WORKER DEATHS IN CONFINED SPACES

A Summary of NIOSH Surveillance and Investigative Findings

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INTRODUCTION

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This monograph contains summary data and investigative reports of fatal incidents involving workers who entered confined spaces. These investigations were undertaken as part of the Fatality Assessment and Control Evaluation (FACE) program conducted by the National Institute for Occupational Safety and Health (NIOSH). The FACE program was initiated in 1982 and directed from its inception by the NIOSH Division of Safety Research.

The program which was originally known as the Fatal Accident Circumstances and Epidemiology program was given its new name in 1992. FACE is a surveillance program for the identification and investigation of fatal occupational injuries. Currently, the investigations are conducted in four categories—falls from elevations, contact with electrical energy, entry into confined spaces, and machine-related incidents. These categories represent frequent causes of nonmotor vehicle-related, fatal occupational injuries.

The NIOSH Division of Safety Research conducts the FACE investigations to gather information on factors that may have contributed to traumatic occupational fatalities. The circumstances of a particular fatal injury can initially appear to be the result of random, or unpredictable, events. However, each incident can be determined to be the product of certain factors, which when analyzed may reveal the causal connection between a chain of events and the fatal outcome.

Derived from the research conducted by William Haddon, Jr. (the Haddon model), this approach reflects the public health perception that the etiology of injuries is multifactorial and largely preventable.[1] For each case, factors associated with the agent (mode of energy exchange), the host (the worker who died) and the environment are identified during the pre-event, event, and post-event time phases. These contributory factors are investigated in detail in each FACE incident, and are summarized in each FACE summary report, along with recommendations for preventing future incidents of a similar nature.

From December 1983, through September 1993, the deaths of 480 workers in 423 incidents were investigated. Seventy of these investigations involved confined spaces where 109 persons died. In 25 of the confined-space incidents, there were multiple fatalities, including those deaths which involved persons attempting rescue.

In addition to the individual FACE reports, a summary of information on the national incidence of fatal occupational injury within confined spaces, over the 10-year period, 1980 through 1989, is provided. This information is taken from the National Traumatic Occupational Fatalities (NTOF) surveillance system also maintained by our Division. It provides a comprehensive view of the national toll of fatal injuries from this cause, by industry, reason for entry, and other epidemiologically significant categorizations.

This document is intended to become a resource and case study manual for safety and public health professionals, safety and health instructors, research personnel, and public safety personnel. It joins various NIOSH Alerts,[2-5] and the NIOSH document Criteria for a Recommended Standard: Working in Confined Spaces,[6] and related publications,[7-11] developed to prevent the deaths of those who must work in confined spaces.

PART I

CONFINED-SPACE-RELATED FATALITIES

OVERVIEW OF CONFINED-SPACE HAZARDS

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NIOSH defines a confined space as one which, by design, has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and is not intended for continuous employee occupancy.[6] Confined spaces include but are not limited to storage tanks, compartments of ships, process vessels, pits, silos, vats, wells, sewers, digesters, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, tunnels, underground utility vaults, and pipelines.[6] Confined spaces can be found in many industrial settings, from steel mills to paper mills, from shipyards to farms, and from public utilities to the construction industry. The hazards associated with confined spaces can cause serious injury and death to workers. Two major factors lead to fatal injuries in confined spaces: 1) failure to recognize and control the hazards associated with confined spaces, and 2) inadequate or incorrect emergency response. The emergency response is usually a spontaneous reaction to an emergency situation, and can lead to multiple fatalities.[8]

Confined spaces may be classified into two categories: 1) open-topped enclosures with depths which restrict the natural movement of air (e.g., degreasers, pits, selected types of tanks, and excavations), and 2) enclosures with limited openings for entry and exit (e.g., sewers, tanks, and silos). **Figure 1** illustrates examples of common types of confined spaces.

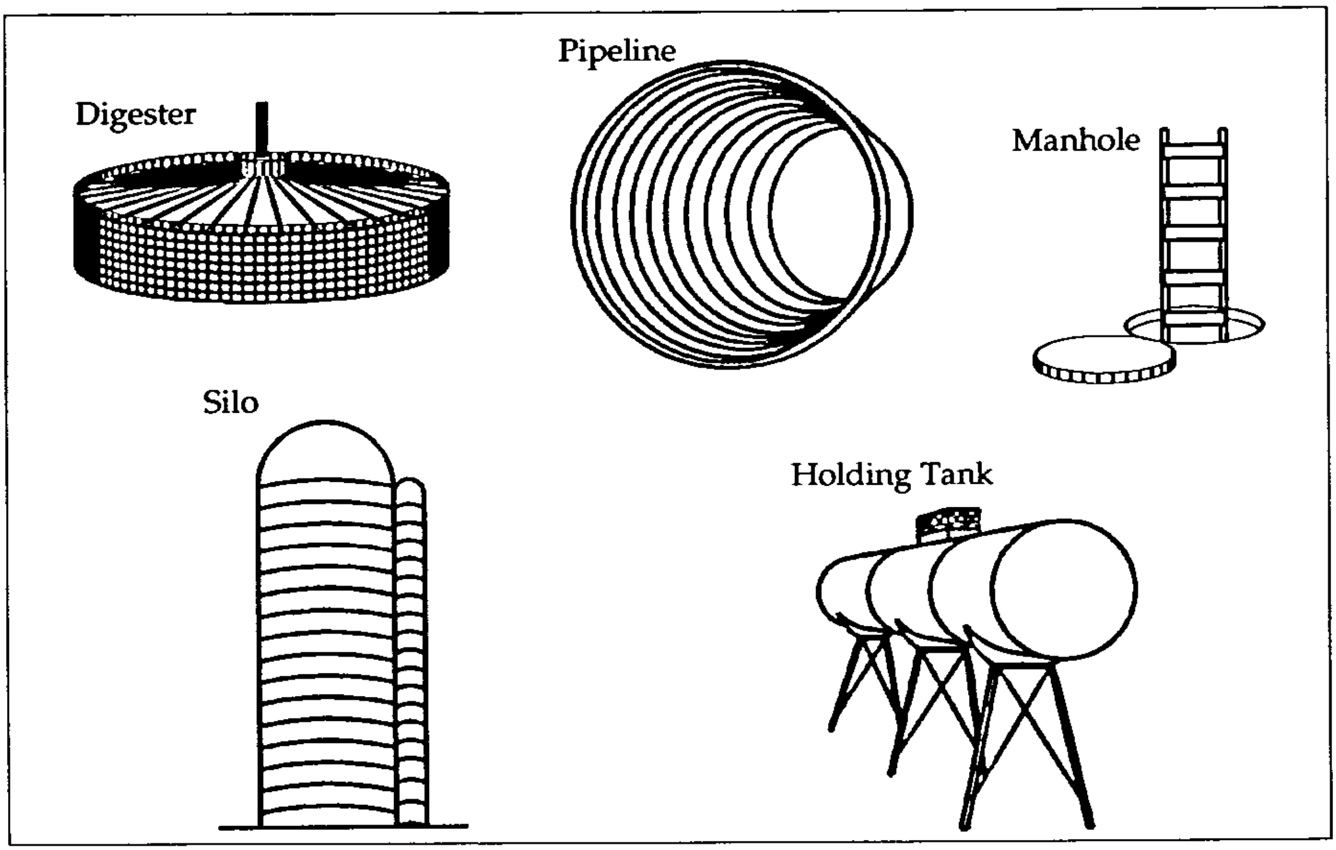

***Figure 1.** Types of Confined Spaces*

The hazards found in any confined space are determined by the material being stored or used, by the process taking place inside the space, and by the effects of the external environment. Worker entry into confined spaces may occur during construction activities or during frequent necessary functions such as inspection, repair, or maintenance. For purposes of discussion, we will separate hazards in confined spaces into atmospheric hazards and physical hazards.

ATMOSPHERIC HAZARDS

Oxygen deficiency

Oxygen deficiency occurs from chemical or biological reactions which displace or consume oxygen from a confined space. The consumption of oxygen takes place during combustion of flammable substances, as in welding, cutting, or brazing. A more subtle form of consumption of oxygen occurs during bacterial action, as in the fermentation process. Oxygen deficiency can result from bacterial action in excavations and manholes which are near garbage dumps, landfills, or swampy areas.[11] Oxygen may also be consumed during slow chemical reactions, as in the formation of rust on the exposed surface of metal tanks, vats, and ship holds.

Ambient air has an oxygen content of 21%. When the oxygen level drops below 17%, the first sign of hypoxia is a deterioration of night vision, which is usually not noticeable. Physiologic effects include increased breathing volume and accelerated heartbeat. Between 14% and 16% physiologic effects are increased breathing volume, accelerated heartbeat, poor muscular coordination, rapid fatigue, and intermittent respiration. Between 6% and 10%, the effects are nausea, vomiting, inability to perform, and unconsciousness. At concentrations less than 6%, there is rapid loss of consciousness, and death in minutes.

Oxygen displacement: Inert gases and simple asphyxiants

A simple asphyxiating atmosphere contains a gas or gases that are physiologically inert and which do not produce any ill effects on the body. However, in sufficient quantity, a simple asphyxiant will displace oxygen and may result in an atmosphere unable to support respiration. The ambient, or normal, atmosphere is composed of approximately 21% oxygen, 78% nitrogen, and 1% argon with small amounts of various other gases. For example, if 100% nitrogen—a non-toxic, colorless, odorless gas—is used to inert (displace oxygen in) a confined space, it will cause immediate collapse and death to the worker if the confined space is not adequately ventilated before worker entry. Other examples of simple asphyxiants which have claimed lives in confined spaces include carbon dioxide, argon, and helium.

Flammable atmospheres

A flammable atmosphere generally results from vaporization of flammable liquids, by-products of chemical reaction, enriched oxygen atmospheres, or concentrations of combustible dusts. Three components are necessary for an atmosphere to become flammable: fuel and oxygen in the proper mixture, and a source of ignition. The proper mixture of fuel and oxygen will vary from gas to gas within a fixed range and is referred to as the lower flammability limit (LFL) and upper flammability limit (UFL).

These terms are synonymous with the lower explosive limit (LEL) and upper explosive limit (UEL). For example, the explosive range for methane is between 5% and 15% in air.[12] Concentrations below 5% methane are below the explosive range, and concentrations above 15% are too rich to support combustion. If a confined space contains 27% methane and forced ventilation is started, the introduction of air into the confined space may dilute the methane in air, taking it into the explosive range.

Toxic gases

Toxic gases may be present in confined spaces because:

1. The manufacturing process uses toxic gases. For example, in producing polyvinyl chloride, hydrogen chloride is used, as well as vinyl chloride monomer.

2. There are biological or chemical processes occurring in the product stored in the confined space. For example, decomposing organic material in a tank or sump can liberate hydrogen sulfide.

3. The operation performed in the confined space can liberate a toxic gas. For example, welding can liberate oxides of nitrogen, ozone, and carbon monoxide.

Some toxic gases such as phosgene or carbon monoxide are particularly insidious because of their poor warning properties. Toxic gases which have been reported to cause death in workers in confined spaces include carbon monoxide, hydrogen cyanide, hydrogen sulfide, arsine, chlorine, oxides of nitrogen, and ammonia.[9]

Toxic gases may be evolved when acids are used for cleaning the interior of a confined space. For example, hydrochloric acid can react chemically with iron sulfide to produce hydrogen sulfide. Hydrogen sulfide is heavier than air and will settle out at the bottom of a confined space. Hydrogen sulfide is extremely toxic and exposure can cause paralysis of the olfactory system (making the victim unable to smell the gas), loss of reasoning, respiratory failure, unconsciousness, and death.[6,13]

Solvents

Hydrocarbon solvents are frequently used in industry as degreasing agents. These agents can cause unconsciousness by depressing the central nervous system.[14] Some chlorinated hydrocarbon solvents, such as chloroform, have been used as anesthetic agents. In addition, certain chlorinated or fluorinated hydrocarbon solvents are toxic to the heart[15] and have been associated with sudden death in confined spaces. The solvent methylene chloride can be toxic in confined spaces both because of its solvent properties and also because it is metabolized in the body to carbon monoxide.[16]

The National Institute for Occupational Safety and Health (NIOSH) developed a classification scheme for atmospheric hazards in confined spaces which is based on the oxygen content of the air, the flammability characteristics of gases or vapors, and the concentration of toxic substances that may be present in a confined space (**Table 1**).

Listing a particular confined space as class A, B, or C is determined by the most hazardous condition present. The usefulness of this classification is that it provides a framework upon which recommendations for work practices and rescue procedures can be made. A detailed listing of safe work practices and procedures for confined-space work is given in the NIOSH criteria document.[6]

Table 1. *Confined-Space Classification*[6]

CHARACTERISTICS		
CLASS A	**CLASS B**	**CLASS C**
Immediately dangerous to life	Dangerous, but not immediately life threatening	Potential hazard
OXYGEN		
CLASS A	**CLASS B**	**CLASS C**
16% or less *(122 mm Hg) or greater than 25% (190 mm Hg)	16.1% to 19.4% * (122-147 mm Hg), or 21.5% to 25% (163-190 mm Hg)	19.5%-21.4% * (148-163 mm Hg)
FLAMMABILITY CHARACTERISTICS		
CLASS A	**CLASS B**	**CLASS C**
20% or greater of lower flammable limit (LFL)	10-19% LFL	10% LFL or less
TOXICITY		
CLASS A	**CLASS B**	**CLASS C**
IDLH**	Greater than contamination level, referenced in 29 CFR Part 1910, Subpart Z (IDLH**)	Less than contamination level referenced in 29 CFR Part 1910 Subpart Z

***** Based upon a total atmospheric pressure of 760 mm Hg (sea level)***

***** Immediately Dangerous to Life or Health***

PHYSICAL HAZARDS

In addition to the atmospheric hazards in a confined space, physical hazards must also be addressed. Physical hazards cover the entire spectrum of hazardous energy and its control. These hazards include those associated with mechanical, electrical, and hydraulic energy; engulfment; communication problems; noise; and size of openings into the confined space.

Engulfment

Engulfment in loose materials is one of the leading causes of death from physical hazards in confined spaces. Engulfment and suffocation are hazards associated with storage bins, silos, and hoppers where grain, sand, gravel, or other loose material are stored, handled, or transferred. The behavior of such material is unpredictable, and entrapment and burial can occur in a matter of seconds. In some cases, material being drawn from the bottom of storage bins can cause the surface to act like quicksand. When a storage bin is emptied from the bottom, the flow of material forms a funnel-shaped path over the outlet. The rate of material flow increases toward the center of the funnel. During a typical unloading operation, the flow rate can become so great that once a worker is drawn into the flow path, escape is virtually impossible.

Loewer and Loewer reported that a typical flow rate for a bin unloading auger is 1000 bushels per hour. This is equivalent to 1350 cubic feet per hour or approximately 21 cubic feet per minute. A person 6 feet tall displaces about 7.5 cubic feet, assuming an average body diameter of 15 inches. From the time the auger starts, there would be perhaps 2 to 3 seconds to react. In 4 to 5 seconds a person could be trapped up to his knees, and in 22 seconds, completely covered in grain.[17]

A condition known as bridging can create additional hazardous situations. Bridging occurs when grain or other loose material clings to the sides of a container or vessel that is being emptied from below, allowing a hollow space to be created. The bridge of material over the space may collapse without warning, entrapping workers who are standing below or on top of the bridge and who are unaware that the surface is unstable. Bridging can occur in storage bins, silos, and hoppers that contain ground grains, soybean meal, or other meals, or other loose materials such as cement, limestone, coal, or sawdust. The diameter of the storage vessel and moisture content of the stored materials are factors that contribute to bridging.

Other physical hazards

The nature of confined-space work may make it difficult to separate the worker from hazardous forms of energy such as powered machinery, electrical energy, and hydraulic or pneumatic lines.

Examples of physical hazards often encountered in a confined space include the following:

1. Activation of electrical or mechanical equipment can cause injury to workers in a confined space. Therefore, it is essential to de-energize and lock-out all electrical circuits and physically disconnect mechanical equipment prior to any work in confined spaces.

2. Release of material through lines which are an integral part of the confined space pose a life-threatening hazard. All lines should be physically disconnected, blanked off, or should use a double block and bleed system.

3. Falling objects can pose a hazard in confined spaces, particularly in spaces which have topside openings for entry, through which tools and other objects may fall and strike a worker.

4. Extremely hot or cold temperatures can make work inside a confined space hazardous. If a confined space has been steam cleaned, for example, it should be allowed to cool before any entry is made.

5. Wet or slick surfaces can cause falls in confined spaces. In addition, wet surfaces can provide a grounding path and increase the hazard of electrocution in areas where electrical equipment, circuits, and tools are used.

6. Noise within confined spaces can be amplified because of the design and acoustic properties of the space. Excessive noise is not only harmful to the worker's hearing, but can also affect communication and cause shouted warnings to go unheard.

CONCLUSIONS

Confined spaces can be hazardous, and they can be hazardous in varied ways. Oftentimes the confined space will not appear to be hazardous; it may have been entered on prior occasions without incident, and may give no apparent sign of danger. At other times there may be ready indications of danger: the distinct odor of irritating or toxic atmospheres, the presence of arcing electrical equipment, continued mild shocks, or flowing grain or sand. By their nature, confined spaces concentrate hazards: atmospheric hazards, in that certain gases will displace breathable air, or that the confined space will allow the accumulation of toxic hazards or flammable or explosive atmospheres; and physical hazards, in that confined spaces limit the ability to avoid contact with electricity, moving mechanical components or machinery, or unstable substances. Recognition of the inherent capacity of these spaces to harbor hazardous agents is a significant element in any workplace hazard assessment. When confined spaces are recognized to be hazardous, provisions for minimizing the need for entry and for use of appropriate work practices and equipment can be made.

EPIDEMIOLOGY OF CONFINED-SPACE-RELATED FATALITIES

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The danger of work in confined spaces has been written about since Roman times, when the Emperor Trajan was noted to have sentenced criminals to clean sewers, an occupation considered one of the worst.[18] Agricola recorded that stagnant air in mines produced difficulty breathing, and that fires in mines soon brought death to those who worked there.[19] Alice Hamilton wrote that decomposing organic matter in vats, tanks, and manholes emitted hydrogen sulfide and cited several examples of how this had caused death from asphyxiation.[20] Asphyxiation at work in specific industries such as steel-making was studied early in this century as part of the Pittsburgh Survey.[21]

The NIOSH criteria document on confined spaces presented an analysis of 276 confined-space incidents, with 193 fatalities.[6] Atmospheric hazards accounted for 78 (40%) of the deaths. This report included a discussion of fatalities due to falls, explosions, fires, and contact with electrical energy which occurred in confined spaces.

A review of confined-space deaths investigated by NIOSH from 1983-1989 as part of the FACE program analyzed 88 deaths in 55 incidents.[10] Only 27% of the employers involved had any written confined-space-entry procedure. Only three of the 88 victims had received any training in confined-space entry.

In a study of asphyxiation and poisoning which was based on OSHA investigations conducted in 1984 through 1986, 188 deaths in confined spaces were identified: 42 were from mechanical hazards such as engulfment in loose materials, and 146 were from oxygen-deficient air or poisoning by gases or chemicals in confined spaces.[9] The 188 deaths made up 4% of fatalities investigated by OSHA during the 3 years. Not included in the confined-space category were 190 deaths from trench cave-ins which OSHA investigated. This study did not include electrocutions, or deaths from explosions which occurred in confined spaces. In 1989 OSHA proposed to establish safety requirements, including a permit system, for entry into confined spaces. OSHA stated that asphyxiation was the main hazard in confined spaces, and that atmospheric hazards were the leading cause of death. The California Department of Labor Statistics and Research reported that in 1981 through 1982, 21 of 1011 (2%) work-related deaths were confined-space-related.[22] For the period 1967 through 1977, OSHA researchers estimated that 5% of injuries in the shipbuilding industry involved confined spaces.[23] For 1979 through 1981, OSHA estimated that 174 fatalities per year occurred in confined spaces.[9]

Epidemiologic studies attempting to assess deaths in confined spaces have been hampered by the lack of data sources which specifically identify this type of fatality. A review of confined-space-related fatalities investigated by the NIOSH FACE program found that when the NIOSH investigation report was matched to death certificate information, none of the death certificates specifically stated that the incident had occurred in a "confined space."

There are epidemiologic data pertinent to deaths in confined spaces which focus on specific hazards or substances rather than on the confined-space environment. In the oil and gas industry, hydrogen sulfide (H_2S) is a particular hazard for workers in areas such as Texas, Oklahoma, and the Rocky Mountain states where crude oil is "sour" and contains considerable H_2S. A review of several sources of data on work-related injury in Alberta, Canada, reported 221 cases of poisoning by H_2S from 1969 through 1973, of which 14 (6%) were fatal injuries.[24] Most of the injuries occurred in enclosed spaces and were among oil and gas workers.

A study of workers overcome by solvents reported that fatal injuries occurred more frequently among young workers.[25] Deaths from solvents in confined spaces that were investigated by OSHA also occurred more often among younger workers than other types of confined-space events.

METHODS

NIOSH has assembled the National Traumatic Occupational Fatalities (NTOF) surveillance system consisting of all U.S. death certificates for 1980-1989 in which the "Injury at Work?" box on the death certificate was marked "Yes," the external cause of death was an injury or poisoning, and the victim was 16 years of age or older.[26] Causes of external injury are coded according to the International Classification of Disease, 9th revision.[27] Confined-space deaths cannot be identified from coded data. One of the advantages of NTOF over other sources of mortality data, however, is that, in addition to containing coded data on the causes of death, each record in the database also contains the written description from the death certificate of the causes of death and the comments made by the certifying coroner, medical examiner, or physician. This allows researchers to make computerized searches for certain words or phrases on death certificates. Because of this feature, the NTOF database can be used as a surveillance tool for counting deaths in silos, bins, vats, sewers, and other work locations likely to have been confined spaces.

Confined-space-related deaths were ascertained from NTOF using a two-step process. All deaths from certain external injury causes were first selected, and then each of these was individually reviewed to ascertain whether the fatality occurred in a confined space. All deaths in which the external cause of injury was asphyxiation (E911-913), poisoning (E850-858 or E860-869), and drowning (E910) were first selected for review. Each of these was then examined for mention of a confined space such as a vat, pit, bin, tank or silo. In addition, deaths caused by poisoning from gases such as methane, hydrogen sulfide, and sewer gas, and deaths resulting from engulfment in grain, were included if the location of injury was unspecified. Deaths from carbon monoxide (CO) poisoning were included only if the death certificate indicated that it occurred in a confined space. Deaths from CO poisoning in automobiles, garages, or repair shops were not considered confined-space-related deaths. Deaths from mine roof falls and mine cave-ins were also excluded. Deaths in confined spaces from electrical energy, explosions, machinery and other physical hazards, except for engulfment in loose materials, were not included because few death certificates for these types of fatalities included a description of the location of death sufficient to determine if it occurred in a confined space.

Deaths from trench cave-ins differ somewhat from other types of mechanical asphyxiation. According to OSHA, a trench or excavation which was 5 or more feet deep would be considered a confined space. Some reports have included trench cave-ins when counting confined-space fatalities,[22] while others have not. Deaths from trench cave-ins have some features in common with deaths caused by engulfment in loose materials such as grain or sand. Deaths from trench cave-in were not included in the case definition of a confined-space death for this technical report. However, they were tabulated separately to allow comparison with other studies.

Deaths from trench cave-ins were first selected by reviewing all deaths from asphyxiation (E911-E913) as described above for mention of a trench cave-in. In addition, a key word search for "trench," "cave-in," "excavation," and "ditch" was done for all other causes of death in the NTOF database, and these records were then reviewed for mention of a trench cave-in.

Confined-space deaths per 100,000 workers were calculated using employment data from the Bureau of the Census' County Business Patterns (CBP).[28] CBP is a census of workers based on payroll records. Because CBP data do not include employment data for government and agricultural workers, CBP data were supplemented with data on government employees from the Current Population Survey[29] and agricultural workers from the Census of Agriculture.[30]

Because the amount of detail provided on death certificates is variable, the number of confined-space and trench cave-in deaths identified in NTOF must be considered as a minimum number of deaths occurring under these circumstances. There were undoubtedly additional deaths which could not be identified because of a lack of detail on the death certificate. A detailed description of the methods and limitations of the NTOF surveillance system has been reported previously.[26]

RESULTS

NTOF Data

There were 585 separate fatal incidents in confined spaces for the 10-year period, claiming 670 victims. Seventy-two (12%) of the fatal incidents involved multiple victims. The distribution of multiple fatality incidents by the number of victims is shown in **Figure 2.**

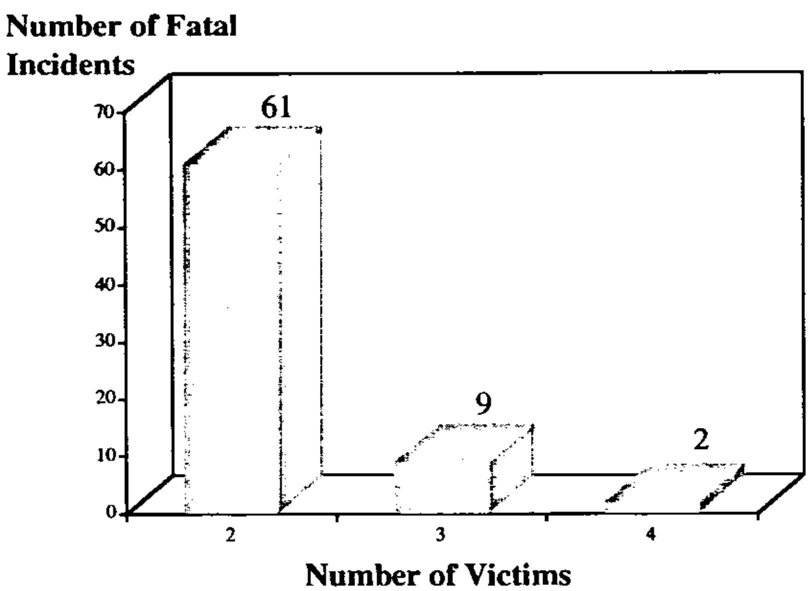

Figure 2. *Number of Victims in Multiple Fatality Confined-Space Incidents Identified by NTOF, 1980-1989 (N=72)*

Figure 3 depicts the frequency of confined-space deaths by year. There was an average of 67 deaths per year, with an average rate of 0.08 per 100,000 workers per year.

Victims ranged in age from 16 to 86 years. The average age (± standard error) was 35 ±19 years. Six hundred sixty victims were male and 10 were female. The race/ethnicity of the victims is shown in **Figure 4**.

The number of fatalities was highest in manufacturing (152), followed by agriculture (128), construction (90), transportation/communication/public utilities (77), and mining/oil/gas (63). Fatality rates are shown in **Figure 5**. Rates were highest in mining, oil, and gas with 0.69 deaths per 100,000 workers per year.

