two other fire fighters. Two other fire fighters then descended the manhole wearing self-contained breathing apparatus (SCBA), put a rope around the victim, and had him hoisted from the manhole. Emergency medical technicians on the scene, unable to find vital signs, began cardiopulmonary resuscitation (CPR) on the victim and transported him to a local medical center. He was pronounced dead 1 hour and 10 minutes after the incident had been reported to the fire department.

Testing of the manhole by state Environmental Protection Agency employees on the day following the incident showed the following oxygen levels at various depths within the manhole:

5 feet below surface 20.5% oxygen
7 feet below surface 20.0% oxygen
9 feet below surface 14.0% oxygen
11 feet below surface 6.5% oxygen
13 feet below surface 4.0% oxygen

CAUSE OF DEATH

The medical examiner gave the cause of death as asphyxiation.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The atmosphere within a confined space should always be checked for oxygen content and the presence of toxic or flammable gases/vapors prior to entry.

Discussion: No attempt was made to check the atmosphere within this manhole prior to entry. Because work in similar nearby manholes had proceeded without problems, the victim apparently assumed that no hazards existed in the manhole where he died. Failure to check air quality within a confined space prior to entry is a common error which is observed in almost all confined space fatalities investigated by NIOSH. If confined space safe work procedures, as discussed in NIOSH Publication #87-113 "A Guide to Safety in Confined Spaces," had been followed, this death could have been prevented.

Recommendation #2: Confined spaces should never be entered without an observer posted outside and without use of appropriate rescue equipment (safety belt/harness and lifeline).

Discussion: In this incident the victim entered the confined space without an observer or safety equipment. An observer, outside of the confined space and equipped with appropriate rescue equipment, could have assisted the victim when he first lost consciousness, possibly preventing this death.

Recommendation #3: Contractors should ensure that all sub-contractors they employ have a safety program which addresses the hazards to which the sub-contractor's employees will be exposed.

Discussion: The prime contractor in this case had a company safety program which addressed work in confined spaces; however, no equivalent program was required for any sub-contractors employed at the work site. All employees at a work site should be trained and covered by a safety program addressing the specific hazards they will be exposed to. In this case, the victim apparently was unaware of the potential hazards with confined space entry.

FACE 91-17: Municipal Water System Operator Dies After Entering Oxygen-Deficient Valve Vault in Montana

SUMMARY

A 35-year-old male water system operator (victim) was asphyxiated after entering a valve vault at a municipal water system plant. The victim was assigned to turn on a water line valve serving a nearby tree farm. The valve was located at the water treatment plant inside an underground valve vault that "always had normal air." The victim entered the valve vault through a ground-level manhole without testing or ventilating the vault atmosphere. A co-worker, who had last seen the victim 1 hour earlier, checked the manhole and saw the victim lying on his back at the bottom. The victim did not respond to any calls. Other workers summoned from the plant building and local fire department personnel ventilated the valve vault and removed the victim. The vault atmosphere was subsequently found to be oxygen deficient. There were no witnesses to the incident, but evidence suggests that the victim lost consciousness and fell from the ladder railings to the bottom of the vault. NIOSH investigators determined that, in order to prevent future similar occurrences, employers should:

- recognize that confined space atmospheres are dynamic environments subject to unexpected changes, and address those dynamics in all written and practiced safe work procedures and subsequent worker training.

- develop and implement a comprehensive confined space entry program to address all provisions outlined in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces."

In addition, municipalities should ensure that:

- police, as well as fire and rescue personnel, are trained in confined space entry and rescue procedures.

INTRODUCTION

On May 23, 1991, a 35-year old male water system operator (victim) was asphyxiated after entering a valve vault at a municipal water system plant. The employer in this incident was a municipal public utilities department that had performed water purification and wastewater treatment operations for 26 years. The employer had 98 employees, most of whom were water and wastewater system operators and maintenance workers. The employer had a written safety policy, safety program, and established safe work procedures. There was no full-time safety manager. Employees rotated the responsibility of "safety manager" among themselves on a monthly basis. This temporary "safety manager" was responsible for conducting safety meetings to discuss a variety of safety issues pertaining to potable water and wastewater systems.

INVESTIGATION

[NOTE: DSR investigators were unable to interview the investigating detective, policeman, and responding fire department personnel, or obtain copies of their written reports.]

Several days before the incident, the victim had told others that he was going to shut off a valve on a water line serving a nearby tree farm, and then drain it to prevent the line from freezing during a forecasted cold snap.

The shut-off and drain valves on this water line were located inside a concrete valve vault below ground at the water treatment plant. The valve vault was 7 feet deep, and 6 feet in diameter. It was accessed by a 24-inch-diameter manhole at ground level, and steel rungs mounted onto the inside wall. The waterline and valves were approximately 6 inches above the bottom of the vault. These valves could be opened or closed from ground level, using an 8-foot-long valve key or portable extension rod.

On the day of the incident, the victim was assigned to turn on the same valve to the tree farm. There were no witnesses of the incident. However, evidence suggests the following sequence of events: At about 2:00 p.m. on the day of the incident, the victim entered the valve vault without first testing or ventilating the vault atmosphere. Since the vault atmosphere was oxygen deficient (the atmosphere, tested at the bottom of the vault, had as low as 2% oxygen on the day the DSR researchers investigated the incident), the victim was overcome, and fell from the ladder railings to the bottom of the vault. A co-worker noticed a utility truck that the victim had been driving, parked next to the vault manhole. Knowing the victim had not been seen for about an hour, the co-worker walked over to the manhole. When he looked inside, he saw the victim lying on his back at the bottom. The co-worker yelled to the victim, but the victim did not respond.

The co-worker ran to the plant superintendent, about 300 feet away, and told him about the victim. The superintendent ran to the manhole, yelled to the victim, and also received no response. Help was summoned from the plant building. Workers arrived within a few minutes with a portable blower fan with an 8-inch trunk hose and a self-contained breathing apparatus (SCBA). The manhole was immediately ventilated with the blower while one of the workers donned the SCBA and entered the manhole. Approximately 15 minutes after the rescue attempt began, the alarm on the worker's SCBA sounded (possibly due to over-breathing by the rescuer who was wearing it).

While this rescuer was returning to the top of the manhole, personnel from the local fire department arrived. One of the firefighters donned an SCBA, entered the manhole, and tied a rope around the victim's chest. The victim was hoisted out. The firefighters and arriving emergency medical service (EMS) personnel performed cardiopulmonary resuscitation (CPR) at the scene and en route to a local hospital. The victim was pronounced dead at the hospital by the attending physician within a few minutes after arrival.

A city detective and a police officer, who were assigned to investigate the incident, arrived at the scene between 6:00 and 7:00 p.m. (about 3 hours after the victim was extricated from the vault). They were admitted onto the grounds by an unidentified plant employee, who led them to the valve vault and removed the manhole cover. Seeing blood on the wall at the bottom of the vault, the detective decided to enter to get dimension measurements but shortly afterwards "came up for air, gasping." Thinking he was only having a claustrophobic reaction, the detective attempted to enter the valve vault again, but came back out, saying that he "just could not do it." The unidentified plant employee retrieved a gas detector, but was not trained in its use and could not interpret the meter readings; so he stuck his head into the manhole to get a general impression and reported a smell like "cleaning fluid or ammonia." The police officer then decided to enter the valve vault but before reaching the bottom became "tight-chested" and came back out. The police officers decided to leave the plant. Neither the detective, the police officer nor the unidentified plant employee were aware that there were any atmospheric problems in the valve vault, so they did not ventilate the vault prior to entry.

Reports to the Montana Department of Labor and Industries indicated that the valve vault was possibly contaminated with toxic chemicals. These concerns were reportedly due to suspicions that sodium metham, a herbicide used by the municipality for root control in underground wastewater and storm drains, had contaminated the local ground water system from sewage material placed in the dewatering pit near this incident site. NIOSH investigators experienced tearing of eyes and respiratory irritation when working around the downwind perimeter of the dewatering pit, but due to the lack of appropriate air sampling detectors or equipment at the remote field worksite were unable to identify the gases and vapors emanating from the pit. Samples of green liquids in the bottom of the dewatering pit were collected and submitted for comparative analysis with samples obtained from the bottom of the valve vault.

CAUSE OF DEATH

The medical examiner listed the cause of death as asphyxia due to oxygen displacement with carbon dioxide and methane.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should recognize that confined space atmospheres are dynamic environments (constantly subject to unexpected changes) and address those dynamics in all written safe work procedures and worker training.