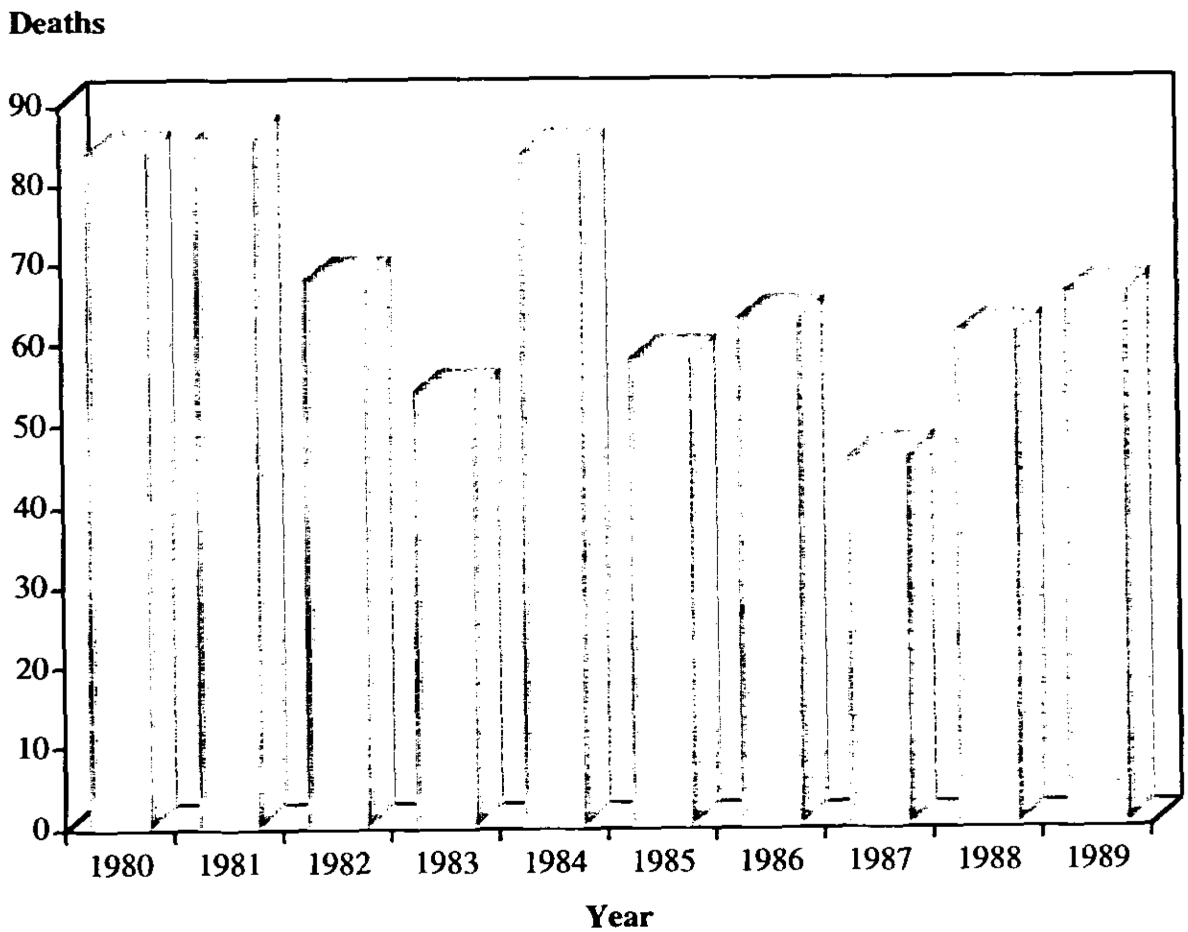

Figure 3. Deaths in Confined Spaces Identified by NTOF by Year, 1980 -1989 (N=670)

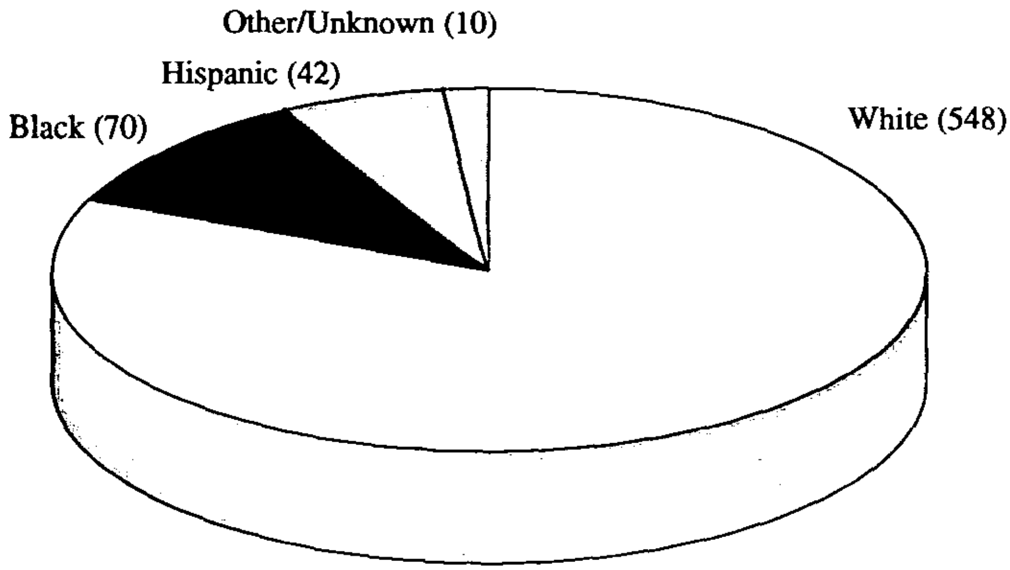

Figure 4. Race/Ethnicity Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)

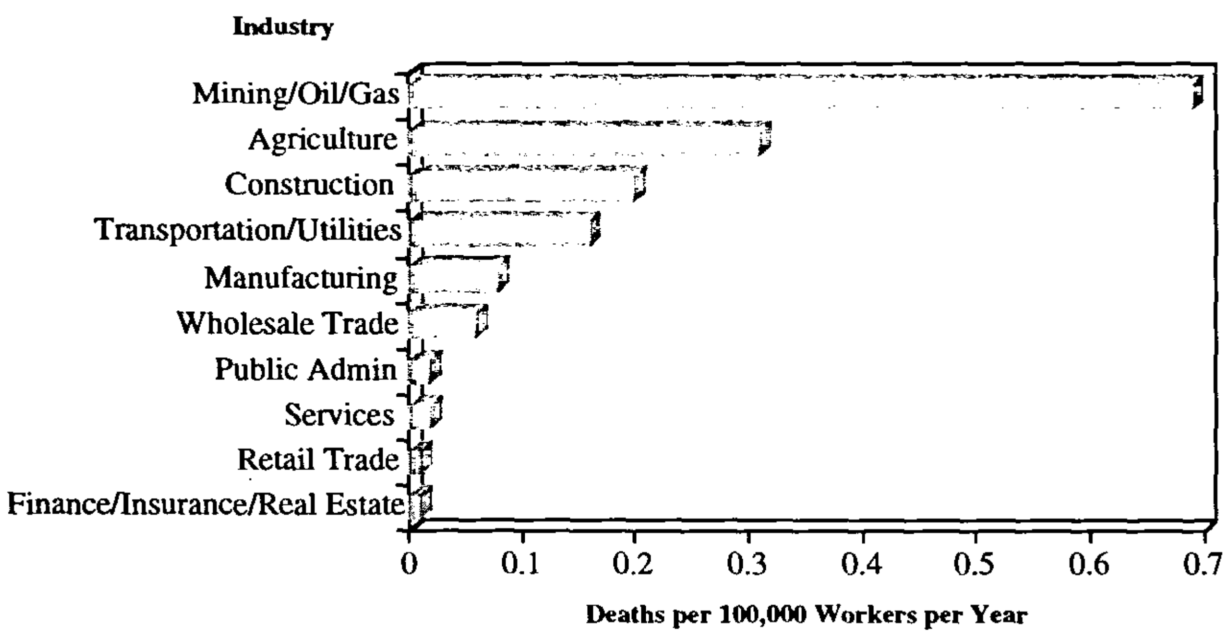

Figure 5. Rates of Confined-Space Deaths Identified by NTOF by Industry, 1980 -1989 (N=670)

The distribution of confined-space-related fatalities according to the external cause of death (E-Code) is shown in **Table 2**. Asphyxiations accounted for 305 deaths (45%), poisonings accounted for 274 deaths (41%), and drownings accounted for 91 deaths (14%). Within specific groupings of E-Codes, the proportion of deaths which could be determined to have occurred in confined spaces varied. For poisoning, NTOF reported 1018 deaths in 1980 through 1989, of which 274 (27%) were in confined spaces. For asphyxiations, NTOF reported 1218 fatalities, with 305 (25%) in confined spaces. Only 91 (10%) of 947 drownings were in confined spaces.

The circumstances of fatal injury in confined spaces are shown in **Figure 6**. Atmospheric conditions, such as presence of toxins, or lack of oxygen, contributed to over half of the confined-space-related deaths. Engulfments in loose materials were the causes of death in about one-third of the cases. The remaining 10% of the deaths were drownings and engulfments in other materials (i.e., sludge and manure), in which it was not possible to determine from the death certificate if atmospheric conditions contributed to the death.

Atmospheric conditions noted on the death certificate are shown in **Figure 7**. Hydrogen sulfide claimed 51 victims; methane, 38; inert gases, 32; and carbon monoxide, 25. Sewer gases were reported to be the cause of death for 25 victims. There were 62 deaths in which the death certificate stated that the victim was in an oxygen-deficient area, but did not specify that any particular toxin or gas was also present. For another 78 victims, the death certificate did not provide enough information to determine the type of atmospheric condition which contributed to the death.

***Table 2.** E-Codes Assigned to Death Certificate Diagnoses for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)*

GROUP	NUMBER (% of TOTAL)	
Poisoning (E850-858, E860-869)		274 (41%)
Drowning (E910)		91 (14%)
Asphyxiation (E911-913)		305 (45%)
(E911, 912-Obstruction of Respiratory Tract)	31	
(E913-Mechanical Suffocation)	274	
TOTAL		**670 (100%)**

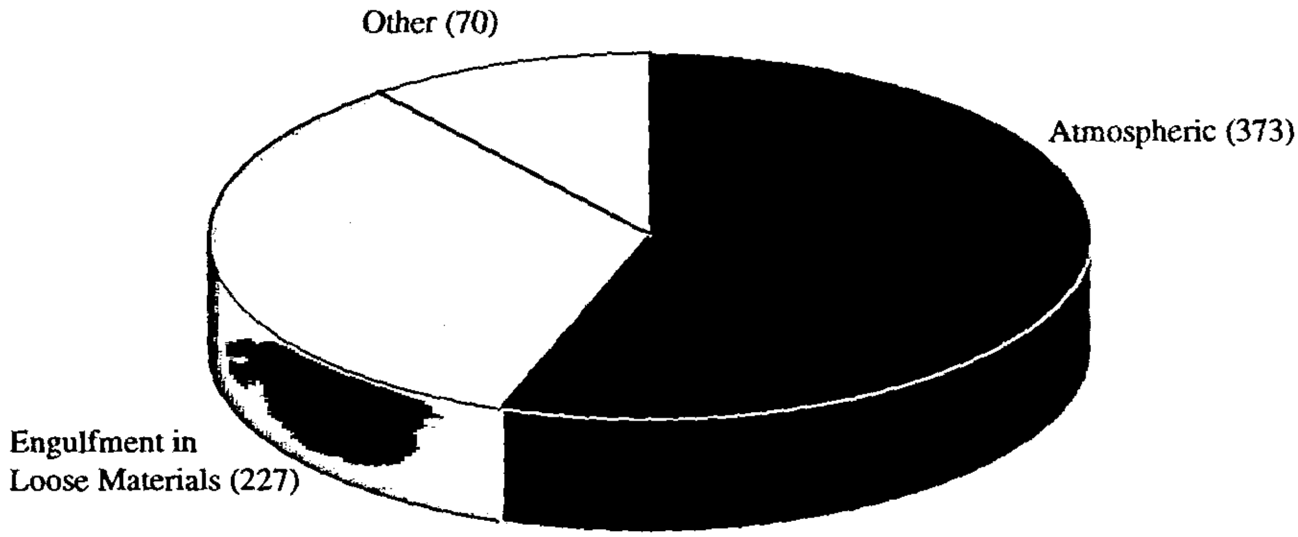

Figure 6. Circumstances Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980-1989 (N=670)

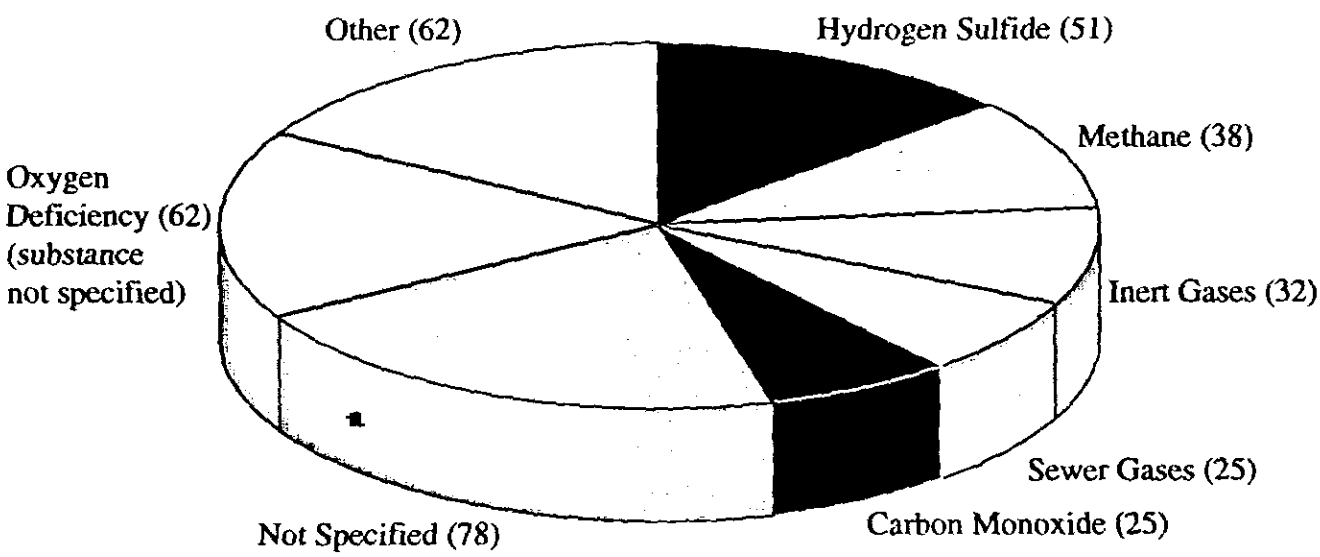

Figure 7. Atmospheric Conditions Noted on Death Certificates for Deaths in Confined Spaces Identified by NTOF, 1980 -1989 (N=373)

Tanks were the most common location of confined-space-related deaths from atmospheric conditions, accounting for 109 of the deaths. Sewers were the location in 61 of the deaths, pits in 32 deaths (16 in manure pits), and silos in 27 deaths. For 71 of the victims, the confined space was not reported on the death certificate but the deaths were assumed to have occurred in a confined space because of the type of gas (i.e., methane or hydrogen sulfide). Confined spaces reported in the remaining 75 deaths were diverse and included vats, wells, bins, pipes, and kilns.

Of the 373 confined-space-related deaths resulting from atmospheric conditions, 85 of the victims worked in the manufacturing sector, 59 in construction, 57 in the transportation/communications/public utilities sector, and 48 in agriculture/forestry/fishing. Industry was not listed on 35 of the death certificates.

As noted, mechanical asphyxiation by engulfment in loose materials claimed 227 lives (**Figure 8**). Entrapment in grain caused 124 deaths, and agricultural products other than grain, such as silage or fertilizer, caused 26 deaths. There were 25 deaths from engulfment in sand, and 22 deaths from engulfment in other building materials such as gravel, cement, and clay. Engulfment in sawdust claimed 11 lives. For 8 victims, the type of material was not denoted on the death certificate, but was assumed to be a loose material because of the location (i.e., silo or hopper).

Silos, bins, hoppers, and grain elevators were the locations of most fatal engulfments, accounting for 158 deaths. There were 13 deaths in pits and 17 in other locations. For 37 of the engulfment fatalities, the death was assumed to have occurred in a confined space even though location was not specified.

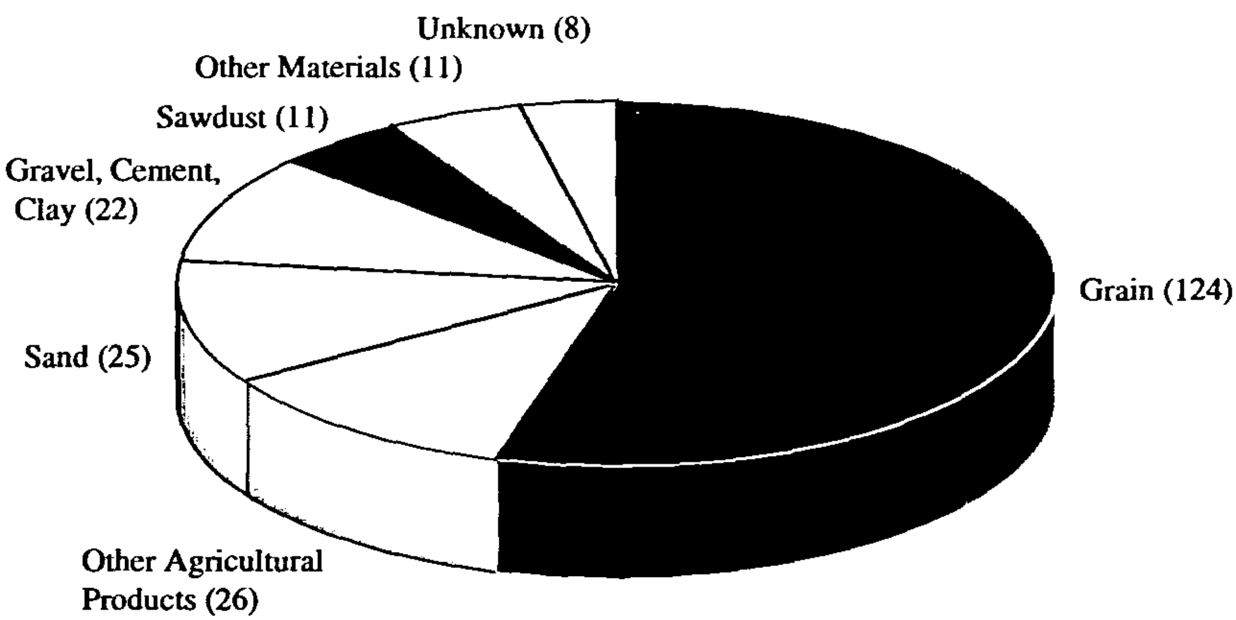

Figure 8. Loose Materials Involved in Mechanical Asphyxiations in Confined Spaces Identified by NTOF, 1980-1989 (N=227)

Nearly one-third (74) of the confined-space-related deaths from engulfment in loose materials were in the agriculture/forestry/fishing sector. Fifty-seven of the victims worked in the manufacturing sector, 24 in wholesale trade, and 24 in construction. There were less than 15 deaths in the remaining industry sectors. Industry could not be determined for 19 of the deaths resulting from engulfment in loose materials.

Trench Cave-ins

For the years 1980 through 1989, there were 606 fatal injuries due to trench cave-ins identified in NTOF, resulting in an average of 61 per year (**Figure 9**). The 606 deaths occurred in 572 incidents. The construction industry accounted for 468 deaths (77%); no other industry had more than 28 deaths (5%) during the 10-year period. Using U.S. employment data for the construction industry as the denominator, the average fatality rate for the construction industry was 1.05 per 100,000 workers per year.

The average victim age was 35 years, with a range of 16 to 72 years. Only one victim was female. Whites were the largest racial/ethnic group, with 454 deaths (75%), followed by blacks with 77 deaths (13%), Hispanics with 64 deaths (11%), and other/unknown with 11 deaths (1%).

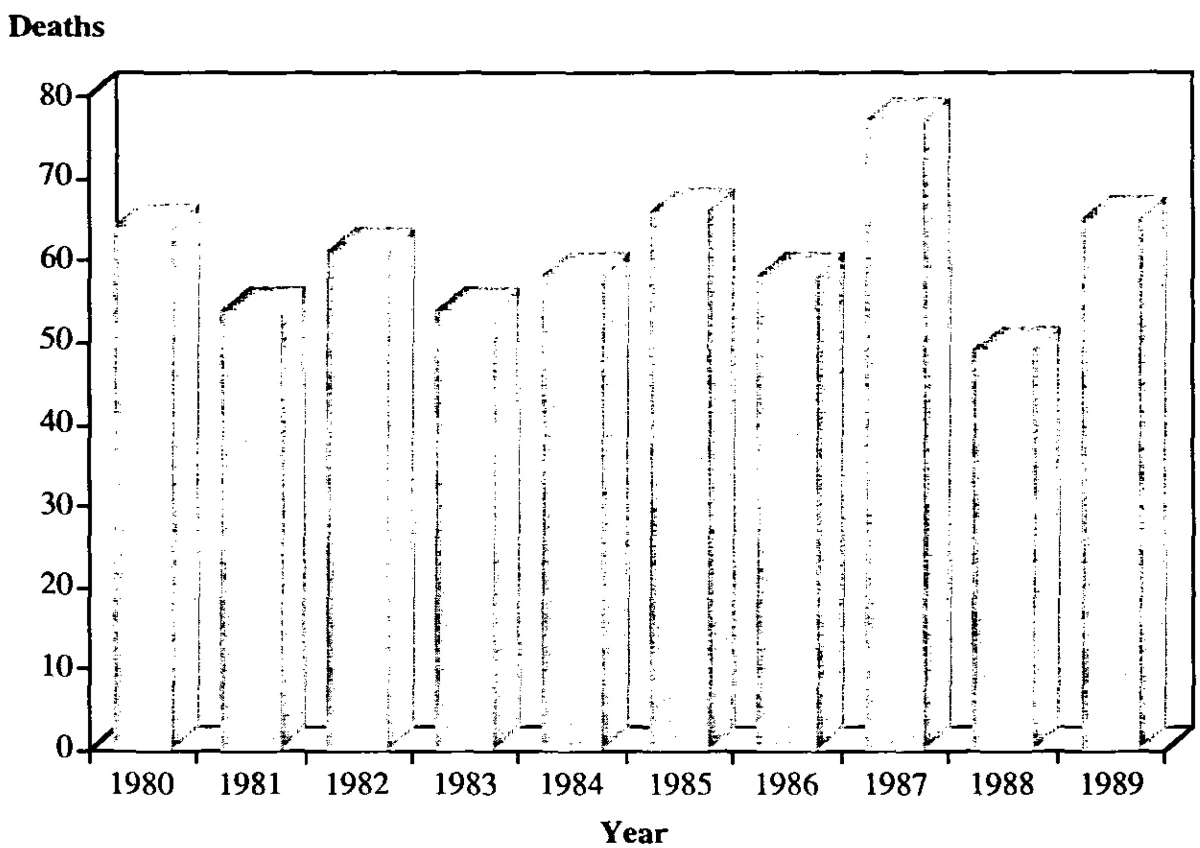

Figure 9. Trench Cave-in Deaths Identified by NTOF by Year, 1980-1989 (N=606)

FACE Investigations

During the period from December 1983 through September 1993, NIOSH conducted 70 onsite FACE field investigations of fatal work-related incidents in confined spaces. There were 109 deaths in the 70 incidents. Three industries accounted for over 62% of the incidents—construction (18, 26%), public administration (13, 19%) and manufacturing (12,17%). Description of these investigations by industry group, hazard type, and other factors is provided below. Case reports for each incident are provided in Part II of this report.

Incident-specific Information

Nearly two-thirds (72) of the confined-space-related fatalities occurred in the months of May through August and one-quarter (26) occurred in July. Forty-five of the incidents (64%) involved only 1 victim and 13 of these were in the construction industry. An additional 24% of the incidents involved at least two victims. The overall victim-to-incident ratio was 1.56:1, with the manufacturing and public administration industries experiencing the highest ratios; 1.75:1 and 1.69:1, respectively **(Table 3)**.

Eighty percent of the confined-space incidents had hazardous atmospheres (43% were oxygen-deficient, 29% were toxic, and 7% were flammable). The remaining 21% had some type of physical hazard present at the time of the incident **(Table 4)**. Fifty-six percent of the construction industry incidents and 46% of the public administration industry incidents involved oxygen-deficient atmospheres.

Forty-seven (67%) of the employers involved in confined-space incidents provided safety training to their workers. In only 28 (40%) of the 70 incidents did the employer have written safety procedures. None of the employers used a permit system for confined-space entry and warning signs were rarely used. A standby person was used in 26 (37%) of the 70 incidents. Industry differences on safety issues are provided in **Table 5**.

Table 3. *Fatal Confined-Space Incidents Investigated by FACE, by Industry and Number of Victims per Incident, 1983-1993 (N=70)*

Industry	Number of Victims					Total
	One	Two	Three	Four	Five	
Agriculture/Forestry/Fishing	8	3	0	0	1	12
Construction	13	4	1	0	0	18
Manufacturing	8	1	2	0	1	12
Transportation/Utilities	6	3	0	0	0	9
Trade	0	1	0	0	0	1
Services	3	1	1	0	0	5
Public Administration	7	4	1	1	0	13
Total	45	17	5	1	2	70
(% of Total)	64.3	24.3	7.1	1.4	2.9	100.0

Table 4. Fatal Confined-Space Incidents Investigated by FACE, by Industry and Type of Hazard, 1983-1993 (N=70)

Industry	Hazardous Atmospheres			Physical Hazards	Total
	Oxygen Deficient	Toxic	Flammable		
Agriculture/Forestry/Fishing	5	2	0	5	12
Construction	10	5	0	3	18
Manufacturing	2	8	1	1	12
Transportation/Utilities	5	1	1	2	9
Trade	0	0	1	0	1
Services	2	0	1	2	5
Public Administration	6	4	1	2	13
Total	**30**	**20**	**5**	**15**	**70**
(% of Total)	**42.9**	**28.6**	**7.1**	**21.4**	**100.0**

Table 5. Fatal Confined-Space Incidents Investigated by FACE, by Industry and Training Procedures Implemented, 1983-1993*

Industry	Training Procedures Implemented				
	Training	Written Safety Procedures	Permit	Stand By	Warning Posted
Agriculture/Forestry/Fishing	1	0	0	4	4
Construction	11	8	0	4	0
Manufacturing	11	6	0	4	1
Transportation/Utilities	9	5	0	3	0
Trade	1	0	0	1	0
Services	2	1	0	2	0
Public Administration	12	8	0	8	0
Total	**47**	**28**	**0**	**26**	**5**
(% of Total)	**67.1**	**40**	**0.0**	**37.1**	**7.1**

*** One incident may involve more than one category**

Victim-specific Information

Thirty-seven percent of the victims were less than 30 years of age and two-thirds were less than 40 years of age (**Figure 10**). The average age of the victims in the FACE investigations was 36 years (range 15 to 73), which was similar to that found on death certificates from NTOF.

Fifty-eight (53%) of the victims worked for the private sector, 25(23%) were employed by state or local governments, and 26 (24%) were self-employed. Industry differences in employment are described in **Table 6**.

The most common reason for entry into a confined space was repair/maintenance, with 44 victims (40%), followed by rescue, with 39 (36%). Of the 39 victims whose reason for confined-space entry was to attempt to rescue someone, only four were emergency responders (i.e., police, fire, or public safety personnel). Tanks, vats/pits, digesters, and sewer manholes were the most frequently encountered types of confined spaces undergoing repair and maintenance or involved in rescue operations (**Table 7**).

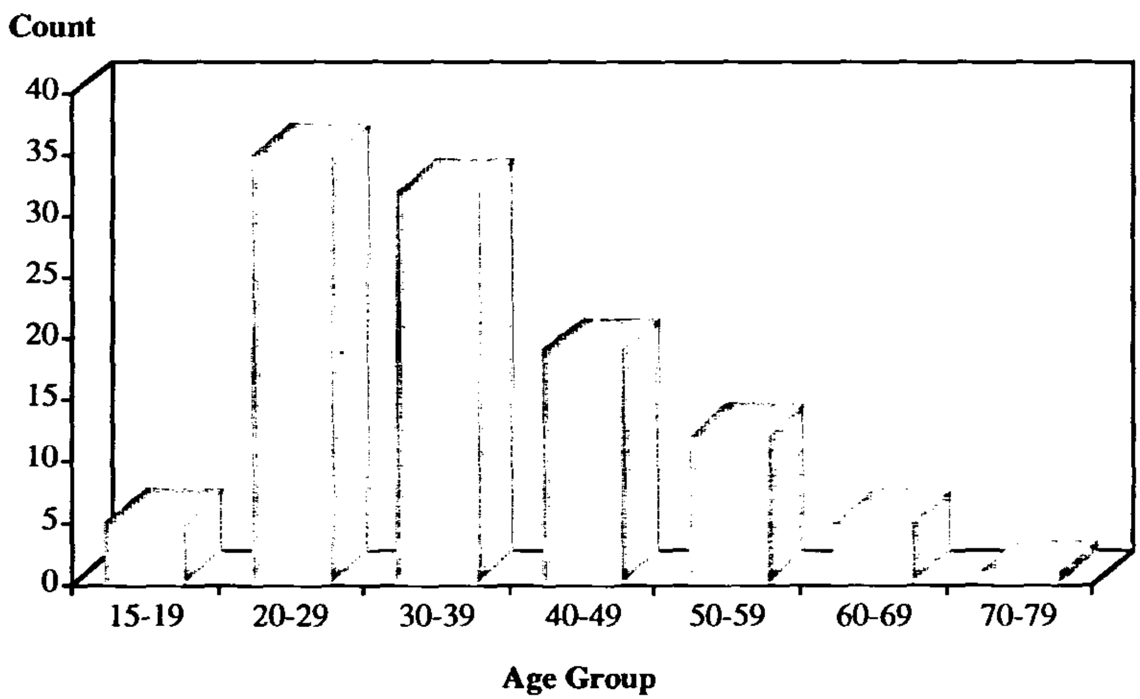

***Figure 10.** Confined-Space-Related Fatalities Investigated by FACE, by Age Distribution of Victims, 1983-1993 (N=109)*

Table 6. Confined-Space-Related Fatalities Investigated by FACE, by Industry and Employment Sector of Victim, 1983-1993 (N=109)

Industry	Employment Sector			Total
	Private	Government	Self-Employed	
Agriculture/Forestry/Fishing	6	0	13	19
Construction	17	1	7	25
Manufacturing	21	0	0	21
Transportation/Utilities	10	2	0	12
Trade	2	0	0	2
Services	2	0	6	8
Public Administration	0	22	0	22
Total	58	25	26	109
(% of Total)	53.2	22.9	23.9	100.0

Table 7. Confined-Space-Related Fatalities Investigated by FACE, by Confined Space Type and Reason for Entry, 1983-1993 (N=109)

Type	Reason for Entry							Total
	Const.	Insp.	Repair/ Maint.	Rescue	Retrieve Object	Dislodge Material	Unknown	
Tank	0	5	14	11	1	0	0	31
Pipeline/Tunnel	1	0	1	1	0	0	0	3
Tanker Truck	0	0	3	0	0	0	0	3
Utility Vault	0	1	3	0	0	0	0	4
Vat/Pit Digester	0	0	10	14	2	0	0	26
Silo/Bin	0	1	0	0	0	5	1	7
Sewer Manhole	4	3	10	10	0	0	0	27
Well	0	1	3	3	1	0	0	8
Total	5	11	44	39	4	5	1	109
(% of Total)	4.6	10.1	40.4	35.8	3.6	4.6	0.9	100.0

Few of the victims had received formal safety training, as shown in **Figure 11**. Thirty-seven (34%) had received no training at all, while 45 (41%) had received on-the-job training only. Formal safety training in the form of classroom instruction or manuals was received by 21 victims (19%). Only six (6%) of the victims received safety training specifically oriented toward confined spaces.