Discussion: The employer had written general safe work practices for entry into underground structures that were reportedly utilized predominately when entering manholes that were part of the municipal wastewater system. The valve that was to be turned on by the victim was located at the water treatment plant complex inside an underground valve vault that contained only freshwater circuits and "always had normal air." Municipal water works employees attested to over 200 entries into this valve vault over the preceding several years, without any problems. Investigations at the incident site disclosed that the environmental dynamics in the valve vault may have changed as follows:

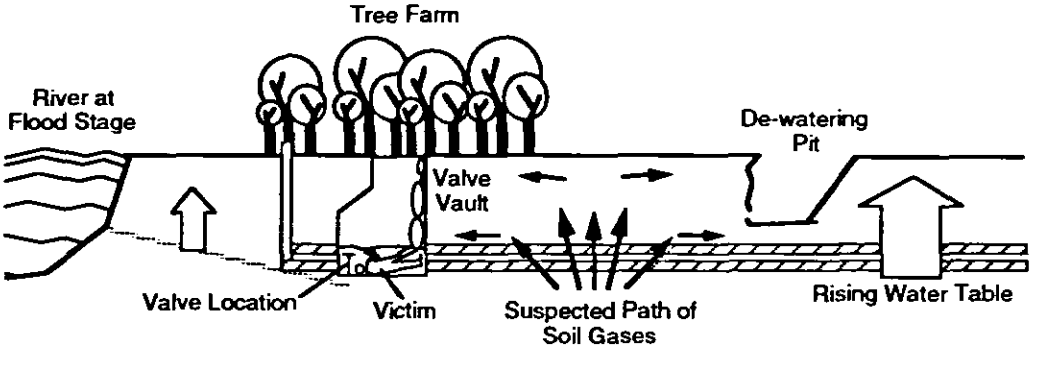
a. the river (located about 170 feet away from the underground valve vault) had been at flood-stage levels for several days preceding the incident;

b. the water table underneath the valve vault field had risen with the rising river to an elevation just beneath the concrete floor in the bottom of the valve vault;

c. the rising water table forced gases and liquids normally trapped deep within the surrounding soils toward the surface;

d. the clay soils and sands used by the municipality for the surface of the valve vault field inadvertently formed a seal, or cap, forcing the gases and liquids to flow into the only two openings into the ground, the valve vault and a sewage dewatering pit (Figure);

e. the soil gases (carbon dioxide, methane, and hydrogen sulfide) entered the valve vault through the drain hole in the center of the concrete floor and possibly through the joints between the sections of preformed concrete pipe forming the walls of the valve vault; as gases filled the valve vault, they displaced oxygen to below the minimal level to support human life; the victim lost consciousness upon entering the oxygen-deficient environment.



(Figure, FACE 91-17)

Cumulative results of atmosphere testing at the bottom of the valve vault by the municipal fire department, municipal water works, Montana Department of Labor, Montana Department of Health and NIOSH-DSR investigators, over a several-day period after the incident (there were no tests made on the day of the incident) detected the following concentrations:

Gas	Concentration Range (% by volume)	
Oxygen	1.8 - 8.8%	(3.5% avg.)
Nitrogen	74.1 - 78.5%	(76.3% avg.)
Carbon Dioxide	11.62%	
Hydrogen Sulfide	0.0 - 1.9 ppm	(0.5 ppm avg.)
Methane	0.1 - 3.8%	(1.7% avg.)
Ethanes to Hexanes	<0.06%	

[Note: The NIOSH investigation involved a liquids analysis for sodium metham, the herbicide used by the municipality and suspected of being a factor in this fatality. Gas chromatography-mass spectrometry (GC-MS) analysis of liquid samples from the bottom of the valve vault did not detect any sodium metham. A secondary thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS) analysis of the liquid head gases also did not detect any methyl iso-thio cyanate (MITC), a volatile gas liberated by sodium metham.]

The perceived sense of security due to numerous prior entries into a valve vault without incident, apparently lulled the victim into not testing the air prior to entry. This requirement was part of the employer's written general safe work practices for entry into underground structures, but was not rigorously enforced for all underground structures.

Recommendation #2: Employers should develop and implement a comprehensive confined space entry program to address all provisions outlined in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces."

Discussion: Although the employer had written general safe work practices for entry into underground structures, they were not followed or enforced at this valve vault. As previously mentioned, municipal water works employees cited over 200 uneventful entries into this valve vault spanning several preceding years without any previous problems. Although testing equipment was reportedly available 200 feet away at a waterworks facility, the valve vault in this incident was not tested prior to entry. This requirement was part of the written general safe work practices of the municipal waterworks department.

Confined space entry procedures should be specific to each type of confined space; e.g., valve vaults, wet wells, lift stations, utility vaults, sewer manholes, etc. Employers should, therefore, develop, implement and enforce a confined space entry program as outlined in the recommended NIOSH publications. At a minimum, the following items should be addressed for each type of confined space:

1. Is entry necessary? Can the assigned task be completed from the outside?

   For example, in this case, the victim entered the valve vault to open and close the valves by hand. These valves were subsequently turned by another municipal water works employee standing on the surface outside the manhole used a homemade valve key or valve extension tool. Many manual and power-assisted extensions are currently available that will allow workers to turn valves at the bottom of manholes from above ground or street levels.

2. Has a confined space safe entry permit been issued by the employer before each confined space is entered?

   No confined space entry permit was issued for the victim's entry into the valve vault. Police detectives entered the property, and later the valve vault, without obtaining a safe entry permit or notifying on-duty waterworks personnel of their presence or plans.

3. Are confined spaces posted with warning signs, and are confined space entry procedures posted where they will be noticed by employees and others (e.g., police)?

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

   - Oxygen supply at least 19.5%
   - Flammable range less than 10% of the lower explosive limit (LEL)
   - Absence of toxic air contaminants?

   [Note: Methane gas has a LEL of 5%. The LEL is the lowest atmospheric concentration of a gas or vapor which will result in an explosion if sufficient oxygen and an ignition source are present. Average methane readings during the investigation period were 1.75% (over three times the 10% LEL criteria level), and the upper range reading of 3.75% indicated a flash fire potential.]

5. Are workers and supervisors being continuously trained in the selection and use of:

   - respiratory protection
   - test equipment, including calibration and maintenance
   - lifelines
   - emergency rescue equipment
   - protective clothing?

6. Have workers been properly trained in working in and around confined spaces?

7. Are confined space entry, safe work practices, and rescue procedures discussed in safety meetings?

8. Is appropriate ventilation equipment available and/or used before and during entry and work?

9. Is the air quality monitored when the ventilation system is operating?

10. Is an outside observer posted and appropriate rescue equipment (safety belt/harness and lifeline) used during every confined space entry?

    For example, in this incident, the victim entered the confined space without an observer or safety equipment. An observer, outside of the confined space and equipped with appropriate rescue equipment, could have assisted the victim when he first lost consciousness. The victim was not provided, or required to wear, a safety belt or full-body harness secured via lifeline to a power winch or other lifting device rated for humans. A hoisting device designed for lifting humans will not subject the individual being lifted to crushing hazards. This is especially important if any part of the body becomes caught during an emergency lift (even though in this incident crushing injuries were not apparent).

11. Are employees continuously trained in confined space rescue procedures?

Recommendation #3: Municipalities should ensure that police, as well as fire and rescue personnel, are trained in confined space entry and rescue procedures.

Discussion: Police department detectives in this incident were not adequately trained in recognizing the hazards posed by confined spaces and in confined space entry and rescue procedures. They failed to get a safe entry permit for entry into the valve vault. Upon arrival at the valve vault site, warning barriers erected by the waterworks employees were removed, the manhole cover was opened, and entry into the valve vault was attempted without first testing the atmosphere. When the detective experienced breathing difficulty, he failed to associate the symptoms with oxygen deficiency or toxic vapors but instead returned to the surface and later attempted a second entry. The police officer attempted entry into

the valve vault, but upon experiencing similar breathing problems also returned to the surface. Fortunately, at this point the detective and police officer decided to abandon their investigation of the valve vault for the evening. Neither the detective nor the police officer wore a safety belt, harness or lifeline for potential rescue.

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, 1987.

FACE 92-17: Driller and Service Rig Helper Die in Fracturing Tank at Gas Well Site—Pennsylvania.