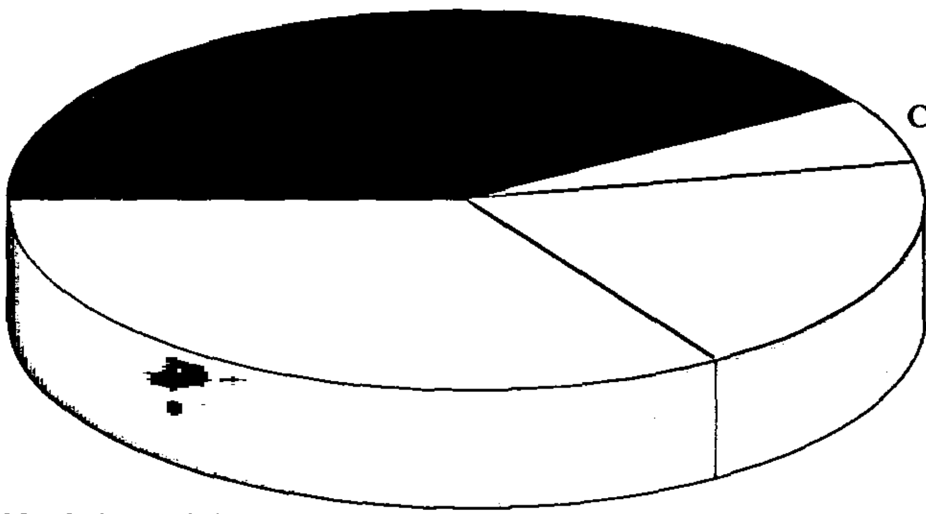

Figure 11. Confined-Space-Related Fatalities Investigated by FACE, by Type of Training Received by Victim, 1983-1993 (N=109)

DISCUSSION

The death certificate data from NTOF help to illustrate the magnitude of the confined-space problem nationally and allow a comparison of the risks in various industries. The information from FACE investigations allows for the identification of more detailed information on confined-space hazards, such as, the lack of a permit system, standby person, written warnings, and other measures needed for proper confined-space work. In addition, the FACE investigations provide information on fatalities among rescuers.

OSHA estimates that 238,853 establishments employing 12.2 million workers, have permit-required confined spaces.[31] These establishments employ approximately 1.6 million workers, including contractors, who enter approximately 4.8 million permit-required confined spaces annually. However, the OSHA confined-space regulations would not apply to workplaces with fewer than 11 employees; federal workers; state and municipal employees in the 24 states under federal rather than state OSHA jurisdiction; self-employed persons; and workers in the transportation, construction, and shipbuilding industries.[32]

FACE reports and death certificates in NTOF identify many of the same hazards for confined-space-related fatalities. The largest numbers of deaths are in manufacturing, construction, and agriculture, with the highest fatality rates in the mining industry (including oil and gas) and in agriculture. Atmospheric hazards cause the largest number of confined-space-related deaths. However, if one were to include trench cave-ins as confined-space-related deaths, then mechanical hazards would be the largest group.

Confined-space-related deaths from mechanical asphyxiation occurred primarily in silos, bins, hoppers, and grain elevators. Those due to atmospheric hazards occurred in a variety of structures and settings; no single structure type was predominant. Sewers and manholes were involved in 61 (9%) of the 670 confined-space-related deaths identified from NTOF and 20 (18%) of the 109 deaths investigated by FACE. The atmospheric hazards in sewers and manholes range from toxic gases like hydrogen sulfide and carbon monoxide, to oxygen deficiency due to the action of bacteria in sewage or soil. Manholes in low-lying or swampy areas may present a particular problem in that the air inside may be depleted of oxygen only under conditions of low barometric pressure, when air is drawn out of the surrounding soil into the manhole.[33] These types of manholes may have been entered many times in the past without difficulty, lulling workers into a false sense of security.

There was a slight downward trend from 1980 to 1989 in confined-space-related deaths but not in deaths due to trench cave-in. All work-related deaths in the U.S. have shown a decline since the early 1980's.[26] The actual number of confined-space-related deaths is probably more than the 67 per year identified on death certificates, as many death certificates lack details as to the manner and location of death. In addition, the "Injury at Work" box is not marked "Yes" in all work-related deaths, and this means of identifying workplace deaths finds perhaps 81% of such deaths.[34]

Rescuers accounted for 39 of 109 deaths (36%) in confined spaces which were investigated by the FACE program. It is difficult to count the number of rescuer fatalities in the NTOF data because the death certificates often lacked detail concerning the victim's activity. However, it should be noted that in NTOF, 23% of confined-space deaths were in multiple-victim incidents. Whatever the true proportion of rescuer fatalities may be, these data indicate the need for recognition of confined-space hazards and the need for established rescue procedures prior to confined-space entry.

PREVENTION: ELEMENTS OF A CONFINED-SPACE PROGRAM

Ted A. Pettit, M.S., R.E.H.S.

The worker who is required to enter and work in a confined space may be exposed to a number of hazards, ranging from an oxygen-deficient or toxic atmosphere, to the release of hazardous energy (electrical/mechanical/hydraulic/chemical). Therefore, it is essential for employers to develop and implement a comprehensive, written confined-space-entry program. The following elements are recommended as a guide in developing a confined-space program.

A confined-space-entry program should include, but not be limited to, the following:

- identification of all confined spaces at the facility/operation
- posting a warning sign at the entrance of all confined spaces
- evaluation of hazards associated with each type of confined space
- a job safety analysis for each task to be performed in the confined space
- confined-space-entry procedures
    - initial plan for entry
    - assigned standby person(s)
    - communications between workers inside and standby
    - rescue procedures
    - specified work procedures within the confined space
- evaluation to determine if entry is necessary—can the work be performed from the outside of the confined space
- issuance of a confined-space-entry permit—this is an authorization and approval in writing that specifies the location and type of work to be done, and certifies that the space has been evaluated and tested by a qualified person and that all necessary protective measures have been taken to ensure the safety of the worker
- testing and monitoring the air quality in the confined space to ensure that
    - oxygen level is at least 19.5% by volume
    - flammable range is less than 10% of the LFL (lower flammable limit)
    - absence of all toxic air contaminants

- confined-space preparation
  - isolation/lockout/tagout
  - purging and ventilation
  - cleaning processes
  - requirements for special equipment and tools

- safety equipment and protective clothing to be used for confined-space entry
  - head protection
  - hearing protection
  - hand protection
  - foot protection
  - body protection
  - respiratory protection
  - safety belts
  - lifelines, harness
  - mechanical-lift device—tripod

- training of workers and supervisors in the selection and use of
  - safe entry procedures
  - respiratory protection
  - lifelines and retrieval systems
  - protective clothing

- training of employees in confined-space-rescue procedures

- conducting safety meetings to discuss confined-space safety

- availability and use of proper ventilation equipment

- monitoring the air quality while workers are in the space.

The NIOSH criteria document, *Working in Confined Spaces*,[6] was developed to provide the user a means for significantly reducing worker injury and death, associated with entering, working in, and exiting confined spaces. This document will provide more detailed information in developing a comprehensive confined-space-entry program. Additional information on confined-space safety is available from other NIOSH publications and journal articles.[2-10]

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PART II

FATALITY ASSESSMENT AND CONTROL EVALUATION (FACE) SUMMARY REPORTS, 1983-1993: CONFINED SPACES

Atmospheric Hazards

Flammable/Explosive

FACE 85-05: Confined Space Incident Kills Two Workers- Company Employee and Rescuing Fireman

INTRODUCTION

On November 15, 1984, one worker died after entering a toluene storage tank. During the rescue attempt, a fireman was killed when the tank exploded.

SYNOPSIS OF EVENTS

The owner of a bulk petroleum storage facility discovered that the toluene storage tank (10 feet in diameter and 20 feet in height) was contaminated and would have to be drained and cleaned. Since the tank's only access portal was located on top of the upright cylindrical tank, the owner decided to have a clean-out access portal installed at the bottom of the tank when emptied. A contractor was called to provide cost estimates for installing the portal. The contractor performed a site survey of the tank and told the owner that the tank must be drained, all sludge removed, and thoroughly ventilated before he would install the portal. The owner directed his maintenance supervisor to get the tank prepared for the contractor.

On the day of the incident the supervisor and an unskilled laborer (a San Salvadorean immigrant on his first day back on the job after working another job for approximately 2 months) drained the tank to its lowest level - leaving 2 to 3 inches of sludge and toluene in the bottom - and prepared for a "dry run" of entry into the tank via the top access portal.

The supervisor rented a self-contained breathing apparatus (SCBA) from a local rental store and instructed the laborer in use of the SCBA and in the procedure they intended to follow. Since a ladder would not fit into the 16-inch diameter access hole, the supervisor secured a knotted, 1/4-inch rope to the vent pipe on top of the tank and lowered the rope into the hole. The 16-inch diameter opening on the top of the tank was not large enough to permit the laborer to enter wearing the SCBA. Therefore, it was decided the SCBA would be loosely strapped to the laborer so it could be held over his head until he cleared the opening. Once entry had been made, the supervisor was to lower the SCBA onto the laborer's back so it could be properly secured.

Immediately prior to the incident, both employees were on top of the tank. The laborer was sitting at the edge of the opening. The supervisor turned to pick up the SCBA. While he was picking up the unit, he heard the laborer in the tank. He turned and looked into the opening and saw the laborer standing at the bottom of the tank. He told the laborer to come out of the tank, but there was no response. The supervisor bumped the rope against the laborer's chest attempting to get his attention. The laborer was mumbling, but was still not responding to his supervisor's commands. At this point, the supervisor pulled the rope out of the tank, tied the SCBA to it and lowered the unit into the tank. Again, he yelled to the laborer in the tank, bumped him with the unit and told him to put the mask on. There was still no response. The laborer fell to his knees, then fell onto his back, and continued to mumble. At this point, the supervisor told the facility manager (who was on the ground) to call the fire department.

The first call went to the police department who relayed it to the fire department. Included in the fire department response was the hazardous materials team, due to the information received about the material in the tank. The fire department (including the rescue and the hazardous materials teams) arrived on the scene approximately 10 minutes after the initial notification. After apprising the situation, fire officials decided to implement a rescue procedure rather than a hazardous materials procedure. Therefore, removal of the disabled person inside the tank was given top priority.

The 16-inch diameter opening at the top of the tank was not large enough to lower a firemen donned in full rescue gear. Therefore, it was decided to cut through the side of the tank to remove the victim. The firemen were aware of the contents of the tank (toluene) and the possibility of an explosion.

The procedure developed by the fire department involved making two 19-inch vertical cuts and a 19-inch horizontal cut with a gasoline-powered disc saw. After the cuts were completed, the steel flap would be pulled down and the victim removed.

While the hazardous materials team was cutting, other firemen were spraying water on the saw from the exterior to quench sparks. Two other firemen were spraying water on the interior cut from the top opening. Three firemen with the hazardous materials team were doing the actual cutting; they were alternately operating the saw because of the effort required to cut through the 1/4-inch thick steel. Sometime during the horizontal cut a decision was made to bring the two firemen off of the top, which meant no water spray on the interior. Simultaneously, the exterior water spray was removed to put out flammable liquid burning on the ground as a result of the shower of sparks from the saw. Thus, at the precise time of the explosion, no water was being sprayed on the saw/cut from exterior or interior. Both vertical cuts were completed and the horizontal cut was 95 percent complete when the explosion occurred.

One fireman was killed instantly from the explosion and several were injured. The man inside the tank was presumed to be already dead at the time of the explosion.

CONCLUSIONS/RECOMMENDATIONS

The conclusions and recommendations are presented in two parts: Part I - the confined space entry; and Part II - the rescue effort.

Part I - Confined Space Entry:

The following factors may have contributed to the confined space fatality:

The company had no confined space entry procedures.

The supervisor was not qualified to direct confined space entry.

The laborer was inadequately trained for confined space entry — possible language barrier.

Appropriate protective clothing and equipment were not provided.

The only access portal required vertical entry.

The access portal was small.

It was the laborer's first day back on the job. (He may have felt obligated to perform any task assigned.)

RECOMMENDATIONS

Written confined space entry procedures should be developed and used. Procedures should contain the following: permit system, testing and monitoring of the atmosphere, training of employees, safety equipment/clothing, safe work practices, rescue procedures, standby person requirements, and use of respiratory protection.

Selection of proper respiratory protection — whether it be a self-contained breathing apparatus (SCBA) or supplied air system — is essential. Selection should be determined by the physical limitations, equipment available, and work procedures.

Confined space testing and evaluation by a qualified person before entry and implementation of safety measures will help reduce risk-taking by employees.

Vertical access from the top of a 20-foot tank by a rope was found to be physically impossible while wearing respiratory protection and protective clothing. An additional access port on the side near ground level would eliminate this problem. The port should be of adequate size to permit entry of a worker wearing full protective clothing.

Workers must be properly trained (in English, Spanish, or the prevailing language) in confined space entry procedures and use of personal protective equipment. Also, the tank contents and known potential hazards should be discussed.

A prior accident should have alerted someone that additional protection was needed. If entry procedures are being followed and an accident occurs, it is necessary to re-evaluate the procedures and make necessary corrections for employee safety.

Part II - The Rescue Effort:

The following factors may have contributed to the rescue effort fatality and injuries:

The condition of the person down inside the tank was not known.

The location and size of the only access portal on the tank precluded entry by a rescuer wearing full protective clothing and equipment.

The fire department's confined space entry procedures precluded entry into a confined space containing hazardous materials without full protective clothing and equipment.

The choice of methods to open the tank for rescue entry introduced an ignition source to an atmosphere which was known to be potentially explosive (see tank calculations).

The use of water sprays to prevent ignition of a flammable/explosive atmosphere in a confined space may not be effective under certain conditions.

There were combustible materials on the ground surrounding the tank which ignited prior to the explosion and necessitated removal of exterior water spray away from saw/cut.

The fire department chain of command possibly created confusion when orders were given without full knowledge of the situation.

The number of fire department personnel in the immediate area may have been excessive.

The victim (fire fighter) was directly in front of the cut during the cutting procedure and when the explosion occurred.

RECOMMENDATIONS

While cutting the tank and assisting fellow firemen who were cutting, one fire fighter stood directly in front of the opening, rather than to the side. This maximized the impact the victim received from the explosion. It is recommended that procedures be outlined that minimize such risk by firemen.

When hazardous tasks are performed only essential personnel should be in the immediate area, regardless of perceived risk by fire fighters. Nonessential personnel should be permitted only after the hazardous task(s) has been completed.

More extensive departmental procedures for efforts involving responses to explosive environments and hazardous materials are needed. Procedures should include command responsibilities, determinations of and distinctions between rescue and recovery efforts, uses of potential sources of ignition, methods to minimize risks of ignition, etc.

City fire departments should establish a registry of confined spaces and toxic/explosive substances for specific companies within the area in which they serve. Such a registry should provide not only the name of the substance, but should also provide sufficient information so that emergency response personnel will have one comprehensive source that provides information sufficient to safely effect a rescue effort.

Research is needed to determine the best methods (if any) to gain entry in such circumstances. Cutting may be too hazardous, even with the use of water sprays.

FACE 87-33: Digester Explosion Kills Two Workers at Wastewater Treatment Plant in Pennsylvania

INTRODUCTION

On February 6, 1987, two workers at a wastewater treatment plant were draining a sewage digester when an explosion lifted the 30-ton floating cover, killing both workers instantly.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident was a small borough within the Commonwealth. The victims worked for the wastewater treatment plant which is under the public works department. The public works department has a total of 10 employees (2 in the wastewater treatment section and 8, including a public works supervisor, in the street maintenance section).

New employees are given a brief orientation on benefits and policies and receive on-the-job training that addresses their assigned duties. Additionally, employees are sent to any pertinent seminars that would be of value in their training. No safety training or safety meetings are conducted at the wastewater treatment plant. Employees are not trained in confined space hazards or safe entry procedures. The only confined space procedures are four basic recommendations that are posted on the bulletin board at the wastewater treatment plant.

SYNOPSIS OF EVENTS

On February 6, 1987, the two operators (a father and son) of the wastewater treatment plant were in the final stages of drainage a digester (30 feet deep by 27 feet in diameter) that had been taken out of service for routine cleaning. The heavy sludge remaining in the bottom of the digester was approximately 8 feet deep. Two tank pumper trucks were brought in to remove the heavy sludge; however, the sludge was not pumping well. The operator of the wastewater treatment plant told the driver of the pumper truck that he would go up on top of the digester and spray water into the sludge to make it pump easier. The driver of the pumper truck reversed his pump to blow air up through the sludge to help loosen the heavy mass. The two plant operators climbed up onto the floating cover of the digester and using a 1-inch garden type hose, they began spraying water into the bottom of the digester to loosen up the heavy sludge. The operators lowered a 200-watt light bulb on an extension cord into the digester through a 22-inch diameter manhole on top of the floating cover to view the sludge level. The light and cord were not designed or approved for use in hazardous (classified) locations. Apparently the light bulb either struck the concrete and broke, or the cold water spray made contact with the hot glass light bulb, causing it to break. The broken light provided a source of ignition for the combustible gas(es) in the digester, probably methane.

The truck driver who remained on the ground stated he heard a "whoomp" but the sound didn't appear to be an explosion. However, his truck and pump were running at the time of the explosion, increasing the ambient noise level. After a few minutes the driver went up the ladder to the top of the digester and saw that the 30-ton floating cover was wedged in the digester on a 45-degree angle. Neither of the workmen was visible.

The rescue squad was called and arrived within a few minutes. However, to remove the victims, a large crane was brought in to tip the wedged cover enough to send in a driver to retrieve the victims. It took approximately 4 hours before the victims were removed from the digester. They were both pronounced dead at the scene by the local coroner.

NOTE: When agitating the sludge, i.e., blowing air up through the heavy sludge, it is possible to release trapped gases such as methane and hydrogen sulfide.

CAUSE OF DEATH

The coroner's report listed the cause of death of both men as cervical fracture.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should develop proper work procedures and should train employees concerning safe maintenance procedures.

Discussion: The municipality did not provide safe operating/maintenance procedures or training in hazard recognition. This training should include recognition of potential hazards associated with digester cleaning operations and proper tools and equipment to be used in a combustible atmosphere. The workers had used this light and extension cord in the past and assumed it was safe. The light and cord were not designed or approved for use in hazardous (classified) locations and should not have been used.

Recommendation #2: The employer should develop comprehensive policies and procedures for confined space entry.

Discussion: All employees who are required to work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. NIOSH Publication No. 80-106 "Working in Confined Spaces" was left with the employer as a reference in developing procedure for confined spaces. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. 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. Has the confined space been isolated/locked out from other systems?

5. 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.

6. Have employees and supervisors been trained in selection and use of approved equipment and tools for use in a confined space?

   - Electric tools approved in accordance with 29 CFR Part 1910, Sub Par 5.
   - Lighting explosion proof design where necessary. Intrinsically safe for the atmosphere involved.
   - Electric lines, junctions approved in accordance with the National Electric Code and National Fire Code.

7. Have employees been trained for confined space entry?

8. Is ventilation equipment available and/or used?

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

FACE 87-50: Tractor-Trailer Repairman Dies While Welding Interior Wall of a Tanker in Indiana

INTRODUCTION

On June 9, 1987, a tractor-trailer repairman (the victim) for a trailer repair company entered an 8500-gallon cargo tank to weld a leak on the interior wall of the tanker. When the victim began welding, an explosion occurred killing him.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a trailer service company that has nine employees: six trailer repairmen and three secretarial staff members. The company is family-operated and has one shop. The company has a written safety program, with the majority of the safety procedures given as part of on-the-job training. Specific safety regulations for confined spaces were in place at the time of the incident that, if followed, would have prevented the accident. As a result of this incident, the company has decided to stop servicing tanker-trailers.

SYNOPSIS OF EVENTS

On June 9, 1987, a 34-year-old welder (the victim) and an assistant began preparing a tanker-trailer for repairs. The victim was the shop foreman and had been performing tanker repairs for approximately 15 years (7 years with this company). The tanker was a multi-compartment type with four compartments of different sizes (see Figure 1) with a leak in an interior wall that required welding. A small baffle area is located between the compartments to prevent chemicals from mixing together if a leak in an interior wall occurs.

The tanker compartments were steam cleaned for 1 to 1-1/2 hours to remove trapped chemicals and vapors from the tanker. The chemical in this instance was lacquer-thinner. Drain plugs were opened the entire time steaming was conducted to allow proper drainage of the compartments and baffles. Opening the drain holes is a standard safety procedure for the company when doing tanker repairs. The victim and his assistant left the tanker to do other tasks while the steam cleaning progressed. Because of this, they were not aware that the drain hole in the second baffle area had clogged (See B, Figure 1).

The victim and the assistant returned after allowing sufficient time for the steaming operation to clean the compartments and baffles. They discovered the clogged drain and cleaned it, which allowed the trapped liquid to drain from the baffle. At that time, the victim decided not to re-steam the baffle, despite the strong fumes. Instead, the tanker was moved into the shop area and the victim instructed the assistant to shoot compressed air into the baffle drain hole to dissipate the vapors. This was done for approximately ten minutes.

After air-blowing the baffle, the victim and assistant entered the tanker compartment to do pre-treatment work to the leak (See A, Figure 1) before welding. The assistant remarked about the "strong fumes" in the compartment; however, the victim decided to continue the repair operations. When the pre-treatment was completed, the victim instructed the assistant to leave the compartment, pass in the welding equipment and to stay on top of the tanker to attach the lids to the other compartments. Upon leaving the compartment, the assistant again mentioned the "strong fumes." The written company safety policy required that an explosion meter was to be used at this point. The explosion meter was available and was in working condition. However, the victim did not follow the safety policy and requested the assistant to pass in the welding equipment. After passing in the equipment, the assistant began replacing the compartment lids as instructed. An explosion, which apparently occurred as the victim began welding the leak, broke the weld of the compartment wall along approximately six feet of the seam line.

The assistant was the first to reach the compartment and saw the victim against the compartment wall opposite the leak (See C, Figure 1). The owner of the company immediately notified the local fire department and emergency medical service. The fire department responded after 10 to 12 minutes, by which time the victim had been removed from the tanker by co-workers. The emergency medical team began CPR at the scene and continued CPR while in route to the hospital. The victim was rushed to a nearby hospital, approximately 10 minutes away, where he was pronounced dead by the attending physician. The time between the incident and arrival at the hospital was approximately thirty minutes.

CAUSE OF DEATH

The autopsy report lists the cause of death as "multiple blunt force injuries."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should initiate a comprehensive enforcement and safety review program for confined space entry procedures.

Discussion: All employees who repair tankers should be aware of the importance of stated company safety procedures, including confined entry policies. The employer should reinforce employee awareness of the potential hazards associated with confined spaces. The employer did have a written policy that was sufficient to prevent the incident if it had been followed; however, this policy should be communicated and enforced. This should include:

1. Posting of confined space procedures;
2. Regularly scheduled safety policy meetings (bi-weekly or monthly) to re-enforce company safety codes;
3. Review process for allowing employees to make recommendations or for improving written company safety codes;
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: The employer should expand confined space policies to address hazards due to oxygen deficient, flammable/explosive, or toxic environments.

Discussion: This incident emphasized the need to address all of the potential hazards in confined spaces. Locating the clogged baffle drain <u>before</u> entering the tanker compartment allowed the baffle to be drained of trapped chemicals. However, if the clogged drain had not been located, the concentration of chemical vapors in the tanker compartment may have been sufficient to place both the victim and the assistant in an oxygen deficient or toxic environment. The need to inform employees about the hazards of confined spaces in <u>all respects</u> should be a priority of the employer. Information concerning confined space entry procedures is available from various NIOSH documents including:

1. "Criteria for a Recommended Standard...Working in Confined Spaces" - DHEW (NIOSH) Publication No. 80-106
2. "A Guide to Safety in Confined Spaces" - DHHS (NIOSH) Publication No. 87-113.

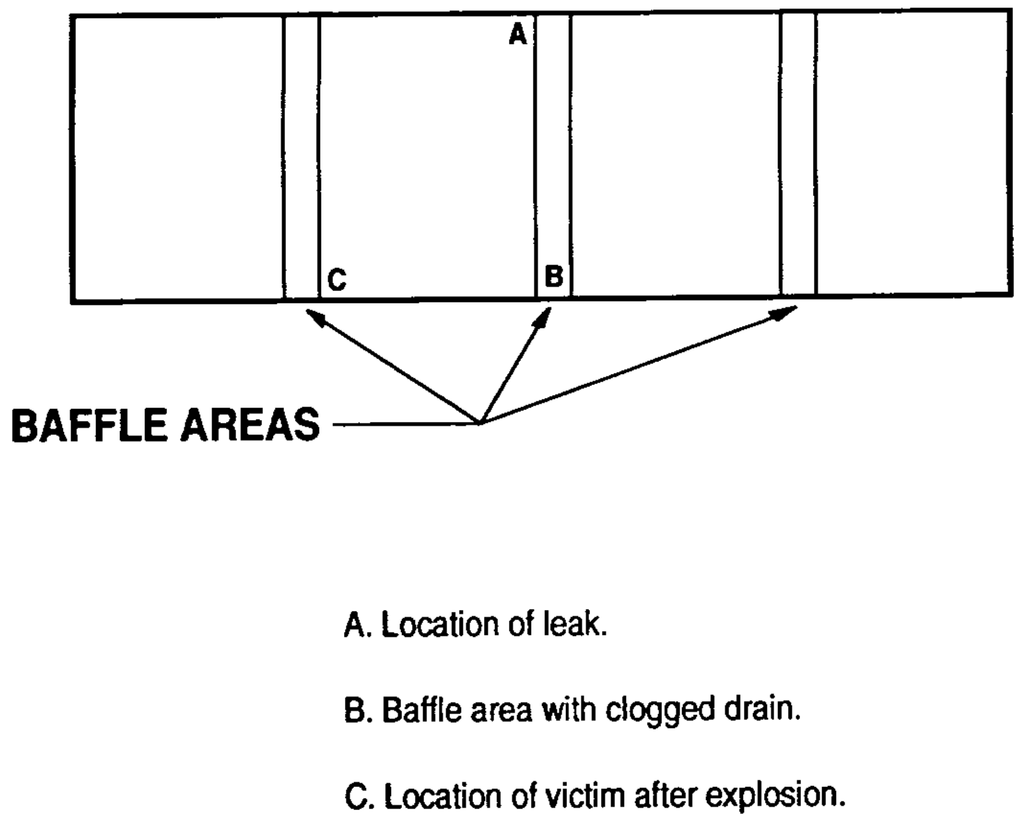


Figure 1 (87-50). Lateral view of the tanker-trailer in which fatality occurred.

FACE 88-30: Laborer Dies in Explosion

INTRODUCTION

On July 14, 1988, an 18-year-old male laborer died as a result of an explosion which occurred while he was making repairs on the interior of a tanker truck compartment.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was one of seven employees of a truck and trailer repair shop. The shop had no written safety policy or safety program. All employees received on-the-job training. The victim had been employed full-time at the facility for 45 days.

SYNOPSIS OF EVENTS

A tanker truck's aluminum cargo tank had developed a crack in an interior compartment wall. The cargo tank was 16 feet long, divided into 4 interior compartments, and had a total tank capacity of 3,000 gallons. The interior compartments were of double wall construction with a dead air space between the walls. This configuration prevented liquid in one compartment from flowing into another should a single wall fail. Each compartment had an individual hatchway located on top of the tank. Each also had its own drain and shut-off valve connected by a manifold pipe to one common outlet.

The crack had developed in a weld in Compartment 3 on the wall located between compartments 3 and 4. Planned repairs involved welding a 20-inch-long piece of 3-inch structural aluminum angle over the crack.

On the morning of the incident, the truck was brought into the garage to have the compartment repaired. Compartment 3 was steam-cleaned while the other three compartments were left sealed. The compartment atmosphere was not tested for toxicity or explosibility prior to entrance. The victim entered Compartment 3 and used an electric grinder to prepare the crack for welding. When the victim finished preparing the weld site, he left the facility to pick up the piece of aluminum angle to be used for the patch. When the victim returned, he and the supervisor ate lunch together but did not discuss the job. After lunch, the victim re-entered the compartment and began welding the patch over the crack.

The supervisor stated that at 2:10 p.m. the victim was using the grinder once again when an explosion occurred in Compartment 2. The top sections of both walls separating compartments 2 and 3 were blown into Compartment 3. The double wall wrapped around the victim's head, crushing his skull. The volunteer fire department was summoned. Firemen used an electric winch to pull the double wall away from the victim. Approximately 40 minutes after the explosion, the victim was removed from the tanker and pronounced dead at the scene by the county coroner.

The petroleum company's manifest was reviewed during the investigation. Immediately before the truck was brought in for service, compartments 1 and 2 had contained gasoline. It is assumed that a small quantity of gasoline was still present in compartments 1 and 2 and in the drainage system. The drains on all four compartments were open which may have allowed explosive vapors to accumulate in the drain lines.