INTRODUCTION

On June 4, 1992, a 39-year-old male driller and a 28-year-old male service rig helper (the victims) were found by co-workers inside a fracturing tank at a gas well located in a natural gas storage field. On June 8, 1992, the county coroner notified the Division of Safety Research (DSR) of these fatalities, and requested technical assistance. On June 11, 1992, a quality assurance specialist and a safety engineer from DSR conducted an investigation of this incident. Representatives of the employer, co-workers, the storage field operator, the county coroner, and the county haz-mat team were interviewed. Photographs and measurements of the incident site were obtained. Also, tests of the tank atmosphere, as it existed on June 11, 1992, were performed.

The employer in this incident was a gas well drilling and service company that had been in business for 30 years. The company employed 400 workers, including 48 drillers and 5 service rig helpers. The employer, a contractor, had entered into an agreement with the storage field operator to supply workers to monitor the wellhead pressure and fluid level in the fracturing tank during the final stages of the hydraulic fracturing operation. The employer had a comprehensive corporate safety program, but no confined space entry program was in effect at the jobsite at the time of the incident. The employer conducted formal first-aid training and weekly safety talks concerning various jobsite hazards, although confined spaces were not discussed. The employer had no history of fatalities.

INVESTIGATION

The incident site was the work area of a natural gas well at which an hydraulic fracturing operation was in the final stages of completion. Hydraulic fracturing is a process in which cracks are produced in the gas-bearing strata of an existing well by the injection of fluid under high pressure. Selected grades of sand or other granular material are added to the fluid in quantities designed to fill the fractures and act as a propping agent, holding the fractures open after the applied hydraulic pressure has been released. This process enhances the fluid-flow characteristics of the gas-bearing strata.

The well is allowed to stand approximately 4 hours after the fracturing fluid has been injected. The fracturing fluid is then allowed to vent or "flow back" from the wellbore under residual pressure. The fluid is normally recovered by allowing it to flow from the wellhead through tubing into a small tank (blow-back tank) which is open to the atmosphere. The blow-back tank allows gases entrained in the returning fluid to vent to the atmosphere, and reduces the amount of frothing or sudsing of the fluid. From the blow-back tank, the fluid is piped into a larger tank commonly known as a fracturing (frac) tank or wheely tank. This is a large, 21,000-gallon tank mounted on wheels and provided with a fifth wheel for towing from jobsite to jobsite by a semi-tractor. The fracturing tank involved in the incident measured 37 feet in length, 8 feet in width, and varied in height from 8 feet at the rear to 11 feet at the front.

The victims' only assignment (at this jobsite) was to monitor the wellhead pressure and fluid level of the fracturing tank at 2-hour intervals during their 12-hour shift. The victims had been assigned to monitor the fluid level by taking depth measurements of the fluid in the fracturing tank. The procedure for the measurement was to use a steel measuring tape as a dipstick by inserting it into a 1-inch-diameter measurement port, located on the top of the tank, until it contacted the tank bottom. The tape would then be withdrawn and the fluid level reading would be taken from the wet mark on the tape. This could be accomplished from outside the tank.

There were no eye witnesses to the incident; however, evidence and interviews with co-workers indicate that on the day of the incident, the victims had arrived on the jobsite just before the beginning of their assigned 7 p.m. to 7 a.m. shift. The co-workers going off duty after their 7 a.m. to 7 p.m. shift informed the victims that the blow-back tank had been bypassed because it was suspected to be leaking and that the fracturing fluid was flowing directly from the wellhead to the recovery tank. The co-workers advised

them not to enter the fracturing tank since the blow-back tank had been bypassed, and the fumes coming from the tank were strong. The co-workers then left the jobsite.

On the morning of June 4, 1992, the two co-workers arrived to relieve the victims and begin work on the day shift. When they arrived at the site, the victims could not be found. A search of the area revealed that the victims were inside the fracturing tank. Just before 7 a.m., local volunteer firefighters were summoned to the scene. After arrival, the firefighters summoned the county haz-mat team which arrived at the scene at 8 a.m. The haz-mat team, wearing self-contained breathing apparatus (SCBA) and rescue harnesses recovered the victims about 15 minutes later. They were pronounced dead at the scene.