The facts suggest at least two possible explanations for the explosion:

1. while the victim was dressing (preparing) the weld with the grinder, a piece of hot metal fell into the drain causing the gas vapors to ignite, or

2. explosive vapors entered the compartment through the drain opening and ignited. If ignition occurred in Compartment 3, the source was either the grinder motor or electrical arcs created by electrical flow between bare conductors on the grinder power cord and the metal compartment.

In either case, the ignition spread through the drainage system to Compartment 2, where an explosive concentration of vapors was enclosed.

CAUSE OF DEATH

The coroner listed the cause of death as blunt force trauma to the head.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should initiate a program of safe work practices and ensure that employees understand and follow specific prerequisites for entering a confined space. These should minimally include the following:

1. ***recognition of confined spaces and associated hazards***
2. ***air quality testing to ensure adequate oxygen supply, adequate ventilation, and permissible levels of toxic and explosive contaminants***
3. ***monitoring of the space to determine that safe atmospheres are being maintained***
4. ***employee and supervisory training in confined space entry, in the selection and usage of required respiratory protection, and emergency rescue procedures***
5. ***availability, storage, and maintenance of emergency rescue equipment.***

Discussion: The air quality was not determined before the worker entered the compartment and ventilation was not maintained. The air quality was not monitored for toxic air contaminants and oxygen level. If the atmosphere in the compartment had been tested prior to the beginning of work, it may have alerted the victim that a problem existed.

Recommendation #2: All containers, such as the truck compartments in this case, which have recently been used for storage, transport or dispensing of flammable liquids, should be emptied, thoroughly cleaned, and purged before initiating repairs to the container. The atmosphere within the compartment should be tested to determine that it is below the lower explosive limits if repairs involve potential ignition sources.

Discussion: Although two other compartments had contained gasoline, only the compartment in which work was to be performed was steam-cleaned. This created a dangerous situation since the drains leading to a common outlet were open in all four compartments. The possibility of an explosion would have been greatly reduced had all four compartments been steam-cleaned and the drains thoroughly flushed.

Recommendation #3: Employers should maintain portable hand tools in safe operating condition.

Discussion: The power cord on the portable grinder had visible bare conductors. This created a condition which could have resulted in an arcing effect due to current flow from the conductor to the metal compartment, thereby producing an ignition source for the explosive atmosphere. Additionally, this hazardous condition exposed users of the grinder to potential contact with electrical energy which could result in injury or death.

FACE 89-38: Painter Dies from Burns Received from Explosion Inside Tank

INTRODUCTION

On May 16, 1989, a 41-year-old male painter (the victim) suffered burn injuries from an explosion which occurred while he was painting the inside of a 1,300-gallon tank. He died 5 days later. A 32-year-old male painter (co-worker) stationed outside the tank suffered burns and a broken arm.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is a sheet metal fabrication company with 30 employees. The company manufactures steel tanks and has been in business for 20 years. Most of the employees are sheet metal workers, welders and painters. The victim had been with the company as a painter for 3 1/2 years. The co-worker had been a painter with the company for 4 years. The company has a management level employee who serves as the safety officer on a collateral-duty basis. The safety officer conducts safety meetings once a month. New employees receive a safety orientation which consists of a brief discussion of company requirements for workers to wear steel toe boots, hearing and eye protection. New employees are given handouts which they are expected to read covering safety requirements. The company has no written safety program and does not have any written confined space entry procedures. Confined space entry procedures regarding ventilation of tanks during welding is discussed at monthly safety meetings.

SYNOPSIS OF EVENTS

The victim and co-worker had been assigned to paint the inside of a recently fabricated 1,300-gallon steel tank. The tank measured 68 inches high, 75 inches in diameter, and stood vertically with a 22-inch diameter manway opening on the top.

The victim entered the tank by stepping on the mixing blades that had been built into the inside of the tank. He was wearing a supplied air respirator (without an auxiliary escape Self Contained Breathing Apparatus (SCBA)), welder's cap, coveralls, rubber gloves, and steel toe boots. To provide lighting for the victim, the co-worker positioned a 500-watt, non-explosion-proof halogen lamp over the manway opening. The co-worker then sat on top of the tank next to the manway to observe the victim. He (the co-worker) was wearing a dust/mist respirator. Using an airless spray gun, the victim began spray painting the inside of the tank with an epoxy-base paint. The victim had completed painting the bottom and sides of the tank, and he was painting the top when the spray gun nozzle hit the lamp, breaking the sealed beam. This ignited the epoxy vapor which caused a flash fire explosion. The victim was able to climb out of the tank unassisted. He then removed the respirator mask and both the victim and co-worker walked approximately 300 feet to the office. There they explained to office personnel what had happened. Office personnel notified the local Emergency Medical Service (EMS). Police officers who were in the area heard an emergency call concerning the explosion and arrived at the scene in 3 minutes. A rescue squad ambulance arrived 10 minutes after being notified and transported the victim to a local hospital emergency room. The co-worker was taken to the same hospital in another worker's car. Both workers were fully conscious and able to converse while being transported to the hospital and while medical care was being administered in the emergency room. The victim suffered second and third degree burns on 40 percent of his body (thighs, hands, arms and chest). The co-worker suffered first and second degree burns on 12 percent of his body (face and neck), and suffered a broken arm from falling off the top of the tank after the explosion. The two workers were transported the same day to a nearby burn center where they were hospitalized. The co-worker recovered sufficiently to be released from the hospital 8 days after the incident. The victim died from burn complications 5 days after the incident.

CAUSE OF DEATH

The attending physician listed the immediate cause of death as respiratory failure. This was due to respiratory complications as a consequence of thermal burns affecting 40 percent of the victim's body.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: All employers should develop and implement a safety program to protect their employees.

Discussion: The company did not have a formal safety program established. A logical first step in developing a safety program is to identify all potential hazards. One way is by analyzing the sequential steps in routine operations to identify potential hazards, and attempting to develop procedures or other control measures which effectively eliminate or reduce the hazards. This type of analysis is known as job hazard analysis. Additionally, each specific job involves hazards particular to that job or the working environment. For example, in the steel tank painting process there were two hazards which should have been identified: 1) The flammable epoxy paint being sprayed inside the tank, and 2) the non-explosion-proof floodlight being used to illuminate the spraying process. An evaluation of these hazards should have led to control measures such as changing to an explosion-proof light and/or substituting the epoxy paint for an acrylic base or other non-flammable paint. NIOSH Publication Number 78-100, "Health and Safety Guide for the Fabricated Structural Metal Products Industry" should be used as a guide in developing the safety program.

Recommendation #2: The employer should develop and implement specific confined space entry procedures.

Discussion: Although the company had verbal confined space procedures for entering and working in tanks, the procedures were unsafe and inadequate. The company should therefore immediately develop and implement a comprehensive confined space entry program as outlined in NIOSH Publications Number 80-106, "Working in Confined Spaces," and Number 87-113, "A Guide to Safety in Confined Spaces." At a minimum, the following items should be addressed:

1. Is 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 posted with warning signs and are 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 based on the following criteria:

   - 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:

   - protective clothing
   - respiratory protection
   - hard hats
   - eye protection
   - gloves
   - lifelines and
   - 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. Is ventilation equipment available and/or used?

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

In addition to the above items, the following should be specifically incorporated into the confined space procedures for work performed inside tanks:

1. The use of explosion-proof lighting and fixtures in and near flammable atmospheres, as required by National Electric Code (NEC) Article 501-9(a)(1) and 501-9(b)(1) and the National Fire Protection Association (NFPA) Standard 33.

2. The use of non-flammable paints (if at all possible) for coating the inside of tanks.

Recommendation #3: The employer should develop and implement a comprehensive respirator program as required by 29 CFR 1910.134, including either quantitative or qualitative fit testing and employee training in the use and limitations of air-supplying and air-purifying respirators.

Discussion: Employees were not trained in the use of respirators. Although the victim wore a supplied air respirator, it was not equipped with an auxiliary, escape SCBA. Respirators should be selected according to criteria in the "NIOSH Respirator Decision Logic" (DHHS [NIOSH] Publication No. 87-108). Additional information on the characteristics and use of respirators is available in the "NIOSH Guide to Industrial Respiratory Protection" (DHHS [NIOSH] Publication No. 87-116

Atmospheric Hazards

Inert Gases and Simple Asphyxiants

FACE 85-02: Two Rescuers Die in Fracturing Tank in West Virginia Gas Field

INTRODUCTION

On October 4, 1984, two workers died while attempting to rescue a third worker who had entered a fracturing tank at a natural gas well. A total of four men entered the tank and were overcome by natural gas. The two workers who died drowned in 30 inches of liquid (water, gas, acid, and possibly oil) which had been released into the tank during "blow down" procedures. The other two workers, both rig hands, required medical treatment at local hospitals.

SYNOPSIS OF EVENTS

On the day of the accident, at approximately 7:30 a.m., a five-man crew assembled in the office of the field supervisor to receive their instructions for the day. The crew consisted of two service rig hands (hereafter designated "rig hands") and their supervisor, the service rig operator (hereafter designated "operator"). In addition, the rig supervisor (hereafter designated "supervisor") and the service rig tool pusher (hereafter designated "tool pusher") were assigned to the crew so that the supervisor could instruct the tool pusher in the assembly job. The crew was informed that they were to "blow the well down" (relieve the internal pressure). If they could get the pressure down to acceptable levels, they were to start putting the tubing down. All members of the crew were familiar with the procedures necessary to blow down the well and insert the tubing. The crew began to work by about 8:30 a.m.

When the well is "blown down," gas, water, acid, and occasionally oil are released. These substances are directed into the fracturing tanks through two-inch steel "flow back" lines. Because of the pressure exerted on these lines, they are secured to the tanks with safety chains. When sufficient steel lines are not available to plumb in all of the tanks, a high-pressure, double-walled, two-inch rubber hose, called a Kelly hose, is used as a flow back line. When the Kelly hose is used, it must be tied down, both to the inside and outside of the tank, to prevent it from whipping around when the well is flowing during blow down.

By approximately 9:30 a.m., the well had blown down sufficiently to begin inserting the tubing, so the operator and one of the rig hands began to disconnect the well from the fracturing tanks. The remaining members of the crew (the supervisor, tool pusher, and one rig hand) were near the service rig, assembling the down hole equipment when they heard the operator yell that the rig hand was in the tank. The operator then entered the tank himself. Despite the warnings by the rig supervisor to stay out of the tank, the other rig hand entered the tank, followed by the tool pusher. When the supervisor got to the top of the tank and looked in, he could see two of the men and they were unresponsive and "dazed looking." He immediately got off the tank and opened the valves to release the water in the tank. He then called for help on the truck radio.

When the call was received at the office, the rescue squad was notified, and arrangements were made to have the supervisor of a second crew meet the ambulance and give them directions. In the meantime, the rig hands from the second crew proceeded to the site to provide additional assistance, and other supervisors and employees proceeded to the site as well.

When the two rig hands from the second crew arrived, they helped the supervisor remove two clean-out panels at the bottom of the tank. By this time, most of the liquids had been drained from the bottom of the tank. When the panels were removed, the bodies of the operator and tool pusher were found lying on the bottom of the tank. One of the rig hands was found standing in the tank, but was unresponsive; the other rig hand, also unresponsive, was found attempting to climb up the internal support bars of the tank, but appeared ready to fall. The two rig hands who had entered the tank and survived the incident reported that within 10 to 15 seconds of entering, they were overcome by the gas. They could not remember anything past that point.

The autopsy reports indicated that the rig operator and the tool pusher died by drowning due to asphyxiation.

CONCLUSIONS/RECOMMENDATIONS

The following factors contributed to this fatal accident:

1. "Blowing the well" releases water, acid, oil, and natural gas into the fracturing tanks. In this area of the country, the primary component of natural gas is methane (75 to 85 percent). Although methane is not considered a toxic gas, it is a simple asphyxiant. In high concentrations, it displaces the oxygen required to sustain life. When methane is present in concentrations exceeding 20 to 30 percent (by volume), the inspired air is usually oxygen deficient, and signs and symptoms of oxygen deficiency may be noted. In addition, methane is an anesthetic at high concentrations. Either oxygen deficiency or the anesthetic qualities of methane could account for the workers' being overcome so quickly.

2. The use of a Kelly hose as a flow back line necessitates entry into a confined space to secure the line to prevent it from whipping around when it's under pressure. Had a sufficient number of metal flow back lines been available, the need to enter the tank would have been precluded.

3. There were no written or verbal safety policies or procedures for safe entry into a confined space. Appropriate procedures would have required testing for oxygen and/or methane levels prior to entry.

4. There were neither policies nor procedures for emergency rescue from a confined space.

5. The workers had not received specialized training for entering confined spaces. The employees stated that they knew what a confined space was. However, they had never received any training classes to inform them about the potential hazards associated with confined spaces, let alone training in confined space entry or emergency procedures.

Recommendation #1: A confined space policy and appropriate procedures should be established by the company. The policy and procedures should indicate the areas designated to be confined spaces, conditions where entry to confined spaces is authorized (for example, when the tanks need to be fiberglassed), procedures to be followed before entry is permitted (testing, entry permit, training, lockout/tagout procedures, etc.), and rescue procedures. Emergency response by office personnel appeared to be good during this incident; however, an emergency procedure should be established, documented, and practiced.

Recommendation #2: A training program should be developed by the company to ensure that workers who are expected, in the course of their work, to enter and work in confined spaces, have knowledge of the hazards they may encounter, are fully cognizant of the requirements of the confined space evaluation and entry procedures, and are versed in emergency rescue procedures.

Recommendation #3 : A procedure which makes metal flow back lines mandatory is needed. This would eliminate the need for entry into the fracturing tanks to either secure or disconnect Kelly hoses. Bars welded across the top opening to the tank would eliminate unauthorized entry into the field. When entry to the tank is authorized, both clean-out panels on the bottom of the tank should be opened. This gives two emergency entries/exits. If safe entry dictates the need for a top opening, the welded bars could be removed.

FACE 85-40: City Water Worker Dies When Overcome by Natural Gas Vapors in a Confined Space in Ohio

INTRODUCTION

On July 1, 1985, an industrial meter reader employed by a mid-sized city in Ohio began his workday as usual at 7:30 a.m. He did not return to the garage at quitting time (4:00 p.m.) and was found face down in a meter vault at 6:45 p.m.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

This city has a population of 235,000 and employs approximately 2,500 permanent and temporary workers. There are six major departments, one of which is the Department of Public Service. The Department of Public Service has several bureaus, including the Public Utilities Bureau. The Public Utilities Bureau has four divisions: Utility Services, Water Supply, Water Pollution Control, and Water Distribution. The victim was employed by the Water Distribution Division. This division employs 145 full-time and up to 25 seasonal workers. There are six industrial meter readers, two of which are assigned to reading meters at any one time. (Meter readers work individually.)

A deputy to the mayor is the designated safety officer and 90 percent of his time is spent handling labor relations and the remainder of his time is spent dealing with safety-related issues.

SYNOPSIS OF EVENTS

On July 1, 1985, route assignments were received by the meter readers at 7:30 a.m. The victim (a 42-year-old meter reader) was assigned 76 accounts to be read that day. The victim had traded the original route assigned for a route with which he was unfamiliar. Industrial meters may be located in basements, at ground level, or in meter vaults and any one route may include all of these meter locations. The victim did not return to the garage at the usual quitting time of 4 p.m. This is not unusual because workers are occasionally late. At 5 p.m. when the victim still had not returned and he did not respond to dispatch calls, the police were notified. At 6:45 p.m. a passerby reported that the meter reader was down in a manhole and a fire rescue unit was dispatched to the accident site. The victim was found face down in the vault. The vault had approximately 4 1/2 inches of water in it. Resuscitation efforts were unsuccessful and the victim was pronounced dead at 9:31 p.m.

The victim had read 33 out of the 76 assigned meters when he reached the accident site. His supervisor felt that this should have taken until approximately 1:30 p.m. The victim was familiar with this vault, having seen it at the time of installation; however, this was the first reading of this newly installed meter. The vault was installed in May 1985 and was inspected for compliance with city regulations at that time. During this inspection, it was noted that the manhole cover did not have holes required for sufficient ventilation. The manhole cover was to be checked for compliance at this meter reading. No holes were present in the cover. According to the employee's supervisor, the victim may have had difficulty in removing the cover because the hook used to pull the lid open was straightened out and a sledge hammer was lying next to the manhole.

The vault (a two-piece, precast concrete structure — 15 feet by 9 feet by 8 feet) contains large water lines and an industrial water meter. No other utility services use this vault. An investigation of the vault was undertaken by the local coroner's office. The investigation revealed a faint odor of natural gas. The local gas company was notified about a possible leak. It was later determined that a leak was present in a nearby line and the gas was then turned off. After the vault was determined safe for entry, the interior of the vault was inspected; however, no signs were present that indicated that the victim may have slipped or fallen. Since natural gas was suspected in this accident, the vault was further tested. On July 3, 1985, the gas line was turned on and the vault sealed. The atmosphere in the vault was periodically tested. It was eventually determined that oxygen (17 percent), methane (15 percent), and carbon monoxide (>600 parts per million) were present. On July 10, 1985, the gas line was excavated by hand. A leak was found at a coupling approximately 34 inches from the vault.

CAUSE OF DEATH

According to the coroner/pathologist, the cause of death was cardiovascular collapse due to the acute myocardial ischemia due to inhalation of toxic fumes: "methane and carbon monoxide."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The city should develop and implement a comprehensive safety program. The Division of Water Distribution should have a documented safety program that identifies safe work practices to be followed. This program should include recognition of potential hazards.

Discussion: The city has no safety program and no written safety policy exists. Additionally, the Division of Water Distribution does not have a written safety policy or manual. Safety training is the responsibility of supervisory personnel and is limited to on-the-job training. The Division of Water Distribution is in the process of starting a new safety program for all employees consisting of four hours of initial training and a monthly, one-hour follow-up. This course needs to be supplemented by a written safety manual.

Recommendation #2: The employer should develop comprehensive policies and procedures for confined space entry.

Discussion: All employees of the city who work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed, prior to entering a confined space. These procedures should minimally include:

1. Air quality testing to assure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants.

2. Employee and supervisory training in the selection and usage of respiratory equipment.

3. Development of site-specific working procedures and emergency access and egress plans.

4. Emergency rescue training.

Air quality was not tested prior to entry into the vault. Although oxygen/air quality monitoring devices are now provided for meter readers, training is necessary in proper usage and calibration of these devices. Respirators are now available for emergency use. Respirator training, fitting, and proper maintenance procedures should be completed by all personnel who may be required to use a respirator on the job. Medical evaluations of employees should be conducted to determine if they are physically able to perform the work while using a respirator. Immediate response to an emergency situation could prevent such fatalities. A full-time dispatcher is employed by the division. It would benefit the city to incorporate routine call-in procedures (indicating location, entrance time, and exit time) before confined space entry. (The employer should make full use of the resources they have available.) Guidance concerning proper procedures for confined space entry are discussed in DHEW NIOSH Publication No. 80-106, Working in Confined Spaces.

Recommendation #3: Vault manhole covers should have holes for ventilation.

Discussion: The Division of Water Distribution requires that manhole covers have holes for ventilation. The manhole cover at this accident site did not have the required holes. Although re-inspection was to take place at the time of this meter reading, this vault should not have passed inspection when initially installed and the victim should have been instructed not to enter the vault unless the proper manhole cover was in place.

Recommendation #4: Employers should assign employees tasks that are commensurate with their physical capabilities.

Discussion: The job of reading meters can involve strenuous physical activity. The victim had a history of medical problems. This medical history apparently was not taken into consideration when the victim was initially hired as a meter reader.

FACE 86-13: Worker Dies in Fermentation Tank in Montana

INTRODUCTION

On January 29, 1986, a 35-year-old worker was hosing down the interior (from the outside top opening) of a fermentation tank when the accident occurred. For some unknown reason, the worker entered the tank and was confronted with an atmosphere of 6 percent oxygen (O_2) and 48 percent carbon dioxide (CO_2).

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim worked for an alcohol and feed mash producing operation which employs nine workers (including the plant manager). The plant contains 30 stainless steel fermentation tanks, 84 inches in diameter by 88 inches high, which hold approximately 1,200 gallons each. The fermentation process is cyclic so when some tanks are coming down, others are starting up. The victim had been on the job for approximately 3 weeks, and had received on-the-job training only. On-the-job training primarily focused on plant operation with very little emphasis on safety. The only training received regarding confined spaces was a warning not to enter the tanks because of the CO_2 hazard. All on-the-job training is taken from the plant operations manual, with extremely basic safety recommendations. The plant has no written safety policies or confined space entry procedures with the exception of the plant operations manual.

SYNOPSIS OF EVENTS

The plant operates on two 12-hour shifts, with 4 days on and 3 days off. The late shift consists of two workmen, of whom one is the team leader or shift foreman. After a fermentation cycle is completed the tank is drained and pumped into the separator. At this time it is necessary to hose down the interior of the tank to remove the slurry that adheres to the sides. The workman usually lies down on top of the tank and sprays water through the 18-inch diameter opening located at the center of the tank.

The incident occurred at approximately 9 p.m. on January 29, 1986, after the foreman told the victim to hose down the interior of one of the fermentation tanks that was being drained. It is believed the workman's hat fell into the tank and he was attempting to retrieve it when the fatal incident occurred. The tank agitator had been turned off, which meant the victim had gone over to the control room to turn off the motor before attempting to remove his hat. It is believed the victim leaned in through the top opening, head first, and slipped/fell through the opening and struck his head on one of the agitator blades located at the bottom of the tank. (The coroner's report listed a semi-circular cut above the right eye.) The tank had approximately 12 to 18 inches of fermented slurry in the bottom. The foreman came out of the dehydration (final distillation) room and heard a thumping/thrashing noise in one of the tanks. He checked and found the victim trying to get out of the tank. Unable to reach the victim, he secured a rope and looped it around the victim's arm; however, he was still unable to pull the victim out of the tank. The foreman then called the plant owner and rescue squad. It was approximately 2 hours from the time the victim was discovered until his removal from the tank. The victim was dead when removed.

The atmosphere in the tank was tested by the OSHA Compliance Officer and revealed the atmosphere was 48 percent CO_2 and the O_2 level was displaced to 6 percent.

A by-product of fermentation is CO_2, a simple asphyxiant, which will displace 0_2 in a confined space. This is known by the plant owner and plant manager and is stressed to all employees. The plant owner stated "entry into a tank is forbidden without the approval of the plant manager or plant owner." The owner also stated if the victim had been trying to retrieve his hat from the tank, a nearby pole could have been used.

It should be noted the plant owner has installed a steel bar across the top opening of every tank so entry is impossible without unbolting this bar. Also, the owner has ordered atmospheric test equipment to test the O_2 and CO_2 levels in the tank before any entry is made. It also should be noted the shift foreman who attempted to pull the victim out of the tank did not enter the tank, which is an all too common response to a man-down in a confined space which frequently results in a double fatality.

CAUSE OF DEATH

The coroner's report listed the cause of death as "asphyxia due to the exclusion of oxygen by carbon dioxide."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: In addition to the operations manual and its limited safety sections, a comprehensive safety program should be developed. As part of this written safety program, the employer should develop procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should include, but not be limited to:

1. Air quality testing to determine adequate O_2 supply and level of CO_2.
2. Ventilation of the space to remove air contaminants.
3. Monitoring of the space to determine a safe oxygen level is maintained.
4. Lockout/tagout procedures to control hazardous energy, i.e., agitator blades.
5. Employee and supervisory training in confined space entry, testing, and use of personal protective equipment (respirators, clothing, etc.).
6. Emergency rescue procedures.

Air quality (O_2 level and CO_2 level) was not tested prior to this unauthorized entry. O_2 and CO_2 testing devices have been ordered for testing the atmosphere. Training on correct use of these devices, plus calibration of each should be stressed. Respirator training, fitting, and proper maintenance procedures should be required of all plant employees.

The plant manager and owner were provided the following:

- NIOSH Document Criteria for a Recommended Standard, Working in Confined Spaces. DHEW, NIOSH Publication No. 80-106.
- NIOSH Alert on Confined Spaces. DHHS Publication No. 86-110.
- NIOSH Recommended Guidelines - Controlling Hazardous Energy During Maintenance and Servicing. DHHS Publication No. 83-125.

FACE 87-27: Truck Driver Dies While Cleaning Out Inside of Tanker in South Carolina

INTRODUCTION

On August 20, 1986, a truck driver (the victim) for a liquid chemical transport company entered a 6,500-gallon cargo tank mounted on an 18 wheel tractor/trailer to wash out the inside. Within a minute the victim was observed lying unconscious inside the tank. The victim was removed from the tank by the local fire department rescue squad and rushed to a nearby hospital where he was pronounced dead on arrival.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a liquid chemical transport company that has approximately 735 employees, consisting mainly of truck drivers and truck service personnel. The company has a main corporate office with numerous trucking terminals distributed throughout the eastern United States. The company has a written safety program. There is a safety officer and five other employees with full-time safety and training responsibilities. A safety committee (management personnel, the safety officer, and employees representing all job responsibilities within the company) meets quarterly and safety meetings are conducted monthly at the various trucking terminals. These monthly safety meetings are used to discuss problems encountered on the job and to reinforce the existing safety program. There is a written safety policy that emphasizes driver safety training and includes some general safety procedures for truck drivers and truck service personnel. New employees receive job-specific training on the job from supervisors and co-workers and complete a three-day job training and safety orientation consisting of formal instruction from professional safety personnel. Truck drivers are also trained on the job by personnel from a chemical manufacturing company concerning loading, handling, transport, and delivery of the chemicals that are hauled by the chemical transport company. General safety rules and a truck driving safety manual are handed out to new drivers. Written confined space policies and procedures were developed and distributed to all truck drivers and truck service personnel after the accident. A signed statement indicating that the employee has read, understands, and agrees to follow safety rules and confined space entry procedures is kept on file by the employer.

[Note: The field evaluation of this incident was delayed for approximately 7 months. During this delay many areas of the safety program were developed or refined.]

SYNOPSIS OF EVENTS

On August 20, 1986, a truck driver (the victim) for a chemical transport company delivered approximately 4,000 gallons of sodium hydrosulfite to a customer. The liquid chemical was being hauled in a 6,500-gallon cargo tanker truck and the space above the liquid in the tank had been filled with nitrogen gas to preserve the quality of the product. As the chemical was off-loaded, the tank was filled completely with nitrogen gas in anticipation of returning to the chemical manufacturing plant to pick up another load of sodium hydrosulfite. This was the standard operating procedure at the trucking terminal which routinely hauls this product.

The victim had hauled sodium hydrosulfite with a nitrogen blanket many times during his 18 months of employment with the company; however, this time on his return trip, he was instructed to pick up a load of clay slurry. In order to haul the clay slurry it was necessary to first rinse out the residual sodium hydrosulfite in the tank. Company-owned truck wash terminals are equipped with mechanical wash/rinse nozzle arms that reach inside cargo tanks, and under normal circumstances, company drivers go to these facilities to clean their cargo tanks. Not being near one of these company facilities, the victim stopped at a nearby truck wash facility owned by another company. This facility does not have a mechanical tank washing device. Instead, a truck wash worker was responsible for washing out tanker trailers manually. The truck wash worker had previously entered cargo tanks on a routine basis (approximately five per month). (According to the compliance officer's report, the truck wash worker did not test or ventilate the atmosphere inside the tanks prior to entry and did not wear a respirator or <u>any</u> personal protective equipment.) The victim was informed by the truck wash manager that the person responsible for washing out tanker trailers (the truck wash worker) was not there. The victim responded that he would wash out the cargo tank himself, a task which he had not previously attempted. The victim opened a four inch drain valve on the back of the cargo tank, then opened the hatch (20 inches in diameter) on top of the tank, and climbed down inside the tank with a hand spray gun attached to the end of a rubber hose. Pressing the hand valve on the spray gun activated the release of steam and hot water (with or without detergent) from a steam compressor located at the other end of the hose. Approximately 1 minute after the victim entered the tank, the manager noticed that the steam compressor was not running and became concerned. He called to the victim, but received no response. The manager climbed up on top of the tank, looked inside the tank through the top hatch, and noticed the victim lying unconscious at the bottom. The manager attempted to climb down into the tank to rescue the victim, but was too large to fit through the 20-inch diameter tank hatch opening. The manager called the local emergency medical service (EMS) and then the victim's supervisor at the trucking terminal office. (The victim's supervisor told the manager that he should remove the victim from the tank immediately and not wait for the EMS to arrive.) The local EMS and fire department rescue squad arrived on the scene approximately 20 minutes after being notified. Fire department personnel donned self-contained-breathing apparatus, entered the cargo tank through the top hatch, and removed the victim from the tank by a rope around his chest. EMS personnel began cardiopulmonary resuscitation (CPR) at the accident site. The victim was rushed to the nearest hospital where he arrived approximately 1 hour after the accident occurred and was pronounced dead by the attending physician.

CAUSE OF DEATH

The autopsy report lists the cause of death as anoxia due to containment in a nitrogen rich atmosphere.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should initiate comprehensive policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. Although the employer did develop written policies and procedures for confined space entry some time after this accident, they should be expanded to include all required aspects of a confined space entry program. These procedures should minimally include the following:

1. Posting of all confined spaces.

2. Air quality testing to determine adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants.

3. Monitoring to determine a safe oxygen level is maintained inside the confined space.

4. Employee and supervisory training in confined space entry.

5. Employee and supervisory training in the selection and usage of respiratory protection.

6. Emergency rescue procedures.

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

Newly written confined space procedures of the employer do address items #2, #6, and #7 above; however, ventilation procedures are not adequately addressed in item #2 and the other requirements listed above (#1, #3, #4, and #5) are not addressed at all.

Recommendation #2: Employers should insure that employees are properly trained in hazard recognition and safety awareness for all potentially hazardous tasks they are assigned.

Discussion: Although the chemical transport company now has a written safety policy and some safety training, it appears that the victim and his supervisor (and although not employees of the transport company, the truck wash manager and the employee responsible for washing out cargo tanks as well) were not aware of the hazards associated with entry into a confined space with a nitrogen rich atmosphere. When confronted with such potentially hazardous on-the-job tasks, employees should be able to recognize these hazards and take appropriate preventive and corrective actions. The victim's supervisor and the truck wash manager were also not aware of appropriate emergency rescue procedures. The only factor that prevented this accident from resulting in a second fatality was the physical size of the truck wash manager, since the victim's supervisor instructed the truck wash manager to remove the downed employee. If the manager had been able to enter the confined space, without following proper rescue procedures, he probably would have died also.

FACE 88-20: Steelworker Dies in Oxygen-Deficient Confined Space

INTRODUCTION

On March 21, 1988, the 36-year-old male general supervisor for the midnight shift at a steel mill died when he entered the oxygen-deficient service area beneath a 75-ton-capacity, turret-mounted, molten-steel ladle.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was employed by a privately owned steel mill that has been in operation for 19 years. At the time of the incident, the mill employed 700 workers. The mill has a designated manager of safety and health and a comprehensive safety training program. The turret-mounted ladle involved in the incident had been placed into service in February 1988. Confined space entry procedures for the turret service area were being developed at the time of the incident and have since been implemented. All workers at the mill have now been trained in confined space entry procedures. Mill policy at the time of the incident prohibited access to the turret service area to all personnel except workers in the maintenance department who had been trained in confined space entry procedures. During steelmaking operations, no one was allowed in the turret area.

SYNOPSIS OF EVENTS

The mill uses two 75-ton electric arc furnaces to blend components into molten steel. During the process, the molten steel is transferred to and from a turret-mounted ladle that travels between the two furnaces. Electrodes in the ladle maintain the temperature of the molten steel during the refining process until any required alloys are added. Argon is piped into the ladle to create turbulence to mix the alloys. An enclosed, 8-foot-high by 14-foot-diameter dome shaped service area, located beneath the turret, houses the gears and motor that drive the turret. The argon is piped through this service area into the ladle. The service area is accessed by any one of three, 24-inch by 36-inch service doors located on one side of the service area.

On March 21, 1988, the victim and his crew worked the 11 p.m. to 7 a.m. shift. They were scheduled to work 2 overtime hours (from 7 a.m. to 9 a.m.) to prepare the plant for a tour of 500 international steelmakers. During the regular shift, one of the crew members informed the victim that a gauge indicated an abnormal consumption of argon. The victim acknowledged this fact, but made no mention of searching for the leak. At 9 a.m. the crew was relieved. Later, one member stated that he had seen the victim in the locker room and presumed he was leaving the plant. At approximately 11 a.m., the victim's wife contacted the mill concerning her husband's whereabouts and was told he had left the mill. Shortly after lunch a worker noticed the victim's truck still in the parking lot. A search was initiated and the victim was found in the service area. Fire department personnel were summoned, and removed the victim from the service area at 1:15 p.m. He was pronounced dead at the scene by the coroner.

The victim did not alert anyone that he was going to enter the service area. Although no one saw the victim enter the service area, it was assumed that he attempted to locate the argon leak in the piping after he and his crew were relieved, entered the oxygen-deficient atmosphere of the service area, and lost consciousness.

During the installation of the turret in January 1988, the victim and two members of his crew entered the service area, lost consciousness, and were rescued. As a result of the January incident, the employer established the policy that only maintenance workers trained in confined space entry procedures were to enter the service area. Since the fatal incident, the piping for the argon has been routed outside the service area and all workers have been trained in confined space entry procedures.

CAUSE OF DEATH

The coroner listed the cause of death as anoxia due to a presumed excessive argon gas exposure in a confined space.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should ensure that restricted areas can be accessed only by authorized personnel.

Discussion: Mill policy allowed only plant maintenance personnel, trained in confined space entry procedures, to enter the turret service area. The victim apparently made a conscientious effort to guarantee proper mill operations for the tour of international steelmakers by entering the service area to locate and correct the argon leak.

The victim knew and understood mill policy. Additionally, he had been exposed to and overcome by argon less than two months prior to his fatal exposure. In this instance, knowledge of the existence of a hazard was not a strong enough deterrent. To ensure that unauthorized personnel do not enter restricted areas, all entrances to such areas should be locked. Only authorized persons should be provided with the means to enter.

FACE 89-44: Two Farm Laborers Die in Oxygen-Deficient Manure Pit

INTRODUCTION

On June 26, 1989, a 31-year-old male dairy farm laborer entered a manure pit to clear a pipe, lost consciousness, and collapsed at the bottom. In a rescue attempt, his 33-year-old brother, also a farm laborer, entered the pit, lost consciousness, and collapsed. Both workers (hereinafter referred to as initial victim and rescuer victim) were pronounced dead at the scene.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is a family-owned farm operated by the father and five sons. The farm consists of a 60-cow dairy herd with 80 acres of wheat, corn, hay, and pasture. The two victims, who had both worked on the farm since the age of 12, were in charge of the dairy operation. The family has owned the farm for 42 years and maintained a dairy herd for the past 28 years. Discussions with the farm owner indicated that the family members were aware of some of the hazards associated with tractors and other machinery, and oxygen-limiting silos. This hazard awareness was mostly due to farm machine manufacturer information.

SYNOPSIS OF EVENTS

The dairy operation has a barn with 60 stalls where the cows are milked twice a day. The barn has a built-in manure removal system consisting of a 2-foot-wide, 1-foot-deep trough (recessed into the concrete floor), which runs the length of the barn under each stall. Inside the trough is an electric-powered, chain-driven paddle conveyer which is turned on once a day to remove the manure. The conveyor discharges the waste into an underground open-top concrete pit adjoining the end of the barn. The 12-foot-square pit is 4 1/2 feet deep. The pit is housed in a small insulated, unventilated room to protect it from freezing. Animal waste at the bottom of the pit is pulled into a 6-inch-diameter steel pipe by a pump powered by a 25-horsepower electric motor mounted 6 inches above the top of the pit. A grinder inside the pipe/pump apparatus breaks up large solids. From here the waste pipe runs underground to a 200,000-gallon, open-top waste storage tank 10 feet away from the barn. The waste pump, grinder and storage tank had been installed 10 years before the incident. During this time, the piping, pump, and grinder inside the pit had corroded. The pipe developed several holes as a result of corrosion. Straw and other solid material moving through the pipe would often lodge in these holes causing blockages. In order to clear such blockages the victims would routinely enter the pit (without first testing the atmosphere and ventilating), disconnect the pipe at a joint, and manually clear the pipe.

On the day of the incident, the two victims went to the barn to milk the cows. Although the incident was not witnessed, evidence suggests the following sequence of events.

When the victims arrived at the barn, the pit contained about 3 feet of waste. The victims turned on the waste pump, but it did not remove any of the waste. Realizing that the suction line inside the pit was blocked, they decided to enter the pit to clear it. The initial victim put on rubber chest waders, entered the pit with a pipe wrench, disconnected the end pipe section and manually removed the blockage. The rescuer victim stood on the edge of the pit providing assistance to the initial victim as he worked in the pit. The victim soon collapsed inside the pit due to the lack of oxygen. [It is presumed that a high concentration of gases (hydrogen sulfide, carbon dioxide, methane, etc.) produced by the decomposition of the waste material, displaced the oxygen in the air inside the waste pit.] In a rescue attempt, the rescuer victim entered the pit and collapsed on top of the initial victim.

When the victims failed to return to their homes 4 hours after they were last seen, other family members began a search for them. An hour later they found the victims submerged in the waste pit. The local volunteer fire department and the emergency medical service (EMS) were notified by family members and arrived at the scene in 10 minutes. Fire fighters put on self-contained breathing apparatus (SCBA), entered the waste pit, and removed the victims.

Efforts to resuscitate the victims were unsuccessful and they were pronounced dead at the scene by the county coroner.

CAUSE OF DEATH

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

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Farm owners should become familiar with the hazards of confined spaces and adopt safe procedures specific for each type of confined space.

Discussion: Manure waste pits, by their design, meet the NIOSH criteria for the definition of a confined space. Entrance into these pits should be governed by NIOSH guidelines for working in confined spaces (NIOSH Publication 80-106). The following items have been outlined in NIOSH Publication 87-113, "A Guide to Safety in Confined Spaces." Not all of these issues can be addressed practically on a family farm. However, they do provide some guidance to farm owners who are adopting their own safe work practices for work in confined spaces.

1. Is entry necessary? Can the assigned task be completed from the outside (such as clearing the blockage through a clean-out pipe outside the pit)? Components of manure waste pits should be designed and installed in a manner that would allow maintenance to be performed on all serviceable parts from outside the pits.

2. Are confined spaces posted with warning signs and are confined space procedures posted where they will be noticed by workers?

3. Are confined spaces tested before entry and continuously monitored while work is being performed, especially when agitation of manure has not occurred recently, thus allowing the buildup of fermentation gases?

4. Is ventilation equipment of explosion-proof design (or silo fans that can be positioned outside of the building that houses the manure pit) available and used before and during entry?

5. Do workers know how and when to use the following:

    - Protective clothing
    - Respiratory protection
    - Hard hats
    - Eye protection
    - Gloves
    - Lifelines
    - Emergency rescue equipment?

6. Can workers recognize confined spaces (pits, tanks, silos, grain bins, etc.) and are they aware of their hazards?

7. Are confined space safe work practices discussed before attempting entry?

8. Is there a confined space safe rescue plan and do workers know how to safely respond in an emergency?

Recommendation #2: Manure pumping equipment should be constructed of materials that are corrosion resistant.

Discussion: Manufacturers of manure pumping equipment should be encouraged to use corrosion-resistant materials such as heavy plastic or stainless steel in pump parts. In this incident the high acid level of the animal waste severely corroded the pump parts. Since its installation 10 years before this incident, the waste pump and piping, which were constructed of steel and cast iron, had been repaired many times due to corrosion. This required workers to enter the pit frequently to clear blocked pipes and to perform pump maintenance. Pump parts constructed of a corrosion-resistant material would require less frequent entry for maintenance.

Recommendation #3: Farm owners and workers need task-specific worker safety guides through improved dissemination efforts.

Discussion: The farm owners in this incident received little if any useful farm safety literature on the operation and maintenance of farm machinery, and no information on the hazards of farm-related confined spaces. Worker safety guides specific to each type of farm machine and confined space should be developed. Dissemination of this material through agricultural extension agents, farm bureaus, and other agricultural associations should be improved. In this way farm workers and owners will receive useful information that will heighten their awareness of farm machine and confined space hazards.

FACE 89-46: Five Family Members Die After Entering Manure Waste Pit on Dairy Farm

INTRODUCTION

On July 26, 1989, a 65-year-old male dairy farmer, his two sons (37 years old and 28 years old, respectively) a 15-year-old grandson, and a 62-year-old nephew died when they entered a manure waste pit with an oxygen-deficient atmosphere.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The farmer owned and operated a dairy farm with his family. The nephew owned and operated a welding repair shop but was at the farm on the day of the incident. The 1,800-acre farm, 800 acres of which is leased for pasture for their 800 head of cattle, has been in the family for 100 years.

The farm has no written safety policy or safety program. Grain silos located on the farm are recognized as potential confined space hazards and are equipped with exhaust fans. The manure pit, which was installed 18 years ago, was not regarded as a confined space hazard. Many times in the past, workers had entered the manure pit to perform maintenance operations without incident.

SYNOPSIS OF EVENTS

The cattle-holding barn at the farm is equipped with a conveyor system to remove the manure. The system runs throughout the barn and conveys the manure to a waste-holding pit which is 24 feet long by 20 feet wide by 10 feet 8 inches deep. The pit is accessed by a 4-foot-square opening located inside a 17-foot by 35-foot service shed attached to the holding barn. A second entrance in the concrete top of the pit is located outside the barn. This entrance measures 3 feet 6 inches by 6 feet and is usually covered by a sheet of plywood. When the pit becomes full, the waste is pumped into a holding pond outside the barn. This slurry system is powered by a 20-horsepower pump located at floor level at the entrance of the pit. The pit contains an agitator to break up large clumps of manure so that it can be pumped out. Although the agitator shaft extends from above floor level down into the pit, the shear pin for the agitator shaft is located approximately 1 foot below floor level inside the pit. The pit had been entered in the past whenever this shear pin needed to be replaced. A 12-foot wooden ladder was used by workers to descend into the pit.

On the day of the incident, it is believed that the farmer's 28-year-old son entered the pit to replace the shear pin on the agitator shaft. One farmhand interviewed stated that the pump had not been operating for several days before the incident. The farmer's 15-year-old grandson was with his uncle. The grandson's 8-year-old brother was outside the barn door. The 8-year-old heard his brother yell for him to get help because their uncle had fallen into the pit. The 8-year-old ran to the farmhouse for help. While the farmer's 37-year-old son and nephew ran to the pit, the wife of the first victim called the fire department, the sheriff's department, and the owner of a farm equipment business located a mile from the farm. The owner of the farm equipment business stated that the call was received at 9 a.m., and that he and two of his workers left immediately for the farm. Apparently, the 15-year-old grandson, the farmer, his 37-year-old son, and his nephew all entered the pit to attempt rescue. A carpet installer working at the farmhouse went to the pit and saw all five men unconscious inside the pit. He entered the pit and was overcome, but did not lose consciousness. He was assisted from the pit by his helper. The farm equipment business owner instructed one of his workers to get a rope from their truck. His worker returned with a rope which had a hook on one end. The worker held his breath, entered the pit, and looped the rope around the waist of one of the victims and hooked it. After the worker exited the pit, he, his co-worker, and their boss lifted the victim out of the pit. All five victims were removed in this manner. The younger son was removed first, then the farmer, the nephew, the elder son, and the grandson. The business owner stated that the last victim was removed from the pit at 9:20 a.m. By this time, EMS personnel had arrived at the scene and begun to administer cardiopulmonary resuscitation along with fire department personnel. The nephew was pronounced dead at the scene by EMS personnel. Four victims were transported to the emergency room. The farmer and the younger son were pronounced dead upon arrival. Although the elder son and grandson were breathing, the elder son died 1 hour later in the emergency room. The grandson was transferred by helicopter to a major trauma center and was pronounced dead upon arrival 6 hours after being removed from the pit.

Gas readings taken the day after the incident by the State Department of Labor investigator showed a methane level of 2 percent and a hydrogen sulfide (H_2S) reading of 18 ppm. This H_2S reading is well below the NIOSH Immediately Dangerous to Life and Health (IDLH) limit (300 ppm), but exceeds the OSHA Permissible Exposure Limit (PEL) of 10 ppm. Readings taken by the DSR team 12 days after the incident showed a methane level of 3.5 percent, an oxygen level of 20.2 percent, and a hydrogen sulfide level of 7 ppm. It should be noted that the temperature and humidity for the 3 days preceding the incident were in the mid 90^{o} F range and the barometric reading at the time of the incident was 30.17 and there was no wind. These conditions would have been favorable for a buildup of methane and/or hydrogen sulfide inside the tank. A thunderstorm occurred later in the morning of the incident that significantly reduced the temperature. While taking gas readings at the inside entrance to the manure pit during their investigation, the DSR investigators removed the plywood cover on the outside opening. The gas levels (H_2S and methane) dissipated almost immediately. On the day of the DSR investigation, the temperature was 55^{o} F and conditions were windy.

CAUSE OF DEATH

The medical examiners listed the cause of death for all of the victims as asphyxiation due to methane gas exposure.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Manure waste pits should be identified as confined spaces.

Discussion: Manure waste pits, by their design, meet the criteria established by NIOSH to define confined spaces. 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 such pits should be governed by NIOSH guidelines for working in confined spaces (NIOSH Publication No. 80-103). Ideally, a manure pit should be ventilated, and the atmosphere within the pit tested prior to entry and monitored 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 must, at a minimum be made aware of potential hazards associated with manure waste pits, such as oxygen-deficient or toxic atmospheres. NIOSH is preparing an alert detailing the hazards associated with manure waste pits. 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: Manure waste systems should be constructed in a manner that would allow maintenance to be performed on all serviceable components from outside the pits.

Discussion: Components of manure waste systems should be installed in a manner that allows maintenance to be performed from outside the pits, or provide for the easy retraction of serviceable parts for maintenance. Typically, these waste systems are not purchased as a single unit; however, it may be possible to install waste pit components that would eliminate the need to enter the pits to perform maintenance. Had the shear pin for the agitator shaft been located outside the pit, it is likely that this tragedy would have been prevented.

Recommendation #3: Manure waste systems should be equipped with some type of powered ventilation system.

Discussion: Waste systems should be equipped with some type of powered ventilation system. Ideally, these 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. The system might be composed of portable fans, but must be of sufficient size to ensure constant circulation of fresh air throughout the waste system, and be of explosion-proof design.

Recommendation #4: Manure waste systems should never be entered unless absolutely necessary.

Discussion: Because dangerous gases may be present, a waste system pit should never be entered unless absolutely necessary. If entrance into the pit is necessary, a standby person(s) with the capability to remove the person from the pit, if necessary, must be stationed outside the pit and must maintain visual or vocal contact with the person in the pit. If the standby person(s) is not physically capable of removing the person from the pit, 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 must wear a safety belt or harness and have a lifeline attached to a substantial anchor point 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 resolved before entry. Should an emergency develop, a short delay caused by lack of preparation could be fatal.

Recommendation #5: Entrances to waste pits should be covered by a grate-like cover.

Discussion: All entrances to waste pits should be covered with a properly secured grate-like cover to prevent someone from accidentally falling into the pit and to aid ventilation.

Recommendation #6: Farm employees must be instructed 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 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 or victims in the pit to be overcome will have the same effect on any would-be rescuer, and the rescuer 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 rescue squad. These squads will have the training and equipment needed to accomplish a rescue without further endangerment of life.

Recommendation #7: Manufacturers of equipment designed for manure waste pit systems should include warnings on the hazards associated with these systems.

Discussion: Manufacturers of equipment designed for animal waste pit systems should include information concerning the hazards of these pits to all purchasers of their equipment, and should provide information (diagrams, etc.,) on how to install their equipment so that it can be serviced without requiring workers to enter the pit.

FACE 91-14: Furnace Operator Dies After Being Overcome by Argon Gas in Pressure Vessel in South Carolina

SUMMARY

A 43-year-old male furnace operator (victim) died after being overcome by argon gas in a 7.5-foot deep pressure vessel with a 24-inch inside diameter. The victim was summoned by the vessel tender to enter the vessel to retrieve three tungsten carbide steel objects that had dropped into the vessel during the unloading process. The victim was lowered into the vessel by holding onto the hook of the overhead crane used to unload the vessel. The victim retrieved one object and handed it out to the tender. The victim then squatted down to reach under the vessel's internal heating element to retrieve the second object and was overcome by argon gas that was present at the bottom of the vessel. NIOSH investigators concluded that, to prevent future similar occurrences, employers should:

- *develop and implement a confined space safety program*
- *alert workers of all hazards that might be encountered during the performance of their duties*
- *continually stress the importance of adherence to established standard operating procedures*
- *develop an extraction tool that would eliminate the need to enter a confined space (pressure vessel)*
- *evaluate the design of the pressure vessel to determine if it could be modified to allow for the extraction of objects from outside the vessel.*

INTRODUCTION

On May 9, 1991, a 43-year-old furnace operator died after being overcome by argon gas in a 7.5-foot deep pressure vessel. On May 13, 1991, officials of the South Carolina Occupational Safety and Health Administration notified the Division of Safety Research (DSR) of the death, and requested technical assistance. On May 30, 1991, two DSR safety and health specialists and a safety engineer traveled to the incident site to conduct an investigation. The incident was reviewed with employer representatives, the county sheriff's office, and the county coroner. Photographs of the incident site were taken.

The employer in this incident is a tungsten carbide steel fabrication plant that has been in operation for 41 years and employs 150 workers, including 9 furnace operators. The plant engineer manages the safety program on a collateral duty basis. There are no written safety rules or safety policy. The workers are provided with classroom, manual, and on-the-job safety training. Workers seen committing unsafe acts are disciplined with 3-days suspensions for the first offense and dismissal for the second offense. The victim worked for this employer for 2.3 years prior to this incident.

INVESTIGATION

The employer fabricates more than 20,000 tungsten carbide items. Two production shifts are run at the facility from 5:30 a.m. until 2 p.m. and from 3:30 p.m. until midnight. The fabricated items are placed on three sections of stacked trays and lowered into a pressure vessel (installed in 1975) using an overhead crane. A cylindrical stainless steel insulating hood is placed over the trays. The insulating hood is 24 inches in diameter and 7.5 feet high and serves as the inner liner of the vessel. The vessel is 7.5 feet deep. It has an inner diameter of 24 inches and an outer diameter of 42 inches. A 9-inch water cooling jacket surrounds the inner wall. Argon gas is piped into the vessel to pressurize it at 15,000 psi and the vessel is heated to a temperature of 1,500 degrees centigrade by an internal heating element. Four and a half hours are required for the vessel to reach peak temperature and pressure. This peak is held for 1 1/2 hours, then the vessel cools for 5 hours. This process assures the quality of the tungsten carbide product. The tender on the following shift reclaims the argon gas to de-pressurize the vessel. The hydraulically sealed lid is removed and the insulating hood and three sections of stacked trays are lifted out of the vessel by the overhead crane. Any argon gas remaining in the vessel is allowed to naturally escape into the atmosphere. The vessel is surrounded by a service pit that is equipped with an oxygen monitoring device. This device does not monitor the oxygen inside the vessel.

The vessel had been shut down and the argon gas had been reclaimed at 11 p.m. the night before the incident; however, the vessel lid had not been removed. When the vessel tender began his shift at 5:30 a.m., he removed the lid and insulating hood then began to remove the three sections of stacked trays. At some point during this removal process, three objects (2 inches in diameter and 3 inches long) fell from the trays into the vessel. The tender called the maintenance foreman to see if it was possible to reload the vessel and continue the operation with the fallen objects still inside. The tender was instructed by the maintenance foreman that if the objects did not interfere with the placement of the insulating hood that the operation could continue. The tender determined that the objects would have to be removed since at least one of the objects would interfere with the placement of the insulating hood.

The tender tried for 15 minutes to remove the objects with a thong-like extraction tool, but was unsuccessful. The tender did not contact the maintenance department, though maintenance was responsible for removing objects from the vessel and had established procedures for this task. Instead, the tender summoned the victim from another area of the facility, to enter the vessel and retrieve the objects, possibly because of the size of the victim. The victim was 5 feet, 6 inches tall and weighed 120 pounds.

The victim arrived at the scene and tried unsuccessfully to remove the objects with the extraction tool. When it was determined that entry would be necessary for the retrieval of the objects, the tender lowered the victim into the vessel using the overhead crane. The victim held on to the crane hook to be lowered into the vessel. He was not tied off to the crane hook. The victim released the crane hook and retrieved one of the objects and handed it out to the tender. As he squatted down to reach under the internal heating element to retrieve the second object, he was overcome by the argon gas that still remained in the bottom of the vessel.

The tender called the plant office, told them to summon the emergency medical squad (EMS) and returned to the vessel with a co-worker. The tender tied himself off to the crane hook and the co-worker lowered him into the vessel. When the co-worker noticed the tender slump over he immediately raised him out of the vessel and laid him on the ground. The tender was unconscious but breathing, and regained consciousness within a minute. When the EMS arrived one of the EMS crew members tied himself off to the hook, held his breath, and was lowered into the vessel where he tied a rope around the victim's chest. The victim was then raised out of the vessel, 35 minutes after he was overcome. EMS personnel immediately initiated CPR. The coroner was summoned, and when he arrived, pronounced the victim dead at the scene.

CAUSE OF DEATH

The coroner attributed the cause of death to an oxygen deficient atmosphere.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop and implement a confined space safety program.

Discussion: The maintenance department had existing procedures for entry into the vessel which included:

1. placing an exhaust fan over the top of the vessel for a period of time

2. flooding the interior of the vessel with compressed air

3. using the overhead crane to lower a man in full body harness into the vessel to retrieve the object.

Although maintenance personnel realized the hazard created by the presence of argon gas in the bottom of the vessel (argon is heavier than air and would accumulate at the bottom of the vessel), it is evident workers in other areas of the plant were unaware of the potential hazard. Employers should ensure that all employees are aware of the potential hazards, possible emergencies, and specific procedures to be followed prior to working in, or around, a confined space. At a minimum, as discussed in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces," the following items should be addressed:

1. testing the air quality to determine adequate oxygen level and the presence of combustible and toxic air contaminants

2. adequate ventilation to remove air contaminants

3. monitoring the space to determine that a safe atmosphere is maintained

4. training the employees in confined space entry, testing, and the use of personal protective equipment, safety harnesses, respirators, clothing, etc.

5. stationing a standby attendant outside the space for communication and visual monitoring

6. emergency rescue procedures

7. identifying and controlling the hazards associated with the confined space involved.

Recommendation #2: Employers should alert all workers of all hazards associated with operations that might be encountered during the performance of their daily duties.

Discussion: Employers should alert all workers within a facility of all hazards associated with the operations within the facility that might be encountered during the performance of their daily duties. The incident site in this instance was not the victim's usual work area. The victim was not familiar with the hazards associated with the argon gas in the pressure vessel. Had he been made aware of the hazards associated with entrance into the vessel, this fatality might have been prevented.

Recommendation #3: Employers should continually stress the importance of adherence to established standard operating procedures.

Discussion: In this instance, standard operating procedures called for the tender to contact the maintenance department to remove the objects from inside the pressure vessel. The maintenance department had established safe work procedures for entry into the pressure vessel that controlled the argon gas hazard. If standard operating procedures had been followed in this instance, the fatality would have been prevented.

Recommendation #4: Employers should develop an extraction tool or system that would eliminate the need for entry into the pressure vessel.

Discussion: The employer should evaluate the design of the extraction tool now being used to remove fallen objects from the pressure vessel. If possible, the tool should be re-tooled to improve its effectiveness. Because 20,000 different items are treated in the pressure vessel, it would be difficult to develop a tool that would be compatible with all items. Possibly, a tool could be developed with interchangeable ends for retrieving items with different sizes and shapes.

Recommendation #5: The employer should evaluate the design of the pressure vessel to determine if it could be modified to allow for the extraction of objects from outside the vessel.

Discussion: The feasibility of incorporating some type of catch basket into the interior design of the insulation hood should be evaluated. If this was possible, the objects could be removed once the insulation hood was removed from the pressure vessel. The employer should also evaluate the design of the trays to determine if they could be modified in such a way that the potential for fallen objects could be eliminated. Possibly, a top and bottom lip could be incorporated into design of the tray or, if possible, and if clearance allowed, a protective sleeve could be placed over the stacked-tray sections to catch any objects dislodged from the trays.

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.

Atmospheric Hazards

Oxygen Deficient Air

FACE 86-37: Workers Die in Underground Valve Pit in Oklahoma

INTRODUCTION

On July 10, 1986, a three-man crew was attempting to shut down a 24-inch water main when the accident occurred. One worker entered the 10-foot-deep valve pit through the 22-inch manhole opening via a built-in steel ladder (steel rungs secured into the concrete wall) and a few minutes later called for help. One of the workers on top went in to assist and was overcome. The third worker started in and realized he would soon be in trouble. He immediately exited and called for help. Both workers died at a local hospital.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a midwest city. The victims worked in the water distribution division of the water and sewer department. The water and sewer department has a total of 736 employees in 9 divisions. Other divisions include: waste water collection, waste treatment, raw water supply, engineering, utilities service, pre-treatment, and sludge removal. The water distribution division has 140 employees that are responsible for maintaining water service for the city (i.e., conduct inspections and make necessary repairs to water lines, add new service, etc.). The water distribution division has a supervisor, crew leaders, and crew workers.

New employees are given a half day orientation which consists of a discussion of benefits and operating policy of the city. When they report to their respective department for work (e.g., the water and sewer department), each new employee is given a small 66-page safety indoctrination. Meetings are held monthly to discuss basic safety issues. On the job safety is the responsibility of each employee. No training is given on confined space entry; however, city policy requires that each confined space be tested prior to entry. The supervisors have necessary testing equipment available to test a confined space atmosphere for oxygen (O_2), hydrogen sulfide (H_2S), and methane (CH_4).

SYNOPSIS OF EVENTS

On July 10, 1986, a work crew for the water distribution division of the water and sewer department was running a water service from one side of the street to the opposite side. The men were boring under the street with an air ram when they hit a 24-inch water line and water started gushing from the bore hole, flooding the street. The crew leader notified the supervisor (by two-way radio in the truck) of the line rupture and the crew was instructed to close valves at three different locations to shut off the water supply to the 24-inch line.