There were no eyewitnesses to the incident, and no known reason for the victims to enter the tank. However, since the blow-back tank had been bypassed, there may have been significant amounts of froth on the surface of the fluid inside the fracturing tank. This would have interfered with attempts to measure the fluid level by causing a false wet mark on the measuring tape. It is probable that the victims attempted to measure the fluid level through a 21-inch by 19-inch access hatch on top of the tank. During this attempt, one of the victims may have slipped and fallen into the tank or may have been overcome by fumes venting from the tank and fallen inside. His co-worker may then have attempted a rescue only to become a victim himself. The worker who located the victims stated to investigators that he had to sweep the froth from the surface of the fluid with a shovel to locate one of the victims.

Gas tests performed during the investigation on June 11, 1992, indicated 19.9% oxygen, 1.5 parts per million (ppm) of hydrogen sulfide, 0.5 ppm of sulfur dioxide, and 0.00% hydrocarbons. This environment, however, may not have been representative of the atmosphere inside the tank at the time of the incident, since the tank had been drained during the recovery of the victims, flushed with water, and additional fluid had been allowed to flow back into the tank when normal operations were resumed.

CAUSE OF DEATH

The county coroner attributed both deaths to asphyxia due to anoxia (severe deficiency of oxygen), accumulation of fumes, or a combination of anoxia and fumes.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should cover openings in fracturing tanks with physical barriers to prevent unauthorized or casual entry.

Discussion: The fracturing tank involved in this incident had an access hatch 21 inches long by 19 inches wide, and the opening was equipped with a hinged cover. Addition of a physical barrier over the opening constructed from steel bar stock or heavy screen fixed to the tank by welding or bolted fasteners could have prevented unauthorized or casual entry. Although it could not be determined why the victims entered the tank, the only access was through this hatch. It is conceivable that one of the victims may have fallen through the opening while attempting to take a measurement of the fluid level and his co-worker may have entered while attempting a rescue. Or, one of the victims may have dropped something inside the tank and tried to retrieve it and the co-worker entered in a rescue attempt. In either case, if the entry port had been barred, no one could have inadvertently fallen through the opening nor would casual entry to retrieve lost objects have been readily possible. The employer began installing physical barriers consisting of steel bars welded in place across the opening shortly after the investigation of June 11, 1992.

Recommendation #2: Employers should develop and implement confined space entry programs at all jobsites where workers are exposed to confined space hazards.

Discussion: There was no confined space entry program in effect at the jobsite at the time of the incident. If a confined space entry program had been implemented, the incident and resulting fatalities may not have occurred. Such a program should include:

- evaluation to determine whether entry is necessary or whether the task can be performed from the outside
- issuance of a confined space entry permit by the employer
- posting of confined space entry warning signs
- testing the air quality in the confined space when entry is necessary to ensure:
- oxygen levels of at least 19.5%
- flammable range of less than 10% of the LEL (lower explosive limit)
- absence of toxic air contaminants
- training of workers and supervisors in the selection and use of:
- respiratory equipment
- environmental test equipment
- lifelines
- rescue equipment
- protective clothing
- training of employees in safe work procedures in and around confined spaces
- training of employees in confined space rescue procedures
- conducting regular safety meetings to discuss confined space safety
- availability and use of proper ventilation equipment
- monitoring of the air quality when ventilation equipment is in use.

Recommendation #3: Employers should evaluate the alternative job procedures used in the instance of equipment malfunctions to ensure that the alternative procedures do not increase employees' risk of injury.

Discussion: In this incident, the normal procedure of piping fluid from the wellbore to the fracturing tank through the blow-back tank was not used due to a suspected leak in the blow-back tank. Use of the blow-back tank allows gases to vent from the fracturing fluid and provides more time for sudsing of the fluid to settle, thereby reducing the amount of froth on the surface of the fluid in the fracturing tank. Bypassing the blow-back tank may have increased the amount of froth inside the fracturing tank, making it difficult for the victims to obtain an accurate depth measurement while remaining outside the tank and thereby providing them reason for entry into the tank.

Recommendation #4: Manufacturers and owners of fracturing tanks, as well as operators of gas wells, should devise improved methods of monitoring the fluid volumes returning from the wellbore during the "flow-back" phase of hydraulic fracturing operations.

Discussion: The tank involved in the incident was equipped with a level indicator consisting of a float within the tank attached by an arm to a shaft running parallel to the side of the tank. This shaft exited the end of the tank where a pointer was attached. A scale, graduated in barrels and gallons, was painted on the end of the tank such that movement of the float inside the tank translated into movement of the pointer across the scale, yielding a volume measurement. According to employer and storage field representatives interviewed during the investigation, the precision of this measuring arrangement was not sufficient to monitor the fracturing operation and it was therefore necessary to perform the measurement manually with a steel tape measure used as a dipstick. Consideration should be given to improving the accuracy of the measurement system by either refining the scale of the indicator, providing a site glass on the side of the tank, or providing an in-line flow measurement device such as a turbine-type flowmeter, or an orifice meter in the tank inlet.

REFERENCES

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health and Human Services. Public Health Service. Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 80-106.

FACE 92-29: Farm Owner and Son Asphyxiated in Manure Waste Pit—Minnesota

INTRODUCTION

On August 11, 1992, a 43-year-old dairy farm owner (victim #1) and his 23-year-old son (victim #2) died when they were asphyxiated after entering a manure pit. On August 12, 1992, officials from the Minnesota Fatality Assessment and Control Evaluation (FACE) program notified the National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research (DSR), of these fatalities, and requested technical assistance. On September 3, 1992, a DSR safety specialist and the FACE field investigator from Minnesota contacted the spouse of the deceased farm owner for permission to conduct an on site investigation. Although the spouse spoke to the Minnesota FACE investigator concerning the incident, her anguished emotional state precluded a site visit. The investigators reviewed the incident with the county sheriff's office, the county coroner, the fire department rescue squad, and the county agricultural extension agent, and obtained their reports.

The incident occurred on a family-owned dairy farm operated by a father and his two sons. The farm had no structured safety program or written safety policy, and training was conducted on the job. There were no previous fatalities on the farm.

INVESTIGATION

Two adjacent manure waste pits had been installed at the end of a dairy barn, one under each half of the barn. The pits, 8 feet deep, were connected by a tunnel that allowed manure from both pits to be pumped from the same side. A portion of both pits was located outside the barn. An outdoor pump, powered by a tractor's power take-off, was located in an opening in the concrete top of one of the pits. The manure could be pumped directly into a spreader tank or into a large holding pond.

On the day of the incident, the wife and mother of the victims last saw the workers at 4:30 a.m. when she left the farm to travel to the city. She returned home at 6:30 p.m. and noticed that the cows were making an unusual amount of noise. She noticed that they had not yet been milked, a task that was usually performed at 3:30 p.m. She walked to the barn and found her son lying at the bottom of the pit, but she could not locate her husband. She called the county sheriff's office, who in turn dispatched the emergency medical service and the fire department. When the sheriff's deputy arrived at the scene, he found that the steel grate cover for the inside opening of the manure pit had been removed, an aluminum ladder had been placed into the pit for access, and that both workers were lying at the bottom of the pit. Upon their arrival, fire department personnel removed the victims from the pit.

Fire department personnel and the deputy coroner stated that one of the pits had been pumped out and that the tunnel connecting the two pits was obviously blocked. Although the event was unwitnessed, it is assumed that when the manure from the second pit failed to flow through the tunnel, the father removed the steel grate covering the entrance of the manure pit being pumped and placed the aluminum ladder into the pit. He then descended the ladder into the pit and walked a short distance to the tunnel. When he bent over to clear the tunnel he was overcome in the oxygen deficient atmosphere and collapsed. The son entered the pit in a rescue attempt and was also overcome. The son was found lying on top of his father.

After examining the victims, the deputy coroner established the time of death to be approximately 4 p.m.

CAUSE OF DEATH

The coroner listed asphyxiation due to hypoxia as the cause of death for both victims.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should identify manure waste pits as confined spaces and post hazard warning signs at all entrances.