The three men proceeded to the first valve pit (approximately 200 yards away) and closed the gate valve. The men then proceeded to the second valve pit (approximately 2 miles away). A crew worker entered the chamber (6 feet by 8 feet by 10 feet) and after 2 or 3 minutes called for help. The crew leader on the outside went in to assist the downed worker and was overcome. The third worker started in and realized he was in trouble and exited immediately to call for help.

The fire department and rescue squad arrived on the scene within a few minutes and started rescue procedures. Two firemen donned full turnout gear with self-contained breathing apparatus (SCBA) and entered the valve pit to remove the workmen. The firemen had four 30-minute, 2215 PSI, 45 cubic feet cylinders lowered into the pit and discharged them in an attempt to improve the air quality. Both workmen were removed and transported to a local hospital by the EMS where they died a short time later.

After the men were removed from the valve pit, the fire department tested the atmosphere and found:

O_2	17% and 18%
H_2S	Negative
CH_4	Negative
CO	Negative

CAUSE OF DEATH

Asphyxia due to oxygen deficiency.

NOTE: While doing the evaluation of this incident, the safety manager and the NIOSH research industrial hygienist tested two manholes for O_2, H_2S, and CH_4. A manhole approximately 1 mile upstream of the accident site had an O_2 level of 20.0 percent, H_2S and CH_4 were negative. The second manhole tested was approximately 2 miles downstream of the accident site and the O_2 level was 3.0 percent, H_2S and CH_4 were negative. Any workman entering a confined space with a 3% O_2 atmosphere is entering a death chamber. Also, both valve pits checked had stagnant water in the bottom (2 or 3 inches) and the steel valves were rusting.

The valve pit where the accident occurred was at a busy intersection so it was not opened and tested. It should also be noted that this valve pit had not been open in 3 years.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should be certain employees are aware of hazards associated with the tasks they are performing.

Discussion: The victims were aware of the requirements for having the valve pits tested before entry. However, during an emergency situation (shutting down a water main because of a break), the valve pit was not tested for oxygen and safe work practices were not followed. The only consideration was to shut off the water.

Recommendation #2: Employers should provide specific information in their employee safety manuals, especially when tasks to be performed are life threatening.

Discussion: The employees safety manual devotes two pages to confined spaces and includes general recommendations. The safety manual states entry should not be "considered safe until it has been determined to be free of harmful gases and to contain sufficient oxygen to sustain life." Ambiguous phrases such as "determined to be free" and "sufficient oxygen to sustain" should be clarified. Also, who is responsible for testing the atmosphere and making recommendations regarding safe work practices in confined spaces can be found in the NIOSH Publication No. 80-106, "Working In Confined Spaces." A safe oxygen level is stated (19.5%) and flammability limits (not to exceed 10 percent of the lower flammability limit), and toxic air contaminants (not to exceed the limits referenced in 29 CFR Part 1910, Sub Part Z) are specified. Testing shall be done by a qualified person prior to entry. This publication also defines and provides recommendations on hot work, isolation, purging, ventilating, entry and rescue, training, posting, safety equipment, clothing, etc.

FACE 86-48: 28 Year-Old Dies in Rescue Attempt in Drainage Pit in Illinois

INTRODUCTION

On August 17, 1986, the owner of a sewer service company and three workmen were in the process of cleaning out a 12-foot deep drainage pit when the accident occurred. The owner entered the pit and experienced euphoria within a few minutes and became incoherent. Two of the workers attempted rescue and were unsuccessful. One of the rescuers died.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is a one-man sewer cleaning operation with absolutely no safety program. The owner has a pickup truck that he uses to transport a portable electrically powered routing machine that is used to clean out sewer lines. The owner of the company generally works alone; however, when the job requires more than one person, he will pick up temporary, unskilled workers from off the street. The victim had worked on a few small jobs for the employer before this job. No employee training or personal protective equipment was provided or "needed," according to the employer.

SYNOPSIS OF EVENTS

A sewer service company had been contracted to clean out a water run-off drainage pit (12 feet deep and 24 inches in diameter) and to unclog and clean out a drain line to the street. The drainage pit is located outside the delivery door of a metal window framing operation. The operation is basically a dry process; therefore, any drainage to the pit would consist of rain water, leaves, and debris from the roof and parking lot. A drain line from the drainage pit to the street was blocked shut by this debris and resulted in run-off water filling the 12-foot deep pit until it overflowed. The owner of the sewer service had worked on and off for two weeks in an attempt to drain the pit and unclog the drain line. Work was done in the evening or on weekends so that access to the delivery door could be maintained so that the business was not interrupted. On Saturday, August 17, 1986 (the day of the accident), the owner and three workers arrived at the site at approximately 10:30 a.m. This was the first day on this job for the victim and a 22-year-old worker. A fourth worker had worked on several different occasions for the owner. Upon arrival at the site, the owner opened the manhole cover to the drainage pit and went in, shimmying down the concrete block walls. No ladder was provided for entry or exit. A rope tied to a bucket was used to remove liquid and sludge from the pit. The owner in the pit would fill the bucket and one of the workmen would pull it out, dump it, and return the bucket to the pit.

After filling and emptying the bucket approximately 20 times, the owner requested a beer and his cigarettes. He was handed a beer and his cigarettes and work proceeded. Within a few minutes, the owner, still in the pit, became euphoric — singing, praying, and stating, "this stuff is really bad." The 22-year-old noticed the owner was in trouble and decided to enter the drainage pit in a rescue attempt. An electric extension cord was tied around the chest of the 22-year-old worker and he was lowered into the pit. When he reached the bottom he tried to untie the cord but was unable to because he stated his fingers were numb. The victim pulled the 22-year-old out of the drainage pit and went in to assist the downed owner. The victim tried to lift the semi-conscious owner up the shaft, but was overcome and fell down with the owner now on top of him. The fire department was summoned and arrived within 10 minutes. Both workers were removed from the drainage pit. Both men were transported to a local hospital where the rescuer was pronounced dead. The owner was treated and released. The blood alcohol level for the rescuer (victim) was negative; however, the owner (survivor) had levels significantly above the state's legal limit for intoxication.

CAUSE OF DEATH

Asphyxia due to oxygen deficiency.

Investigation Notes:

- Atmospheric tests done by the fire department revealed the O_2 level to be less than 5 percent at the bottom of the pit on the day of the accident.
- During the site visit field evaluators observed that the manhole cover was off the drainage pit and that the 12-foot deep pit was half full of water. Also, an extension cord had been run under the metal delivery door into the pit to supply electricity to a pump. The extension cord was below the water level. FACE field evaluators removed the extension cord from the pit to prevent a possible electrocution. No work was being done on the day of the site visit.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should develop a comprehensive safety program for confined space entry that clearly documents procedures for safe entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should include, but not be limited to:

1. Air quality testing to determine adequate O_2 level.
2. Ventilation of the space to remove air contaminants.
3. Monitoring of the space to determine a safe oxygen level is maintained.
4. Employee training in confined space entry, testing, and use of personal protective equipment.
5. Emergency rescue procedures.

Air quality (O_2 level and CO_2 level) was not tested prior to entry. O_2 and CO_2 testing devices should be ordered and used for testing the atmosphere. Training on correct use of these devices, plus calibration of each should be stressed. Respirator training, fitting, and proper maintenance procedures should be required of all employees.

Recommendation #2: Companies contracting to have a service performed on their property should implement and enforce a safety program to be followed by the contractor.

Discussion: The company that contracts out work to be performed on their property and assumes the contractor is an expert and adheres to safety procedures can be operating on a dubious assumption. Especially when hazardous tasks such as confined space entry are contracted out, outside contractors should be required to comply with a written safety policy that includes safe work procedures, and these requirements should be enforced. For confined space entry, the recommendations in NIOSH Publication No. 80-106, "Working in Confined Spaces" should be used.

FACE 86-54: Insufficient Oxygen Level in Sewer Claims the Life of Plumbing Contractor in Georgia

INTRODUCTION

On September 15, 1986, a plumbing contractor and two co-workers were in the process of laying out a new sewer line for an industrial building under construction when the fatal accident occurred. The owner of the plumbing company entered the manhole opening and descended into a 15-foot deep sewer to measure a stub out location for the new sewer line. Co-workers were unsuccessful at rescue attempts. The owner was removed by the fire rescue squad and pronounced dead on arrival at a local hospital. Atmospheric tests revealed oxygen level at the bottom of the sewer to be 6 percent.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim operated a small plumbing contracting company and employed two other workers. The company did not have a written safety program or confined space entry procedures. At the time of the accident this company was under a subcontract agreement with a larger plumbing and heating contractor (employing 10). This larger contractor did not have confined space entry procedures either.

SYNOPSIS OF EVENTS

On September 15, 1986, the victim and two other workers were planning to install a sewer line from a building to the main sewer line in the street at a construction site. The sewer vault was entered through a manhole in the middle of the street. The manhole was 2 feet in diameter and 15 feet deep. In an effort to measure the length of the sewer line snub, the victim entered the manhole and descended a fixed ladder to the bottom. The sewer line snub extended from the vault, 15 feet towards the construction site. Upon reaching the bottom of the sewer he complained of a strong odor and then passed out. The other two workers that remained outside entered the manhole in an attempt to rescue the victim. However, before they could reach the victim, they both became dizzy and exited the manhole. Several unsuccessful rescue attempts delayed notification of the fire department rescue squad for approximately 20 minutes.

The rescue squad arrived in 5 minutes. Rescue squad personnel entered the sewer using self-contained breathing apparatus, life lines, and other personal protective equipment. The victim was removed approximately 8 minutes after the arrival of the rescue squad. Attempts to resuscitate the victim were unsuccessful. The victim was then transported to the local hospital where he was pronounced dead.

Prior to entry the employer did not test the atmosphere or ventilate the sewer vault. The victim and the workers were not aware that entering the manhole might be hazardous. Prior to entering the manhole, the workers argued over who would go into the manhole. Their concern at that time was the depth of the hole. Additionally, the water company had informed the contractor of the location of the snub line, but the victim wanted to double check the distance. No confined space entry procedures were used by the workers. The atmosphere was tested after the victim was removed and was found to contain 20 percent methane, 6 percent oxygen, and was negative for hydrogen sulfide and carbon dioxide.

CAUSE OF DEATH

Asphyxia due to oxygen deficiency.

RECOMMENDATION/DISCUSSION

Recommendation #1: Employers should be certain employees are aware of the hazards associated with the tasks they are performing. Additionally, employees should be aware of all safety procedures to be followed and the reasons for these procedures.

Discussion: Both the plumbing company and the larger contractor were not aware that a manhole was a confined space and as such was a hazardous place to enter. Neither company had any confined space procedures to follow when entering a manhole.

Recommendation #2: Employers should initiate comprehensive policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. The procedures should minimally include the following:

1. Air quality testing to assure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;

2. Monitoring of the space to determine a safe oxygen level is maintained;

3. Employee and supervisory training in confined space entry;

4. Employee and supervisory training in the selection and usage of respiratory protection;

5. Emergency rescue procedures;

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

The air quality was not determined before the worker entered the manhole and no ventilation was maintained. The air quality was not monitored for toxic air contaminants and oxygen level. Respirator training and proper maintenance procedures should be required of all employees

FACE 87-06: Two Dead, Five Injured in Confined Space Incident in Oregon

INTRODUCTION

On October 10, 1986, a self-employed contractor (specializing in backflow devices) was in the process of inspecting the backflow valve on the city water line at a sawmill when the accident occurred. The contractor descended into the underground vault which housed the water line and backflow device and collapsed. The shipping supervisor of the sawmill attempted to rescue the contractor and collapsed.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The self-employed contractor was a one-man operation that according to the state investigators had no safety program or confined space entry procedures. The contractor was licensed and certified by the state to inspect and approve/certify backflow prevention devices.

The sawmill where the accident occurred cuts large timber into marketable sizes that are shipped around the world. The sawmill cuts approximately 7 million board feet of lumber a month and has 110 employees. The sawmill has a written safety policy and holds monthly meetings to discuss safety issues with the workers and management. A collateral duty safety officer conducts walk-through safety inspections and reports safety problems to the management. The sawmill does not have confined space entry procedures. However, the management stated the manhole where the men died is not entered by mill employees.

SYNOPSIS OF EVENTS

The sawmill where the accident occurred has a city water line running underground (through a vault) along the front of their property. The below ground vault which measures 12 feet long, 6 feet wide, and 8 feet deep with a 30-inch manhole at the ground level was installed in 1978 to house a backflow device on the city water supply from possible contamination in the event of a negative pressure on the water line. The sawmill's fire protection system is connected to this water supply; therefore, a backflow device is required. The city requires the annual inspection of backflow devices by a person trained and certified in cross connection control.

The independent contractor (the victim) called the superintendent of maintenance on October 6, 1986, to set up a date and time to inspect the backflow device on the water line. The date and time mutually agreed upon was October 10 at 3:30 p.m. The contractor arrived at the sawmill at 3:30 p.m. on October 10 and proceeded with the inspection, which he had completed annually for the past 3 years. The steel cover was removed by the contractor and a ladder was lowered into the 8-foot deep vault. There were 14 inches of water in the bottom of the vault.

At 4:00 p.m. a truck driver stopped at the sawmill office to inquire about a load of lumber he was to pick up. When he walked out of the office he noticed the victim's truck and an open manhole close to where he would have to drive through. He walked over to the open manhole and saw a body in the water at the bottom of the vault. The driver went back to the office and reported a man was down in the vault. The emergency squad was called by the secretary. After calling the emergency squad, the secretary and truck driver went outside to the manhole. The secretary called for help and the first to arrive at the scene was the shipping supervisor, who entered the vault in a rescue attempt. A few seconds later, one of the maintenance men arrived on the scene and descended into the vault to assist in the rescue. Neither man was wearing respiratory protection and within 2 or 3 minutes both men had passed out.

Two policemen arrived at the scene, entered the vault (without respiratory protection), and had to be helped out. The paramedics arrived and attempted rescue (without respiratory protection) and also had to be helped out. The firemen arrived on the scene, donned their breathing apparatus, and went in to remove the three men at the bottom. Two were face down in the water (the contractor and the shipping supervisor) and the third man (the maintenance man) was in a sitting position against the wall, his head was not in the water.

The three men removed from the hole (the contractor, the shipping supervisor, and the maintenance man), the two policemen, and the two paramedics were transported to a local hospital. The contractor and shipping supervisor were pronounced dead on arrival by the attending physician. The maintenance man was hospitalized in serious condition. The two policemen and two paramedics were treated and released.

Test of the atmosphere in the vault by the state investigators revealed the following:

O_2	7%
CO_2	>3%
% LEL	Negative
H_2S	Negative

NOTE: The state investigator surmised that the algae bloom and bacterial action in the water resulted in 0 percent free O_2 in the water. CO_2 (waste product from bacterial action and algae growth) was liberated, displacing O_2 level in the vault.

CAUSE OF DEATH

Asphyxiation due to drowning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Companies contracting to have a service performed on their property should implement and enforce a safety program to be followed by the contractor.

Discussion: Companies contracting out work to be performed on their property should require as part of the contract that the contractor adhere to all safety rules. Particularly when hazardous tasks such as confined space entry are contracted out, outside contractors should be required to comply with a written safety policy that includes safe work procedures, and these requirements should be enforced by the company. For confined space entry, the recommendations in NIOSH Publication No. 80-106, "Working in Confined Spaces" should be used.

Recommendation #2: If the employer has any confined spaces, comprehensive policies and procedures should be developed for confined space entry, where confined space entry is required.

Discussion: All employees who are required to work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. Has the air quality in the tank 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. Is ventilation equipment available and/or used?

Recommendation #3: Public service employees (i.e. police officers, emergency rescue workers, and firemen) that respond to emergency situations involving confined spaces should be trained in confined space hazards and rescue procedures.

Discussion: Public service employees are required to respond to a wide variety of emergency situations. These personnel must be trained in and be aware of the following in order to be properly prepared for emergencies involving confined spaces:

1. Recognition of Confined Spaces

2. Hazardous Atmospheres

   - Oxygen deficient or enriched
   - Flammable
   - Toxic
   - Irritant or Corrosive

3. General Safety Hazards

   - Mechanical/Electrical
   - Communicative
   - Thermal
   - Noise
   - Structural barriers
   - Limited space
   - Size of opening(s)

4. Rescue Procedures

   - Respiratory protection
   - Protective clothing
   - Harness
   - Life lines
   - Standby person

Recommendation #4: Employees, self-employed contractors, and others that are required to work in confined spaces should be trained in confined space entry as part of the certification process.

Discussion: All employees who are required to enter or work in confined spaces should be given adequate training in confined space hazards and safe work practices. For confined space entry, the recommendations in NIOSH Publication 80-106, "Working in Confined Spaces" should be used. The certification process for the state should include training that addresses confined spaces that may be encountered while performing the duties for which the contractor was certified.

FACE 87-23: General Maintenance Person Asphyxiated Attempting to Repair Water Leak

INTRODUCTION

On October 21, 1986, a general maintenance person was asphyxiated when he became lodged in a water meter pit.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim worked as a general maintenance person for a construction company which employed 13 persons. The construction company provides construction-related maintenance for a local chain of restaurants. The safety functions at the construction company are managed by the Director of Operations. A written safety policy and a comprehensive safety program exist. Management personnel also conduct weekly staff meetings including discussions of safety-related matters.

SYNOPSIS OF EVENTS

On the morning of October 21, 1986, a supervisor for the construction company instructed a maintenance person (the victim) to inspect and repair a leaking water valve. The water valve (a screw handle type) controlled the flow of water from the municipal water system to a local restaurant. After the supervisor instructed the victim, he then left the site of the restaurant to check on another job.

As there were no eye witnesses to the accident, the following scenario is based on inspection of the accident site and from interviews conducted with supervisors from the construction company and the state OSHA compliance officer.

Apparently, the victim proceeded to the fiberglass water meter pit (14" diameter x 4' deep) approximately 25 feet from the side of the restaurant where the water valve was located. The water meter pit was buried in the ground and the top of the pit was at ground level. A metal cap was attached to the rim of the water meter pit and a water meter with an in-line shut off valve, a screw handle water valve, and the municipal water line were located in the pit. The valves were approximately 36 inches below the top of the pit (or ground level). The victim removed the metal cap covering the pit and placed the cap on the ground next to the pit opening. He then knelt beside the opening on both knees and reached into the pit until his head, both arms, and part of his shoulders were inside the water meter pit. Apparently, the victim became stuck upside down in the opening and could not free himself, causing asphyxiation due to positional deprivation of air.

NOTE: The victim was observed drinking alcoholic beverages before starting work on the morning of the accident. A blood alcohol analysis of postmortem blood found a concentration of ethanol of 188 mg/dl (0.18%). The legal intoxication level for Indiana is 0.10%. Of the 129 occupational electrical-related or confined space-related fatalities evaluated by NIOSH, as part of the FACE program, this is the second incident where the use of drugs or alcohol have been identified as contributory factors.

CAUSE OF DEATH

The coroner's report listed the cause of death as positional asphyxia.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Supervisory personnel should routinely monitor employee performance to determine if employees have impaired physical and mental capabilities which may be related to the use of alcohol, illegal or over-the-counter drugs, or prescription medications.

Discussion: This fatality occurred because the victim's physical and mental capabilities were impaired by the ingestion of alcohol. Supervisory personnel should be trained to recognize changes in job performance as they may relate to alcohol or drug use and in accepted and proven methods of dealing with these problems. Employees should not be assigned tasks when impaired physical and mental capabilities are observed, but should be taken to medical personnel who are trained to deal with these problems.

Recommendation #2: Supervisory personnel should identify, evaluate, and address all possible hazards associated with the job site.

Discussion: When employees are expected to work alone at job sites, the area should first be evaluated and all possible hazards identified and addressed by supervisory personnel. The location of the water valve inside the water meter pit required the use of extension tools, thereby eliminating the need to enter the water meter pit (even partially).

FACE 87-39: Farm Worker Asphyxiated in Grain Silo in Indiana

INTRODUCTION

On November 1, 1986, a 51-year-old farm worker (for unknown reasons) entered an oxygen limiting silo through the top opening and was asphyxiated.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is a privately owned farm which has one full-time worker and one part-time worker. The farm has no written safety program. Safety is left up to the individual worker. However, the owner has standing orders that no one is to enter any of the silos.

SYNOPSIS OF EVENTS

On November 1, 1986, the owner of the farm and his full-time employee (the victim) were filling an 80-foot-high silo with alfalfa silage at the farm's feed lot. The feed lot has four 80-foot-high oxygen limiting silos. On the day before this incident one of the other silos had been filled with alfalfa silage to within 5 feet of the top and sealed.

Around 3 p.m. on the day of the incident, the farm owner told the victim he had to go into town. While the owner was gone, the victim was to clean up the spillage around the silo being filled and to put away the equipment. When the laborer had completed these tasks he could go home.

A part-time employee at the farm arrived at 4 p.m. Upon arrival, he noticed the tractor's engine was running; however, the victim could not be found. The part-time employee went home and brought his parents back to help look for the victim. The father noticed a 10-foot ladder was located under the ladder permanently attached to the silo filled previously. (The 10-foot ladder was needed to access the first rung of the ladder permanently attached to the silo.) The part-time employee proceeded up the ladder searching for the victim. When he reached the top of the silo, he observed that someone had opened the 17-inch diameter hatch, removed the breather bags, and tied them off on the top of the silo. The part-time employee looked into the silo and did not see anyone. The father then ascended the silo, looked inside, and saw the victim approximately 10 feet from the opening. The father yelled down to his wife to go for help. The father then entered the silo and crawled over to the victim. The victim was unresponsive. The father pulled the victim over to the opening where he was assisted by his son in removing the victim from the silo.

The emergency call was responded to by the county sheriff's office, the volunteer fire department, ambulance personnel, and the farm owner. Fire department personnel began CPR on top of the silo and CPR was continued during transport to a nearby hospital. The victim did not respond to resuscitative efforts and was pronounced dead in the emergency room.

CAUSE OF DEATH

The coroner's report stated "accidental suffocation as a result of aspiration of plant material." The coroner's verdict and the sheriff's report proposed similar scenarios; when the victim opened the door on top of the silo, he was overcome by fumes (nitrous oxide) and fell through the opening into the silo.

NOTE: Following interviews with the farm owner and his advisor, the manufacturer of the silo, and review of the sheriff's report and the coroner's verdict, these points of interest and unanswered questions were brought out.

- No one "except the owner" is to enter the silos, when silo entry is required.
- The silo entered was filled and the top hatch sealed the previous day. The farm owner and the victim were filling another silo on the day of the incident.

- The victim moved the ladder from the silo being filled to the silo previously filled, climbed to the top of the silo, opened the hatch, removed the breather bags, and tied the bags to the top of the silo. The coroner and police reports state that the victim fell through a 17-inch diameter opening and crawled or staggered approximately 10 feet from the opening to the side of the silo.

- The work procedure assigned (cleaning around the silo being filled) did not require ascending or entering the silo previously filled.

- A representative of the manufacturer of the silo stated the convection potential of the silo gases would be vented when the first cam (of four cam latches) was released on the hatch on top of the silo. After being closed for 24 hours the O_2 level inside the silo would be less than 10 percent and the CO_2 level would be in excess of 25 percent. Also, small quantities of nitrous gases (nitrous oxide and dioxide) could be present. Since CO_2 and NO_2 are heavier than air, they would not come out the top except through the convection current potential, which would be released immediately upon removal of the hatch. The heavier than air gases would settle along the top of the silage. The gases coming out of the top opening would have a pungent odor and cause some eye irritation; however, these gases would not be sufficient concentration to overcome the worker.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Personnel evaluating this accident and formulating conclusions should reevaluate these conclusions, as they do not coincide with the sequence of events.

Discussion: The coroner's verdict stated the victim was overcome by nitrous oxide, fell into the silo, and died of suffocation as a result of aspiration of plant material. As stated, the cause of death was apparent. However, the possibility that opening the hatch, pulling out the breather bags, tying these bags off at the top, and then passing out from the nitrous oxide, falling through a 17 inch diameter opening, and crawling away from that opening is extremely remote. The silo manufacturer's representative stated the gases would be vented when the fist cam on the hatch was opened. By the time all four cams were opened and the hatch removed, the interior of the silo should have reached equilibrium with the exterior. Residual gases heavier than air would remain inside the silo.

Recommendation #2: The employer should develop comprehensive policies and procedures for confined space entry.

Discussion: All employees who are required to work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. NIOSH Publication No. 80-106, "Working in Confined Spaces" was left with the employer as a reference for developing confined space entry procedures. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. 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. Has the confined space been isolated/locked out from other systems?

5. 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

6. Have employees been trained for confined space entry?

7. Is ventilation equipment available and/or used?

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

FACE 87-57: Parks and Recreation Director Dies in Oxygen Deficient Atmosphere in West Virginia

INTRODUCTION

On July 15, 1987, the parks and recreation director of a small town in West Virginia died when he entered a manhole at the municipal swimming pool. The director had entered the 18-foot-deep manhole to instruct one of the life guards on how to switch from one sump pump to another.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a small municipality which has 75 employees in seven departments (public works, police, fire, sanitation, parks and recreation, finance and administration, and water). The victim was the director of the parks and recreation department. Each department director reports to the mayor. The municipality has no formalized written safety program. Each department has operating instructions, e.g., the wastewater treatment plant has written procedures provided by equipment manufacturers. The only safety training provided is on-the-job training and use of common sense.

SYNOPSIS OF EVENTS

On July 15, 1987, at approximately 1 p.m., the director of the parks and recreation department (victim) arrived at the newly constructed municipal swimming pool and was going to instruct one of the life guards on the procedure for switching sump pumps. The two sump pumps, which are used to pump subsurface drainage water from the pool area to a nearby creek, are located adjacent to the pool, at the bottom of a manhole (4 feet diameter by 18 feet deep with a 2-foot diameter manway). Metal rungs permanently fixed into concrete provide access to the equipment located in the manhole. The procedure for switching from one sump pump to another requires a person to enter the manhole, descend approximately 9 feet, reach across to the opposite side of the 4-foot wide space, unplug one twist lock receptacle (not moisture proof or designed for us in wet environments) from one sump pump, and plug in the other sump pump to the 208 volt, three phase receptacle.

The director and the life guard proceeded to the sump pump manhole, where the director removed the steel cover from the manway. The director then entered the manway and descended via the fixed rungs into the interior of the manhole, which had not been opened in 2 months. The water in the manhole was approximately 7 feet deep, since the circuit breaker feeding power to the sump pump motor had previously tripped. However, pump control power was still available in the manhole. When the director had descended approximately 11 feet into the manhole, he started shaking as if he were convulsing, let go of the rung he was holding on to, and fell backwards into the water. This was witnessed by the life guard who had remained on the outside of the manhole to observe the procedure for switching the pumps. The director had not touched electrical lines to the sump pumps before this occurred. His feet and lower legs were in the water.

The life guard did not enter the manhole to attempt rescue because he was concerned about electrical/ electrocution hazards. The life guard ran to the maintenance/pump room area (approximately 100 yards) and reported to one of the maintenance men that the director was in trouble in the sump pump manhole. The circuit breakers were switched off, the fire department/emergency rescue was called, and a maintenance man observed the director under the water and stated that the victim was unresponsive. The maintenance man entered the manhole (without respiratory protection) and at that time experienced difficulty breathing when he reached the water level (7 feet from the bottom). Because he was concerned about the electrical connections in the manhole, he exited the manhole and called to a co-worker to shut off the main breaker for the entire area. The main breaker was shut off (which removed the control power) and he re-entered the manhole (without respiratory protection); however, he was unable to reach the victim (not sure of the depth) so he exited again. The fire rescue squad arrived about the same time the maintenance man had exited the manhole for the second time. Two firemen entered the manhole (without respiratory protection) after being informed the power was off and removed the victim. The victim was unresponsive when removed and cardiopulmonary resuscitation was started immediately. The victim was transported to a local hospital where unsuccessful life saving efforts were continued for 30 minutes.

CAUSE OF DEATH

After completing an autopsy, the medical examiner determined that death was due to drowning in water. This occurred when the victim, who had arteriosclerotic coronary artery heart disease, collapsed after entering an oxygen deficient environment.

INVESTIGATIVE NOTATIONS

- First report of fatality was listed as an electrocution. Upon investigating the incident, this was truly possible. This manhole was installed as part of the new pool construction in November 1986. The contractor installed two sump pumps, two float switches (one for each sump pump), and twist-lock cord and plug connectors at the 9-foot level for pump motor and pump control power. Neither the receptacles nor the plugs were approved for wet environments. The receptacles were taken apart by the electrical consultant hired by the city, and both had damage to the wiring connections and were heavily rusted. This deterioration is apparently what led to tripping the circuit breaker which fed to the pump motor and the subsequent rise of water in the manhole.

- *The engineering consultant hired by the city conducted a voltage test (power restored) to measure the potential between the water in the manhole and the stainless steel pool. A copper wire was lowered into the water and the reading was less than .05 of a volt.*

- *After the voltage test was completed, the sump pump was turned on and the water was pumped down to the 1-foot level. When the water level exceeds 1 foot, the pump turns on automatically.*

- *The atmosphere in the manhole was tested on July 17, 1987, for O_2, CH_4, and H_2S. The results of those tests were:*

O_2	-	*14%*
CH_4	-	*Negative*
H_2S	-	*Negative*

- *The manhole was closed on July 17, 1987, and reopened on July 20, 1987, and tested again. The results of those tests were:*

10:00 a.m.	O_2	-	*14%*	*10:10 a.m.*	O_2	-	*17%*
	CH_4	-	*Negative*		CH_4	-	*Negative*
	H_2S	-	*Negative*		H_2S	-	*Negative*

  Because the manhole has a lateral branch to an adjacent manhole, which opens to a creek, a static air condition will change rapidly to a dynamic condition when the top is opened.