Discussion: Manure waste pits, by their design, meet the NIOSH definition of a confined space. A space is considered "confined" if it: 1) has limited openings for entry and exit; 2) has unfavorable natural ventilation which could contain or produce dangerous air contaminants; and 3) is not intended for continuous employee occupancy. Entrance into a confined space, as described in this incident, is addressed in NIOSH Publication No. 80-106 (Working in Confined Spaces). Ideally, a manure pit should be ventilated, and the atmosphere within the pit tested prior to entry and monitored continuously while work is being performed. Self-contained breathing apparatus should be utilized by those entering the pit if an oxygen-deficient and/or toxic atmosphere is found to exist. Although such specialized equipment and training in the use of this equipment may not be readily available to many farm workers, these workers should be made aware of potential hazards associated with manure waste pits, such as oxygen-deficient or toxic atmospheres. Signs to alert farm workers of the hazards associated with manure waste pits should be posted at all entrances. These signs should be understandable to workers who may not be able to speak or read English. In some areas, signs in more than one language may be necessary. NIOSH has prepared an Alert detailing the hazards associated with manure waste pits on farms (NIOSH Publication No. 90-103). Additionally, NIOSH requests the assistance of agricultural extension agents, farm journals, agricultural associations, and farm equipment manufacturers in alerting farm workers to the hazards associated with manure waste pits.

Recommendation #2: Employers should instruct farm employees never to enter manure waste systems unless absolutely necessary and only when following safe entry procedures.

Discussion: In this incident, the manure pit was entered by the first victim on numerous occasions without incident. Previous uneventful entries may lead farm workers to feel safe about entering these pits. Because dangerous gases may be present, a manure pit should never be entered unless absolutely necessary. If entrance into the pit is necessary, workers must follow safe confined space entry procedures (See NIOSH Publications 80-106 and 90-103). Additionally, a standby person(s) with the capability to remove the person from the pit, if necessary, should be stationed outside the pit. Visual and/or audible contact must be maintained with the person in the pit at all times. If the standby person(s) is not physically capable of removing the person from the pit, then some sort of mechanical lifting device (a winch, hoist, etc.) should be in position over the pit. Anyone entering the pit to perform any work should wear a safety belt or harness and have a lifeline attached to a lifting device outside the pit. This would enable a standby person(s) to remove someone from the pit without entering the pit. Details of a rescue plan must be developed and implemented before entry. Should an emergency develop, a short delay caused by lack of preparation could be fatal.

Recommendation #3: Employers should instruct farm employees never to enter a manure pit, or any other confined space to attempt a rescue operation without proper consideration for their own safety.

Discussion: Farm workers should never, under any circumstances, enter a manure pit to attempt a rescue operation unless properly equipped and trained in the use of the equipment and methods required for rescue. The agent that caused the victim(s) in the pit to be overcome will have the same effect on any would-be rescuer, and the rescuer(s) themselves may become a victim. Farm workers should be instructed that if anyone is observed unconscious or ill inside a pit, they should immediately contact the local fire department or emergency rescue squad. These squads will have the training and equipment needed to accomplish a rescue without further endangerment to life.

Recommendation #4: Employers should install manure waste systems in such a manner that need for entry is eliminated.

Discussion: In this incident, the tunnel connecting the adjacent pits allowed both pits to be pumped simultaneously without having to make any additional connections; however, the tunnel posed a need for entry if it became obstructed. A "Y" connection equipped with shut-off valves at each branch of the "Y" located at the pump intake would allow either pit to be pumped by opening or closing the valves. During installation of any manure waste system, and whenever possible, any component of that system that might require service should be located outside of the manure pit.

Recommendation #5: Employers should equip manure waste systems with some type of powered ventilation system.

Discussion: Ideally, manure waste systems should be equipped with both supply and exhaust ventilation to eliminate the accumulation of gases. In the case of explosive gases such as methane, the system should be of sufficient size to prevent the gas from reaching its explosive limits and should be of explosion-proof design as defined in the National Electrical Code, Article 100-A. The system may be composed of portable fans, but must be of sufficient capacity to ensure constant circulation of fresh air throughout the waste system, and be of explosion-proof design.

Recommendation #6: Manufacturers of equipment designed for use in manure waste pit systems should include warnings on the potential hazards associated with these systems.

Discussion: Manufacturers of this type of equipment should provide purchasers with information concerning the potential hazards that may be encountered when using this equipment in manure waste systems. Where possible, information (such as diagrams, etc.) on how to install this equipment so that it can be serviced without requiring workers to enter the pit should also be provided.

REFERENCES

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Morgantown, WV: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80-106.

NIOSH [1990]. NIOSH Alert: Request for assistance in preventing deaths of farm workers in manure pits. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-103.

National Electrical Code: ANSI/NFPA 70. An American National Standard. August 14, 1992.