- *On the day of the accident, the manhole had not been opened for 2 months and contained 7 feet of water. From the atmosphere test readings on July 17, 1987, and July 20, 1987, it is likely that the O_2 level was less than 10 percent when the victim entered.*

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should take corrective action to remove the electrical hazard(s) from the sump pump manhole and bring the electrical system into compliance with the latest edition of the National Electrical Code (NEC).

Discussion: The electrical connections in the manhole are not approved or designed for use in wet environments. The connection box at the top of the manhole is not moisture proof. The twist lock receptacles (at the 9-foot level) have been under water. The silt, corrosion, and electrolysis evident in these receptacles (less than 9 months) are classic examples of what can occur when the wrong type of receptacles are used in an environment subject to moisture and/or flooding. The switching changeover operations from one pump to the other could be done by means of switches located in a covered protected area above the ground (not in the manhole) and need not be at the manhole site in the public access area of the pool. Also, ground fault circuit interrupters should be installed.

Recommendation #2: The employer should develop comprehensive policies and procedures for confined space entry, where confined space entry is required.

Discussion: All employees who are required to work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. 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. Is ventilation equipment available and/or used?

Recommendation #3: Public service employees (i.e. police officers, emergency rescue workers, and firemen) who respond to emergency situations involving confined spaces should be trained in confined space hazards and rescue procedures.

Discussion: Public service employees are required to respond to a wide variety of emergency situations. These personnel must be trained in and be aware of the following in order to be properly prepared for emergencies involving confined spaces:

1. Recognition of Confined Spaces

2. Hazardous Atmospheres

   - Oxygen deficient or enriched
   - Flammable
   - Toxic
   - Irritant or Corrosive

3. General Safety Hazards

- Mechanical/Electrical
- Communicative
- Thermal
- Noise
- Structural barriers
- Limited space
- Size of opening(s)

4. Rescue Procedures

- Respiratory protection
- Protective clothing
- Harness
- Life lines
- Standby person

FACE 87-59: 73-Year-Old Self-Employed Pump Service Contractor Dies in Well in Maryland

INTRODUCTION

On June 27, 1987, a self-employed water pump service contractor died after falling to the bottom of a 50-foot-deep water well at a private residence.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer was a privately owned well service company and the owner (victim) was the only employee. There was no written safety program on confined space entry procedures.

SYNOPSIS OF EVENTS

On June 27, 1987, a self-employed water pump service contractor (victim) was responding to a call from a private residence when the accident occurred. The owner of the private residence called the victim the previous day and stated something was wrong with his water system because, "they had no water in the house." The victim responded to the call on the morning of June 27 (Saturday) and proceeded to check out the water system. No problems were found in the house so the victim decided to check out the well, which was located adjacent to the house. The well was approximately 50 feet deep, 2 feet in diameter, and cased with concrete rings to the bottom. The victim opened the cover to the well and hung a chain type ladder (approximately 10 feet down) into the well. The victim was going in to check the piping leading from the well to the house. As he descended the chain ladder into the well, he either slipped or was overcome by an oxygen deficient atmosphere and fell down the shaft of the well. The owner, who witnessed the fall, called the fire/rescue squad immediately.

The fire/rescue squad arrived within a few minutes and decided to send in a fireman to rescue the victim. The fireman called down into the well and there was no response from the victim. A fireman with no type of respiratory protection was lowered via a rope attached to a harness into the well. Approximately 10 feet down, the rescuing fireman became incoherent and had to be removed and transported to a local hospital. A second fireman, wearing a self-contained breathing apparatus, was lowered into the well to the level of the victim. The fireman could not find a pulse or get any response from the victim, so he was pulled out of the well. Removal of the victim from the well took over 4 hours and required a retrieval hook manufactured locally. The victim was pronounced dead at the scene.

CAUSE OF DEATH

Not known at this time.

[NOTE: No atmospheric tests were performed during the site visit because the well had been filled with dirt.]

RECOMMENDATIONS/DISCUSSION

***Recommendation #1:** A trained standby person should remain outside of the confined space when a worker enters or works inside. The standby person should visually monitor the tasks being performed inside and should be able to communicate with the worker(s) inside the confined space.*

Discussion: A person trained in emergency rescue procedures, assigned to remain on the outside of the confined space for communication and visual monitoring of the person inside is of utmost importance and might have prevented this fatality.

***Recommendation #2:** The employer should develop comprehensive policies and procedures for confined space entry.*

Discussion: All employees who are required to work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. 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. Has the confined space been isolated/locked out from other systems?

5. 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

6. Have employees been trained for confined space entry?

7. Is ventilation equipment available and/or used?

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

FACE 87-64: Mechanic Asphyxiated Within Steam Service Passageway

INTRODUCTION

On July 25, 1987, while a 35-year-old male mechanic was working (in a concrete vault) in an attempt to regulate the pressure in an 8-inch steam line, a strainer on the steam line ruptured. The victim was trapped in a blocked passageway by the escaping hot steam and died as a result of asphyxiation.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The company which employed the victim manages a small utility operation which generates and distributes steam. The company, which employs 61 full-time and 5 part-time workers, does not have a formal written safety program nor written confined space entry procedures. Training is provided on-the-job and employees are told to "work safely."

SYNOPSIS OF EVENTS

There were no eye witnesses to this incident. The following scenario was developed from an evaluation of the incident site, and from discussions with the vice-president and other management personnel of the company, co-workers, and the state of OSHA compliance officer assigned to the case.

On July 25, 1987, a mechanic (the victim) in the company's customer service department was dispatched to complete a service call. The victim was to reduce the pressure in an 8-inch steam line from approximately 150 pounds per square inch (psi) to 30 psi (the customer's specifications). The steam line is located in a concrete vault measuring 10 feet deep by 9 feet wide by 15 feet long. The top of the vault is covered with removable sections of steel grating. At one end of the vault, a 200-foot passageway leads to the basement of the customer's establishment. A louvered door used for ventilation is located approximately 75 feet into this passageway. Part of the doorway can be opened from the customer's side.

The victim arrived at the site and removed several sections of grating from the top of the vault. A ladder was lowered into the vault for entry. Once inside the vault the victim apparently opened a hand-operated valve on the 8-inch steam line. As the steam (366 degrees F) started surging through the line, the 4-inch strainer, located approximately 1 foot downstream of the 8-inch valve, ruptured.

When the strainer ruptured, hot steam escaped and filled the vault area. In an attempt to escape the steam, the victim proceeded down the passageway until he encountered the louvered door. Unfortunately, the door could only be opened from the customer's side. The victim apparently tried to break through the door, but died as a result of asphyxiation.

Employer, fire department, police department, and rescue squad personnel responded. The steam line was deactivated and the fire department used two fans to vent the passageway. The victim was located approximately 30 minutes after the fans had been started. Fire fighters carried the victim to the customer's basement area where he was pronounced dead. A subsequent investigation disclosed that faulty engineering design, due to erroneous expansion and flexibility calculations, was a contributing factor in the rupture of the strainer.

CAUSE OF DEATH

The medical examiner reported the cause of death as asphyxiation.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop and implement comprehensive safety programs. As part of this written safety program, the employer should develop procedures for entry and work in or around confined spaces.

Discussion: Since the employer does not have a written comprehensive safety program, rules and procedures addressing the hazards associated in work of this nature should be developed, implemented, and enforced. Procedures for entry and work in confined spaces should also be developed, implemented, and enforced. One procedure which may have prevented this death is having a designated standby person. This person could have alerted others to open the louvered door to allow the victim to escape. Another relevant procedure is having rescue and emergency procedures established if a worker is in immediate danger of injury or death while in the confined space. The worker should have been provided a self-contained breathing apparatus prior to his entry into the confined space. Use of an alternate air source would probably have prevented this death.

To aid in the development of confined space entry procedures, the vice-president of the company was provided the following:

- A Guide to Safety in Confined Spaces. DHHS (NIOSH) Publication No . 87-113.
- A NIOSH Alert on Confined Spaces. "Request for Assistance in Preventing Occupational Fatalities in Confined Space." DHHS Publication No. 86-110.
- Braddee, R.W., Pettit, T.A. "Warning-Posting of Confined Spaces." Professional Safety, February 1987.

Recommendation #2: Employers should maintain equipment in proper operating condition.

Discussion: Steam traps are designed to remove excessive water condensate from piped steam. A steam trap located upstream from the strainer which ruptured was found to be partially plugged. A poorly operating steam trap might have contributed to the generation of pressure due to water condensate buildup. The employer should institute a preventive maintenance program based on periodic inspection to ensure that all equipment is fully functional.

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:

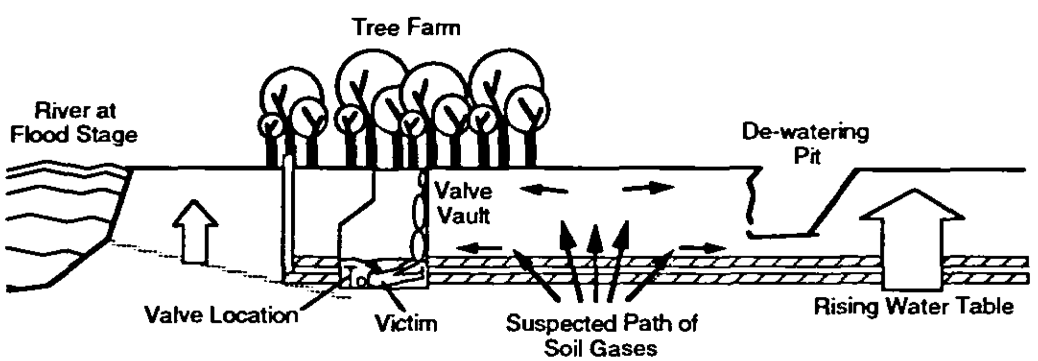
a. the river (located about 170 feet away from the underground valve vault) had been at flood-stage levels for several days preceding the incident;

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.

Atmospheric Hazards

Solvents

FACE 85-09: Worker in Vermont Dies in 20,000 Gallon Gasoline Bulk Tank While Wearing Closed Circuit SCBA

INTRODUCTION

On January 30, 1985, at approximately 11:30 a.m., two members of a family owned and operated waste oil service company and one employee arrived at a tank farm and began their preparations for cleaning a gasoline storage tank. The tank was entered by the son who was wearing a closed circuit, constant flow self contained breathing apparatus (SCBA). After descending the ladder and motioning that he was okay, he took several steps and fell forward into the sludge where he died before he could be rescued.

SYNOPSIS OF EVENTS

On January 28, 1985, a waste oil service company was subcontracted to clean a bulk storage plant tank. The waste oil service company was a family-owned and operated business. The father and son had employed a laborer to help them with this clean-up operation. Upon arrival at the bulk plant, they discovered that the tank to be cleaned was a 20,000 gallon elevated horizontal gasoline tank. They had come prepared to clean a fuel oil tank. Because the gasoline tank presented an explosion hazard, they couldn't exhaust the tank by use of a truck mounted blower which was their usual procedure for oil tanks. Instead, they pumped 200-300 gallons of waste gasoline from the tank, opened the 16-inch diameter top access hole and left the site.

Two days later, on January 30, the three men purchased a used closed circuit SCBA, which was adequate for the job to be done, and returned to the bulk plant. The son, a trained volunteer fireman, skimmed through the closed circuit SCBA instruction manual, donned the unit and fitted it in preparation for entry to the tank. He then removed the closed circuit SCBA and ascended the ladder to the top of the storage tank. In order to enter the tank, he put the face piece on and had the laborer hold the unit above his head while he descended the ladder several rungs to clear the access opening. The laborer handed him the closed circuit SCBA and he mounted the unit on his chest, cinching it up after reaching the bottom of the tank. The laborer asked if he was okay and the victim nodded. He then circled to the other side of the ladder, took one more step and collapsed face down into approximately 1 1/2 inches of sludge.

The laborer yelled to the victim's father to call for help and then descended into the tank. He had no protective equipment and was not equipped with any rescue equipment (lifelines, harnesses, etc.). The laborer entered the tank and shook the victim. When there was no response, he tried to tie a rope around the victim's chest, but had to leave the tank to get some fresh air. He re-entered the tank and was again unsuccessful at getting a rope around the victim.

The fire department arrived approximately 5 to 6 minutes after the victim went down. Two fire fighters attempted to enter the tank wearing protective clothing and open circuit SCBAs. Because of the size of the opening, they had to remove their turnout coats and the harness-backpack assembly of their SCBAs prior to the entry. They, too, had their open circuit SCBAs held over their heads to permit entry through the small diameter access hole. One of the firemen checked the seal on the victim's face piece and thought it was adequate. He then broke the seal in an attempt to determine whether or not there was air flow. Upon sensing that there was no flow, * he felt for a valve. (He noted that it was dark in the tank, and that there was poor visibility.) When he felt the valve which he believed to be the by-pass valve, he turned it and heard a flow of oxygen. The two fire fighters tried to remove the victim from the tank but because of the small (16 inch) access port, they were unable to. After approximately 20 minutes, when their low pressure alarms sounded, they exited the tank. Another fire fighter entered the tank, tied a rope around the victims feet and hoisted him out feet first. A ladder truck was used to lower the victim to the ground.

Resuscitation was initiated and the victim was transported to a local hospital where he was pronounced dead.

CONCLUSIONS

Various factors contributed to the occurrence of this fatal accident. Some of these factors follow:

1. The victim was a volunteer fireman who was experienced in wearing an open circuit SCBA. The unit he purchased and used to enter the gasoline tank was a closed circuit unit. There are major differences in the way these units operate. For example, if an open circuit unit doesn't have the air cylinder turned on, you can't inhale. In a closed circuit unit with a breathing bag, (such as the one worn by the victim) there is enough residual volume in the bag to allow you to inhale and exhale normally even without the oxygen cylinder turned on. If, however, the oxygen cylinder is not adding oxygen to the breathing environment, the user quickly depletes the oxygen in the breathing bag and becomes anoxic. It is not known whether this occurred, but inadequate training and experience with the unit could be considered to be a factor in this incident.

   * It should be noted that with this unit, there is a constant O_2 flow of approximately 3 l/m. This flow would probably not have been discernible to the fireman.

2. Access into and out of the confined space was via a 16-inch port at the top of the tank. There were no openings in the bottom or sides of the tank.

3. This small, family-owned and operated company has no written safety procedures, no SCBA use procedures, and no confined space entry procedures. Furthermore, the company does not take O_2, CO, or combustible gas measurements prior to tank entry.

4. The victim was not wearing emergency escape equipment such as a harness or wrist harness with attached life line.

5. The top man was not equipped with emergency rescue equipment, i.e., SCBA, protective clothing, rescue lifting device, etc.

6. The bulk plant management and the contractor presumably have access to reports published by the American Petroleum Institute and by various oil companies about the hazards of confined spaces and safe entry procedures. The family owned and operated sub-contract company, on the other hand, did not have access to this information and was not aware of confined space safe work practices.

RECOMMENDATIONS

***Recommendation #1:** Prior to donning and using any SCBA, the user should be thoroughly familiar with the unit's operation, intended uses, limitations, and emergency airflow. In addition, fire fighters, paramedics and anyone else responsible for emergency rescue from confined spaces should be cognizant of the differences between open and closed circuit SCBAs. Knowledge of one SCBA does not presume adequate knowledge of all SCBAs.*

***Recommendation #2:** Working and emergency access and egress plans should be made prior to entering any confined space. Entry into a confined space with only one access and/or a small access should be considered a high-risk activity and emergency egress plans should be carefully made.*

***Recommendation #3:** Owners of storage tanks which must be entered for maintenance and/or repair, and which have only a single, small access portal, should have an additional portal cut into the tank at a location which would permit easy egress in case of emergency.*

***Recommendation #4:** A confined space entry policy and procedures should be written and utilized for each entry. The policy and procedures should indicate: work areas designated as confined spaces, conditions where entry into confined spaces is authorized, procedures to be followed before entry is* *permitted (testing, entry permit, training, personal protective equipment, lockout/tagout procedures, etc.) and rescue procedures.*

Workers who, in the course of their work, may have to enter confined spaces should complete a training program designed to inform them of the hazards they may encounter, procedures to be used in evaluating a confined space, entry procedures and emergency rescue procedures.

Recommendation #5: Employers who elect to contract out hazardous work, such as cleaning fuel storage tanks, should consider safety procedures part of the contract and should enforce those safety procedures.

FACE 85-26: Inspector Dies in a Gasoline Storage Tank in Ohio

INTRODUCTION

On June 7, 1985, a father and son inspection team, under contract to a petroleum company, were inspecting the seals between the internal panels of a floating roof and the sides of a 150,000 barrel storage tank containing regular gasoline. At 12:30 p.m. the victim's father contacted the yard office and reported that his son was 7 minutes overdue. At 2:30 p.m. the victim's body was located on the opposite side of the tank on top of the floating roof. By 4:30 p.m. a rescue team removed the victim from inside the tank. He was pronounced dead at the scene.

SYNOPSIS OF EVENTS

The petroleum company awarded a contract to perform scheduled inspections of gasoline storage tanks. The contractor selected to perform these inspections was from Louisiana. The contract was required because the petroleum company does not permit its employees to enter these tanks. Because of that policy, there were no respirators on site. The contract specified that the contractor would provide all necessary equipment and that at least two workers would be stationed outside the tank. Prior to the inspection of the 150,000 barrel storage tank, the victim had completed a similar inspection on a smaller tank (40,000 barrel). The inspection of the 150,000 barrel tank began at approximately noon on June 7, 1985. At the time of the inspection, the storage tank contained approximately 3 million gallons of gasoline (approximately half full). The victim entered the tank through the access hatch at the top of the tank and proceeded down the access ladder to the floating panel inside the tank. The victim then walked around the tank on top of the floating panel inspecting the rubber seals between the walls of the tank and the floating panel. The victim's father remained on the outside, on top of the tank.

At approximately 12:30 p.m. the victim's father contacted the yard office and requested that a rescue squad be called. He said his son was 7 minutes overdue. Company officials and the rescue squad were called immediately. A rescue squad from a neighboring community arrived about 25 minutes later. Additionally, a local fire department and a medical transport helicopter responded. Two hours after the father reported the victim was overdue and after several unsuccessful attempts, the body was located on the opposite side of the tank, approximately 150 feet from the ladder. An additional 2 hours were required to remove the victim from the tank.

An open-circuit, self-contained breathing apparatus (SCBA) in the demand mode was available. However, when the victim was found, the face mask was on the top of his head, not over his face. A life line was found at the foot of the stairs outside the tank. Neither the victim nor the victim's father was wearing safety shoes or chemical protective clothing. Only one respirator was available (the one used by the victim). No other safety equipment was found at the accident site. A small tape recorder was found with the victim. The tape recorder was used to record the victim's remarks concerning the condition of the seals. The quality of the victim's voice on the tape indicated that the respirator face piece was not in the proper position at the time of the recording; also his voice "trails off" at the end of the recording. A small rock was used to tap on the outside wall of the tank; presumably the victim also carried a rock with which he was to tap on the inner wall of the tank in response. This was the only system of communication between the victim and the outside of the tank.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should develop written procedures for working in confined spaces and provide training in these procedures to all employees.

Discussion: The employer should develop procedures for working in confined spaces, such as those outlined in the NIOSH document "Working in Confined Spaces." These procedures should contain an outline of the following: permit system, testing and monitoring of the atmosphere, training of employees, safety equipment and clothing, safe work practices, rescue procedures, standby person requirements, and use of respiratory protection. Employees should receive extensive training in all of these procedures, once they are adopted. The employees should also be made fully aware of the hazards that may be encountered if these procedures are not followed. If the victim had followed instructions concerning the proper use of respiratory protection, he would not have removed the face mask to speak into the tape recorder. Additionally, if the victim had used a safety belt with a life line to the standby person, the time taken to locate and remove the victim from the tank would have been greatly reduced.

Recommendation #2: Constant communication and visual contact, if possible, should be maintained between the worker inside the confined space and the standby person.

Discussion: The possibility exists that a person might suddenly feel distressed and not be able to summon help. Therefore, it is of the utmost importance that constant communication be maintained between the worker inside the confined space and the standby person. The standby person in this incident failed to notify anyone, until the victim was seven minutes "overdue." Visual monitoring of the worker should be maintained whenever possible. If visual monitoring is not possible, a voice or alarm-activated explosion-proof type of communication system should be used.

Recommendation #3: Companies that contract various activities to outside contractors should assure that these activities are performed in accordance with the contract and that safety is maintained at all times.

Discussion: The petroleum company recognized the hazards associated with this activity and included requirements in the contract to address these hazards. Additionally, the company should have determined that the inspection company was complying with all of these requirements.

Recommendation #4: Personnel using respirators in an environment that is (or could be) immediately dangerous to life or health (IDLH) should use pressure-demand SCBA.

Discussion: The victim was wearing a demand SCBA in an environment that could have been IDLH. The environment was not tested (see Recommendation #1).

FACE 85-33: Construction Worker Dies as a Result of Applying Coating in Confined Space in California

INTRODUCTION

On July 12, 1985, a construction worker died as the result of exposure to 2-nitropropane and coal tar pitch vapors. The victim and a co-worker were painting water line sleeves and valves.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim, who was the crew foreman, was employed by a general engineering contracting firm that employs approximately 45 people. The firm has been in operation approximately 3 1/2 years.

The crew foreman is responsible for safety at the job site. Weekly "tool box" meetings are used to instruct workers in accident prevention. Each new employee is issued a code of safe practices when hired. The company has a safety policy that outlines procedures for work in confined spaces. If these procedures had been followed, the likelihood of this incident occurring would have been reduced, perhaps eliminated.

SYNOPSIS OF EVENTS

In November 1984, the engineering contracting firm was contracted to replace a valve in a 72-inch underground water line. The water line had separated due to land subsidence. The company enclosed this portion of the line in a rectangular concrete service area (12 feet by 15 feet by 15 feet). The concrete service area was covered with a removable wooden roof with a steel access door (3 feet by 5 feet). Three vents (approximately 6 inches by 24 inches) were present on two opposite sides of the service area, above ground level. Inside the service area the 72-inch line was reduced to 54 inches and a valve was installed on the concrete-coated steel water line. By the end of June 1985, the job was nearing completion. One of the tasks remaining was to paint the valve and the steel flanges with an epoxy coating that contained 2-nitropropane and coal tar pitch.

Toward the end of June 1985, the victim and a co-worker began to apply the epoxy coating to water line support rods in a similar water line service area that was located approximately 300 feet from the service area that housed the 54-inch valve. There was no roof over this service area. After work on July 1, the co-worker complained of nausea and a headache; however, at the start of the shift the following morning (July 2, 7 a.m.), the co-worker apparently had recovered and said he felt fine. The victim and a co-worker then entered the service area that housed the valve. The access door was left open to provide light for the painting operation. Some time during the morning a third worker and a safety inspector (employed by the architect/engineering firm overseeing the construction project) entered the service area. Although the third worker and a safety inspector both complained about the "fumes," nothing was done to rectify the situation. At noon the victim and co-worker exited the service area to eat lunch. The co-worker again complained of nausea and a headache. The victim made no such complaints. The victim and co-worker entered the service area after lunch and continued to paint until the end of the work shift (approximately 3:30 p.m.).

During the drive home, both men began to complain of nausea and headaches. The victim then vomited into his hard hat. After feeling progressively worse, both men decided to go to the hospital from their homes. They were admitted on the evening of July 2 and discharged the following day. The victim was re-admitted to the hospital on July 6; he lapsed into a coma and died on July 12 of acute liver failure induced by the inhalation of the 2-nitropropane and the coal tar pitch vapors. Although seemingly recovered from the incident, the co-worker has been advised by the attending physician not to return to work due to the fluctuation of his liver enzyme count.

Labels on the protective coating cans clearly state that the coating should be used in confined space "only with adequate forced air ventilation to prevent dangerous concentrations of vapors which could cause death from breathing." The victim stated when assigned this task that he had used this material previously; however, it is doubtful that the victim or the co-worker, who were of Hispanic descent and spoke broken English, fully understood the level of toxicity of the epoxy. A blower, provided at the site for ventilation purposes, was never utilized.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should be certain employees are aware of the hazards associated with the tasks they are performing and the materials they are using. Additionally, employees should be aware of all safety procedures to be followed and the reasons for these procedures.

Discussion: Even though the victim stated that he had used this material previously, it is highly unlikely that he fully understood the extent of the toxicity of this substance in a confined space. It is unlikely the victim or the co-worker would have returned to the service area to paint after becoming nauseous and developing headaches had they realized that breathing concentrations of the epoxy vapors could cause death. This may require the communication of information concerning hazards to be made to an employee in a language other than English. Upon issue of the material, supervisory personnel on the job should have explained fully all hazards associated with the use of the epoxy material and should have followed up to determine if the blower that was provided for ventilation purposes was necessary.

Recommendation #2: Employer should implement and enforce existing safety policies.

Discussion: The employer had a written safety policy that included procedures to be followed while working in confined spaces. Had this policy been followed the risk of this fatality would have been greatly reduced. The employer should assure that these safety procedures are fully understood and enforced.

FACE 86-23: Foundry Worker Dies in Indiana

INTRODUCTION

On April 5, 1986, a foundry worker died as a result of inhaling methyl chloroform vapors while spraying a solvent on a conveyor drive chain during a degreasing operation.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was employed by a foundry that produced molded grey iron casting for various industries. The foundry, in operation since 1911, was destroyed by fire in 1953, but was rebuilt and placed back in operation by 1955. The foundry employs 310 workers on a three-shift basis; with full production being run only on the day shift. Partial production is run on the afternoon and graveyard shifts, while maintenance is being performed on equipment.

The safety function is managed by the personnel director on a collateral-duty basis. A written safety program exists at the foundry. New employees receive training on the job. Although respirators are used throughout the foundry, no training in the proper usage of respirators exists. A safety committee, consisting of two company officials, two union officials, and a representative of the insurance carrier, meets monthly to discuss safety issues.

SYNOPSIS OF EVENTS

On the night of the incident the victim was performing maintenance operations on a conveyor drive chain that required spraying a degreasing solvent containing methyl chloroform (NIOSH recommended exposure limit 350 ppm, 15 minute ceiling - IDLH level 1000 ppm). The drive chain propelled the mold cars which carried the grey iron castings through the firing chamber. The service area, which contained the conveyor drive chain and its motors, was a pit (28 feet long, 14 feet wide, and 5 feet deep). A permanent ladder on one side of the pit provided access. The conveyor ran across the top of the pit, while the drive chain itself was located below the conveyor approximately 2 1/2 feet above the floor level of the pit. The solvent was contained in a 55-gallon drum located outside and above the service area. The solvent was dispensed by a hand-held nozzle with two manual valves; one for the gravity fed solvent, the other for the forced-air flow. The victim was to begin spraying the solvent at one end of the pit and work his way to the other end of the pit. The conveyor was not in operation at the time this maintenance was being performed. Three windows on the wall directly above the service area were covered with cardboard and a ceiling exhaust fan was not in operation due to cold weather. The victim was equipped with rubber gloves and overshoes, safety goggles, hard hat, and an air-purifying respirator with an organic vapor cartridge. He was instructed by a supervisor to change the cartridge, if the fumes became too noticeable.

The victim remained inside the service area until dinner time, reportedly between 2 a.m. and 3 a.m. The victim then proceeded to the lunch room to eat dinner. While eating dinner he complained to co-workers that the fumes were bothering him more than usual. He was advised by a co-worker to "go outside and clear you head" before reentering the service area. After eating his dinner the victim returned to the service area and resumed spraying. At the end of the shift (approximately 6 a.m.) a co-worker decided to notify the victim that the shift was almost over. When the co-worker arrived at the service area he found the victim lying on his side underneath the conveyor and the nozzle still spraying. The victim was lying approximately 10 feet from the ladder. It was estimated that between 10 and 20 gallons of solvent were present on the floor around the victim.

The co-worker immediately went to notify a supervisor. The supervisor and co-worker returned to the service area. The supervisor descended the ladder into the pit and was immediately overcome by the fumes. He fell to his knees, but was able to stand up and climb back up the ladder. The co-worker and supervisor then attempted to enter the pit while holding their breath, but again had to leave the pit. On their third attempt they managed to drag the victim from the pit. Mouth-to-mouth resuscitation was begun and continued until the emergency service arrived. The victim was pronounced dead at the scene by the deputy county coroner.

CAUSE OF DEATH

Preliminary findings of the medical examiner indicate the victim died as the result of inhalation of methyl chloroform vapors.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should initiate comprehensive policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should minimally include the following:

1. Air quality testing to assure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;
2. Monitoring of the space to determine a safe oxygen level is maintained;
3. Employee and supervisory training in confined space entry;
4. Employee and supervisory training in the selection and usage of respiratory protection;
5. Emergency rescue procedures;
6. Availability, storage, and maintenance of emergency of rescue equipment.

The air quality was not determined before the worker entered the pit and ventilation was not maintained. Also, the vent windows were covered with cardboard and the exhaust fan was not utilized. The air quality was not monitored for toxic air contaminants and oxygen level. Respirator training and proper maintenance procedures should be required of all employees and supervisors. The employee in this case received no training in the proper use of respiratory equipment. The air-purifying respirator used in this case was not the proper respirator for this application. NIOSH recommends a supplied-air or self-contained breathing apparatus when working in the presence of methyl chloroform. Emergency rescue procedures for confined spaces should be stressed to all employees. The supervisor and co-worker should never have entered the pit without proper respiratory equipment, which should have been readily available. They greatly enhanced the possibility of this incident becoming a multiple fatality.

The personnel manager was provided the following:

- NIOSH Document Criteria for a Recommended Standard, Working in Confined Spaces. DHEW, NIOSH Publication No. 80-106.
- NIOSH Alert on Confined Spaces. DHHS Publication No. 86-110.
- Confined Spaces Hazard Recognition. Article by Ted A. Pettit. Reprinted from Occupational Health and Safety (July 1983), 52:17-45.
- NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) Publication No. 85-114.

FACE 86-34: Three Dead in Confined Space Incident in New York

INTRODUCTION

On July 5, 1986, three workmen were cleaning out a trichloroethylene degreasing tank when the accident occurred. The tank is only cleaned out when the plant is not in operation, therefore, only the three assigned the cleaning task were in the plant. A relative of one of the workers stopped by the plant that evening and found all three workmen down in the tank. All were unresponsive.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The metal products finishing operation has two owners, a general manager (victim), a foreman (victim), a secretary, and 25 laborers. The company has been in the business of cleaning and painting metals parts for 25 years. The company has no written safety policies or procedures. Training for new employees is provided on the job by an experienced worker, the foreman and/or owner.

SYNOPSIS OF EVENTS

On Saturday, July 5, 1986, three employees (the plant manager, the foreman, and a laborer) for a metal parts painting company reported to work to clean out a degreaser tank. The tank is always cleaned when the plant is shut down for the weekend. The plant operates on a 5-day work week (Monday through Friday) and when it is time to clean the degreaser tank (3 or 4 times a year), it is scheduled on Saturday.

The basic operation of the plant consists of: Receiving metal parts from a vendor, hanging the parts on a conveyor system which then transports them through a trichloroethylene degreaser tank (see Figure), allowing them to air dry, then painting, baking, and shipping the parts back to the vendor.

The degreaser is an irregularly shaped metal tank, 8 feet high by 30 feet long by 6 feet deep with a 30 by 40 inch opening at each end. The chemical degreaser used in the tank is trichloroethylene and is usually maintained at a level of 8 to 10 inches (approximately 75 gallons). The tank has steam lines along the bottom which heat the degreasing agent to 160 degrees F, creating a vapor action.

Every three or four months it is necessary to clean out the tank. The unwritten procedures for cleaning the tank (according to the plant owner) are as follows:

On Friday night the steam that heats the trichloroethylene to 160 degrees F is shut off and the trichloroethylene is drained. The bottom doors are opened and the tank is allowed to cool and vent overnight. On Saturday morning a three-man crew reports to work to clean the tank. A 20 inch house fan is used to ventilate the tank.

The cleaning procedure is to have one man enter the tank via a ladder and physically pick up metal parts and debris that have fallen off the conveyor and place them in a box to pass out to a person on the outside. The third person is a standby for whatever is needed.

After approximately 5 minutes, the man in the tank rotates with the man on the outside, and this continues until the tank is cleaned of all metal debris.

Since there were no witnesses to what happened, and all three workers died, the following scenario was developed: The men were found at approximately 7:30 p.m. by a relative who had stopped by to see what was the problem. The tank is cleaned out on Saturday morning and the three men were still there at 7:30 that evening. The relative found all three men in the degreaser tank, unresponsive. He immediately called the fire department for help. The fire department and police department responded to the call and the men were removed from the tank. One was dead when removed, one died a few hours later at a local hospital, and one remained critical until July 17, 1986, when he died without regaining consciousness. Two police officers were also hospitalized with chemical burns.

The tank had been cleaned of metal debris. However, the trichloroethylene had not been drained off and the temperature of the chemical was 100 degrees F. Also, no ladder was used for entry. Therefore, this meant the men had to hand-walk the conveyor line into the tank. Several boxes of metal parts were on the floor near the degreaser.

The tank had been cleaned the same way for 25 years and the owners did not know why the procedure was changed.

CAUSE OF DEATH

Not listed at this time.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should be certain employees are aware of the hazards associated with the tasks they are performing and the materials they are using. Additionally, employees should be aware of all safety procedures to be followed and the reasons for these procedures.

Discussion: Although this procedure for tank cleaning had been followed for several years, it is unlikely the employees fully understood the toxicity of the substance in the tank. The procedure established (which was apparently not followed) is also hazardous. Entry into a degreaser tank without adequate ventilation, personal protective clothing, and respiratory protection subjects employees to a toxic, irritant, and potentially lethal atmosphere.

Recommendation #2: The company should develop and implement a written safety and training program. This program should include recognition of hazards and methods to work safely.

Discussion: The company has no written safety program or policy. Safety and training is practically non-existent at this plant. Any training that is done is on-the-job with little emphasis on safety and health. The company should develop a training program that would instruct employees on hazards associated with the operation of the plant, methods of working safely and the use and need of personal protective equipment.

Recommendation #3: The employer should develop comprehensive policies and procedures for confined space entry.

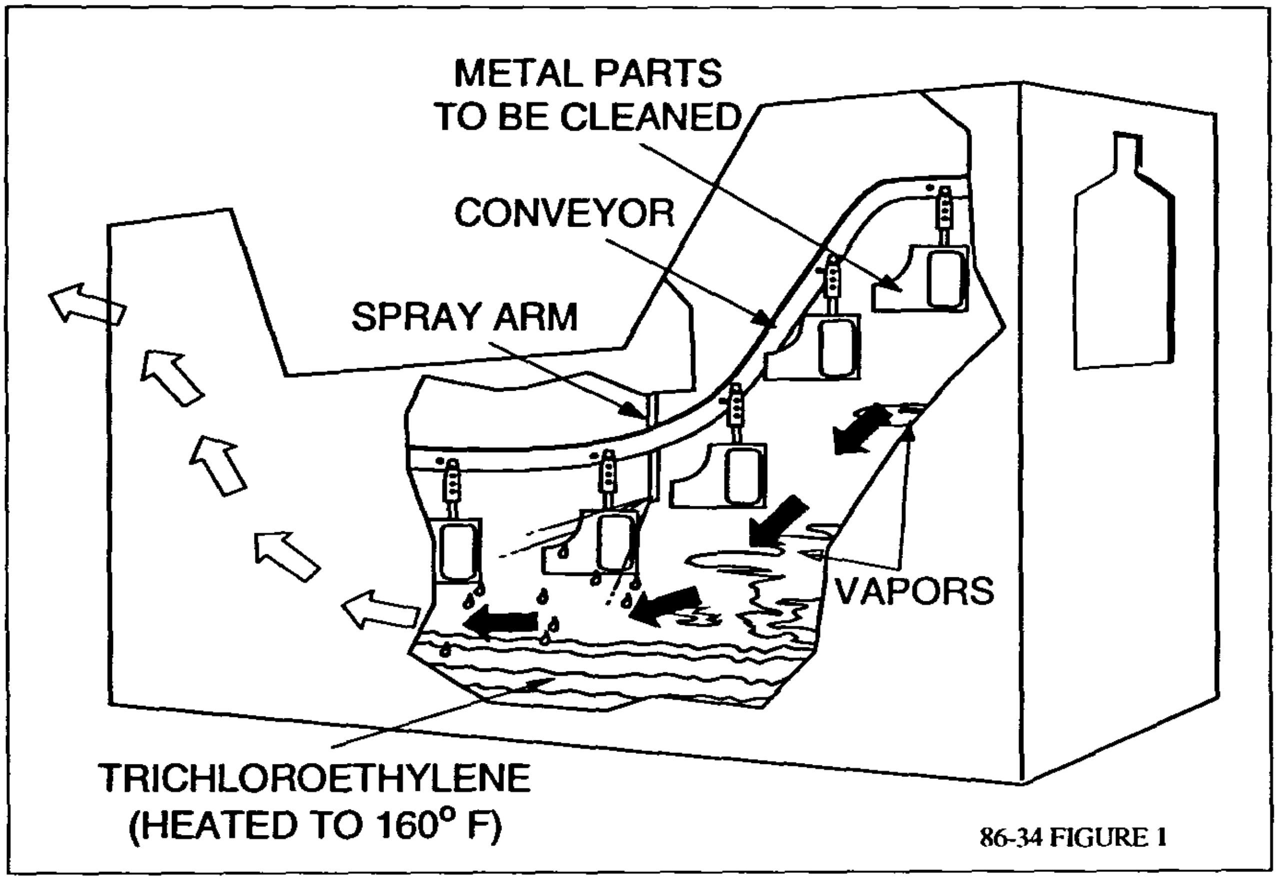
Discussion: All employees who work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed, prior to entering a confined space. These procedures should minimally include:

1. Air quality testing to assure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants.

2. Employee and supervisory training in the selection and usage of respiratory equipment.

3. Development of site-specific working procedures and emergency access and egress plans.

4. Emergency rescue training.



86-34 FIGURE 1

FACE 87-17: Worker Dies While Cleaning Freon 113 Degreasing Tank in Virginia

INTRODUCTION

On November 21, 1986, three workers at a fuel plant were assigned the task of cleaning out a vapor (Freon 113) degreaser. The process involved draining off the solvent and cleaning out the residue on the bottom. A fourth worker who was experienced in the cleaning operation agreed to help. This worker went into the tank and within a few minutes exited the tank and collapsed.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a chemical fuel plant that has 900 employees; engineers, chemists, technical specialists, technicians, and general duty employees. The company has a corporate safety officer with safety specialists in major divisions. An overall safety program is in place with specialized programs for various functions within the company.

Detailed procedures with sophisticated safety measures are provided for the manufacturing process. The company has developed and implemented confined space entry procedures for highly specialized areas of the manufacturing process. However, the entry procedures in place for vapor degreaser do not appear to be adequate to protect workers.

New employees are given a thorough safety orientation by safety specialists within the company. New employees also receive on-the-job training concerning specialized procedures required for specific manufacturing processes. Safety meetings are conducted monthly with all employees to discuss any problems and reinforce existing safety programs.

SYNOPSIS OF EVENTS

On November 21, 1986, a three-man crew (a lead man and two technical operators) on the afternoon shift at the chemical fuel plant was assigned to clean out a vapor/ultrasonic degreasing tank. The degreasing tank is housed in a small building that is used only for cleaning metal parts (see Figure for diagrammatic view and tank dimensions). The chemical name for the solvent used in the degreaser is 1, 1, 2 Trichloro - 1, 2, 2 trifluoroethane, commonly referred to as Freon 113. The chemical formula for this solvent is CCL_2FCCLF_2. The solvent has an odor similar to carbon tetrachloride at high concentrations and is considered to have poor warning properties.

The company has developed written instructions for cleaning out the degreasing tank. These instructions are as follows: 1) every six months the accumulated contaminant in the sump should be cleaned out; 2) shut off heater switches; 3) drain solvent from boil sump and discard; 4) pump solvent from ultrasonic sump and store for future use; 5) turn off main breakers; 6) do not enter until well ventilated and solvent vapors have been removed. <u>Never Work Alone</u>. One operator should stay out of degreaser to assist if the other worker is overcome by fumes; 7) thoroughly clean heaters and sumps."

The three men assigned to clean the degreaser were not familiar with the cleaning procedure so they obtained a copy of the above written procedures. Since this degreaser had not been used for several months, it was not necessary to shut off the heaters (i.e., solvent temperature would not have exceeded the ambient temperature). The three workers proceeded to drain and pump the solvent into 55-gallon drums. Without entering the tank they had drained off all but approximately 1 gallon of solvent. At this point they decided to take their lunch break. On their way back from lunch they met a worker from another section that was familiar with solvent recovery and cleaning of the degreaser. The worker volunteered to assist in the cleaning operation. The men obtained rags to clean the bottom to finish the job. The worker who had volunteered to help and one of the other workers used removable wooden stairs to climb into the tank. Shortly after entering the tank, both men experienced breathing problems and climbed out. The worker who had volunteered collapsed and fell to the floor. The rescue squad was called and the victim was transported to a local hospital where he was pronounced dead on arrival by the attending physician. The second worker did not experience any ill effects.

It was reported that all four men were using air-purifying (half-mask, cartridge type) respirators. These respirators are designed for limited use with organic solvents, not in an oxygen deficient or immediately dangerous to life and health (IDLH) atmosphere.

Below are calculations of the possible saturated concentration of solvent vapors near the workers' breathing zone:

Assuming a static condition with 1 gallon of Freon 113 in the degreaser:

$$C = Pv \times \frac{106}{Pb}$$

C = Saturation concentration in ppm

Pv = Vapor pressure of liquid Freon 113
(284 mm Hg)

Pb = Barometric pressure (760)

$$Pv\ (284\ \text{mm Hg}) \times \frac{106\ (1{,}000{,}000)}{Pb\ \ (760)} = 1316$$

Pv (284 mm Hg) x 1316 ppm/mm Hg = 373,744
C = 373,744

IDLH for Freon 113 is 4500 ppm

CAUSE OF DEATH

Not determined at this time.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should perform a preliminary hazard analysis to determine hazardous areas (physical, chemical, environmental, etc.) within the company and then complete a more detailed task specific job hazard analysis for hazardous task identified. Based upon this analysis existing procedures can be updated or new procedures developed and implemented.

Discussion: Although the employer has detailed procedures in the manufacturing areas, it appears other areas should be evaluated (i.e., solvent recovery/degreaser cleaning), The employer should perform a preliminary hazard analysis of the entire operation to determine hazardous areas, conditions, and tasks that are performed. This evaluation should identify hazards that exist in current safety procedures. A task(s) specific job hazard analysis should be performed to determine that all hazard have been identified and evaluated. Once the task specific job hazard analysis is complete, existing procedures should be updated or new procedures should be implemented to ensure worker safety.

Recommendation #2: The employer should initiate comprehensive policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should minimally include the following:

1. Air quality testing to determine adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;

2. Monitoring to determine a safe oxygen level is maintained inside the confined space;
3. Employee and supervisory training in confined space entry;
4. Employee and supervisory training in the selection and usage of respiratory protection;
5. Emergency rescue procedures;
6. Availability, storage, and maintenance of emergency rescue equipment.

The air quality was not determined before the workers entered the degreasing tank and adequate ventilation was not maintained. The air quality was not monitored for toxic air contaminants and oxygen level. Respirator training and proper maintenance procedures should be provided to all employees.

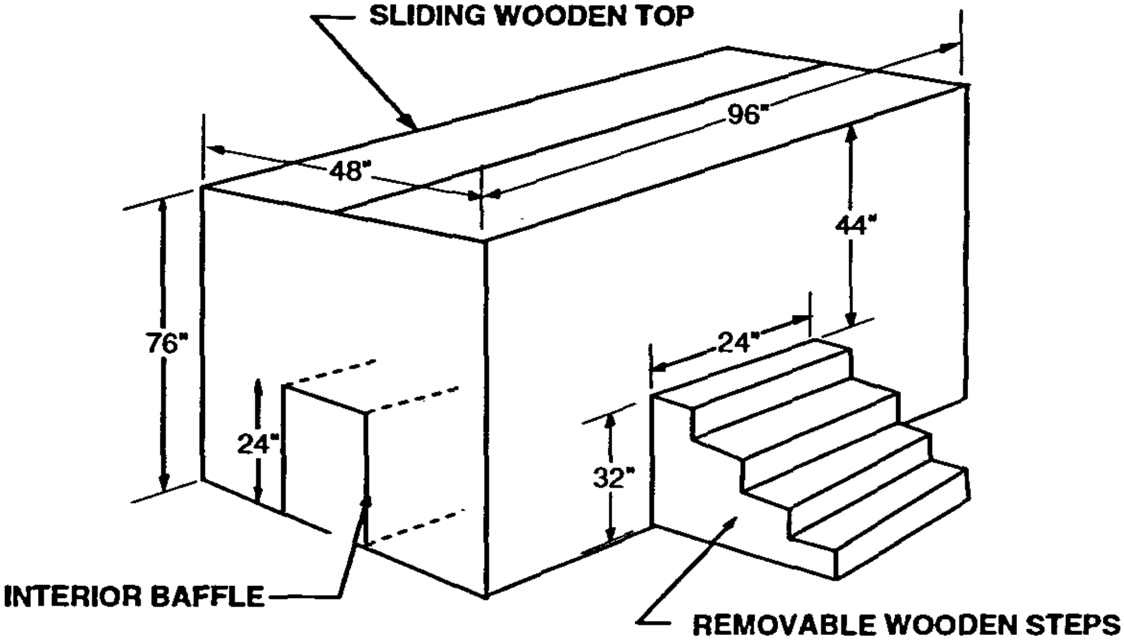
The recommendations in NIOSH Publication No. 80-106, "Working in Confined Spaces" should be used for confined space entry.

Recommendation #3: The employer should develop and implement a more comprehensive respirator program, including either quantitative or qualitative fit testing and training in the use and limitations of air-purifying respirators. The respirator program should be under the auspices of the safety department rather than the medical department.

Discussion: The employer has a respirator program in place. However, this program has several deficiencies. First, the employees were not given the opportunity to wear the respirator in a test atmosphere. The only fit testing done was a negative or positive fit test. Second, the respirator program did not use adequate selection criteria, such as the NIOSH/OSHA Respirator Decision Logic, in assigning respirators to be used in the degreasing operation. The employer issued the employees respirators even though the exposures encountered during normal use were below the appropriate Threshold Limit Value (TLV) or the Permissible Exposure Limit (PEL). Third, it appears that the employees received inadequate training on the limitations and use of air-purifying cartridge for protection against a solvent with poor warning properties. In fact, Freon 113 is reported in the literature as nearly odorless with only slight, transient irritant effects at the PEL. The safety department should have the responsibility for the respirator program, since they have the knowledge and expertise regarding the specific chemicals to which the workers are exposed. Several components of the current respirator program are good; the workers are given physicals to determine if they are capable of wearing a respirator initially and every 6 months thereafter; however, the respirator program needs to be expanded and strengthened to prevent the workers from wearing inappropriate respirators for the task assigned.

VAPOR/ULTRASONIC DEGREASER

87-17 FIGURE. VAPOR/ULTRASONIC DEGREASER



FACE 89-05: Painter Dies in a 140-Foot Fall at a Municipal Water Tower

INTRODUCTION

On September 22, 1988, a 34-year-old male painter died when he apparently inhaled vapors from paint containing xylene, lost consciousness, and fell 140 feet within the vertical water supply pipe of a municipal water tower.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a small contractor specializing in painting water towers. The contractor has been in operation for 7 years and employs seven individuals. The company has no formal safety program and all training is "on the job." The victim had been employed by the company for 3 months, and had worked as a painter for the 2 months prior to the incident.

SYNOPSIS OF EVENTS

The victim was a member of a seven-man crew involved in painting a municipal water tower. The crew consisted of a foreman, four painters and two "groundmen." The crew had worked on this tower for several days prior to the incident.

The tower is a large, elevated water tank supported by seven legs. A 5-foot-diameter riser (vertical water supply pipe) extends from the center of the tank bowl to the ground approximately 145 feet below. Access to the top of the tank is provided by a fixed ladder on one of the tank legs. A hatchway on top of the tank provides access to the interior, with a second fixed ladder leading down to the tank floor. The top of the riser, located in the center of the tank floor, is normally covered with a metal grating; however, this grating had been removed for the painting operation. The interior of the riser contains a fixed ladder leading to the bottom, and a 6-inch-diameter overflow pipe. A 24- by 15-inch port located 5 feet above the bottom of the riser provides access to the interior of the riser from the ground.

Prior to painting the interior of the tower, air lines (for supplied-air respirators) and paint lines (for the paint spray guns) had been run through the bottom port and up the riser to the tank bowl. A 3/8-inch steel lifeline had been run from the top of the riser to the bottom for use during painting of the riser interior. A boatswain's chair (a seat supported by slings attached to a suspended rope to support one person in a sitting position) was suspended at the top of the riser for the painter's use while working inside the riser.

At the time of the incident the victim was working alone, painting the inside of the riser. On previous days, he had applied two coats of paint to the interior. Three other painters were working on the exterior of the tank, and the two groundmen were handling the paint lines and air lines on the ground.

The previous afternoon the foreman had observed the victim exiting the riser in an apparently intoxicated condition. The victim had not been wearing his issued supplied-air respirator, relying instead on a bandanna worn across his mouth and nose. Since the paint being used contained both xylene and methyl ethyl ketone, the victim had probably become intoxicated by breathing vapors containing these chemicals. The foreman reprimanded the victim for not wearing his respirator.

On the morning of the incident, the foreman reminded the victim that he must wear his respirator when painting inside the tank. The victim and one co-worker entered the tank to prepare the equipment for painting the interior of the riser. The victim told the co-worker that he would be painting the riser from the fixed ladder instead of using the boatswain's chair because it was "easier." Once preparations for this work were completed, the co-worker left the interior of the tank. The victim had been painting for approximately 1/2 hour when one of the groundmen, who was located outside near the access port at the base of the riser, heard a noise and observed the paint line falling within the riser. Moments later the victim, who had fallen from the ladder, landed at the base of the riser.

The groundman immediately called to his co-workers that a man had fallen within the riser. Members of the local fire department rescue squad who were training in a field adjacent to the tower, immediately arrived at the scene. One paramedic, who entered the riser through the access port, examined the victim and was unable to detect any vital signs. The victim's body was removed through the access port and cardiopulmonary resuscitation (CPR) was begun. CPR was continued while the victim was transported to the local hospital where he was pronounced dead on arrival.

Fire department personnel involved in the rescue attempt reported that the victim was wearing a safety belt when they reached him inside the riser, but that the belt was not connected to the lifeline within the riser. They further reported that the victim was wearing a bandanna over his face, and that no respirator was present on the body. A police department detective along with one of the victim's co-workers entered the tank approximately 1 1/2 hours after the incident occurred. The police detective reported that vapor was visible in the tank at this time. (The vapor is also visible in photographs taken by the detective.) The victim's supplied-air respirator was found lying on the floor of the tank. Later inspection revealed that the victim had painted the top 8 to 10 feet of the riser before falling.

An autopsy conducted on the victim revealed 0.2mg% xylene in a sample of blood taken from the victim's heart.

CAUSE OF DEATH

The medical examiner's office gave the cause of death as multiple fractures and internal injuries. The fall which produced these injuries was very likely a direct result of loss of consciousness due to acute xylene toxicity.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should ensure that all employees understand hazards associated with their jobs.

Discussion: The employer in this case had provided no formal training, relying instead on on-the-job training to prepare workers for the tasks to which they are assigned. Although the victim had previously been reprimanded for failure to use his respirator, he apparently did not understand that the respirator was essential for his safety during this job and he neglected to wear it, relying instead on a bandanna to protect himself from the chemicals in the paint. A training program providing the employee with knowledge of the possible consequences of breathing the vapors from this paint might have increased his understanding of the potential danger involved in painting without a respirator. In addition, the victim failed to use the boatswain's chair and to connect his safety belt to the lifeline provided for fall protection. A comprehensive safety training program which stressed the importance of using the safety equipment provided by the employer, and which increased employee understanding of hazards and how to utilize protective equipment might have prevented the fatal fall.

Recommendation #2: Employers should verify that safety equipment provided is used by their employees.

Discussion: The victim in this case had been reprimanded the previous day for failure to use his respirator, and had again been reminded to wear it the day the fatality occurred. Employers should ensure that employees understand why they need to use their safety equipment at all times. Appropriate disciplinary action or additional training should be provided when employees continually neglect to use this equipment. Periodic spot checks to verify compliance with safety rules might have encouraged the victim to use his equipment and might have prevented this fatality.

Recommendation #3: Rescue considerations should be addressed by employers whenever workers are assigned to areas where the potential for falls or entrapment exist.

Discussion: In this case the victim was working at an elevation within a confined space. Because of this, the potential for falling or being overcome by chemicals within the confined space existed. Despite the hazards involved, no pre-planning for any type of rescue operation had been made. When working in similar locations employers should develop a written rescue procedure to be used in the event an incident should develop. This rescue procedure should include actions to be taken by other employees as well as prior notification of local fire department/rescue personnel.

FACE 93-08: Three Contract Workers Die while Repairing a Sodium Hypochlorite Tank at a Wastewater Treatment Plant—Virginia

SUMMARY

Three contract workers (the victims) died while repairing the interior rubber lining of an 18,000-gallon sodium hypochlorite tank at a wastewater treatment plant. The three workers were working in a confined space, using extremely toxic and flammable chemicals (toluene, xylene, methanol, isopropanol, and methylethylketone), with no ventilation, no respiratory protection, no standby person, and no emergency procedures. Their last contact was with a maintenance worker at the wastewater treatment plant on September 23, 1992. They were found by the plant maintenance engineer at the bottom of the tank, near the ladder two days later. After the victims were discovered, the fire rescue squad was called. A paramedic (donning respiratory protection), entered the tank and determined all three men were dead. Before the victims could be removed, the tank had to be thoroughly ventilated, to clear the explosive atmosphere. NIOSH investigators determined that, to prevent similar occurrences, employers should:

- *develop, implement and enforce a comprehensive confined space entry program*
- *provide a standby person on the outside of a confined space when work is being done inside the space*
- *require that all contractors have a written safety program specific to the work to be performed.*

INTRODUCTION

On September 25, 1992, three contract tank repair workers (the victims), a 39-year-old male foreman, and two male laborers, ages 53 and 22, were found by the plant maintenance engineer inside a sodium hypochlorite tank at the wastewater treatment plant (WWTP). On November 23, 1992, the Virginia Department of Labor and Industry, Occupational Safety and Health Program (VAOSH), notified the Division of Safety Research (DSR) of these fatalities and requested technical assistance. On December 16, 1992, an environmental health and safety specialist from DSR conducted an investigation of this incident. Representatives of the WWTP, county safety specialists, and VAOSH compliance officers were interviewed and photographs were taken of the incident site.

The employer in this incident was a contractor that specialized in repairing and fabricating storage tanks. The company had 13 employees, including the company owner, a secretary, 2 shop workers, 2 welders, 3 rubber workers (the victims), 2 sales personnel, and 2 field workers. The employer had entered into an agreement with a county WWTP to spark test the interior of two 18,000-gallon, rubber-lined, horizontally mounted sodium hypochlorite tanks. After testing was completed, the contractor provided the county a written report of the test results and the cost of repairs. The county hired the contractor to repair the tanks in accordance with the test results. The contractor did not have a written safety program or a confined space entry program; therefore, the contractor hired a consultant to provide training to the employees on hazard communication, which included the chemicals used by the contractor, the effects of these chemicals on the body, and the need for ventilation in enclosed spaces.

The county that issued the contract has a comprehensive safety and confined space entry program; however, the contractor was not required to comply with the county's safety policies. The contract required the contractor to follow all applicable federal and state regulations.

INVESTIGATION

The site of this incident was a wastewater treatment plant for a large metropolitan area. The WWTP had eight rubber-lined chlorination tanks, six of which were repaired in 1989. The two remaining tanks were to be repaired in 1992. The rubber lining of these two sodium hypochlorite tanks had been spark tested (an electronic test device used to locate holes or imperfections in a rubber lining) by the contractor in July, 1992. The tests revealed that the rubber lining of the tanks was in need of repair.

The three rubber workers (1 foreman and 2 workers) arrived at the WWTP at 8 a.m. on September 22, 1992, and met with the plant maintenance engineer to discuss the proposed repair work on the tanks. Since the workers did not have hard hats or an atmospheric gas testing instrument, the plant maintenance engineer provided the workers with hard hats and an atmospheric testing instrument capable of testing oxygen content, flammability, and hydrogen sulfide, and instructions on how to use the instrument. The plant maintenance engineer also told the foreman that the tanks were confined spaces and that the foreman would be required to test and monitor the atmosphere. The foreman stated they had airline respirators in the truck and requested permission to use the compressed air system in the building. The plant maintenance engineer told them to use the air piping connection next to tank number 4; however, this type of air supply system did not have provisions for supplying breathing-quality air. The foreman asked if there were any equipment rental places in the area where they could rent an air mover. The plant maintenance engineer gave the foreman the name of the closest equipment rental shop, assuming they would rent appropriate ventilation equipment. Before leaving, the plant maintenance engineer told the men where the telephone was located, and directed them to dial 911 for emergency assistance or contact the plant operator to reach him by radio.

The next morning, September 23, 1992, at the beginning of the shift, the plant maintenance engineer observed the three workers at their van outside the building that housed the chlorination tanks and stopped to talk. The foreman told the plant maintenance engineer that the day before, after approximately 6 hours of use, the atmospheric gas test instrument had been displaying a low battery reading. The plant maintenance engineer told him he would need to exchange the instrument when a low battery reading was indicated. The three workers then went into the building to continue the repair work on the interior of the tanks. They carried a gas testing instrument with them; however, the plant maintenance engineer did not know if they took the instrument they had used the day before or another one.

A maintenance worker for the WWTP was doing metal repair work to the interior of tank number 3 while the three rubber workers were working in tank number 4. The two 18,000-gallon tanks were approximately 6 feet apart. The maintenance worker needed to talk to the foreman about the metal patch work he was doing, so he went down into tank number 4 via the 24-inch-diameter top opening. The maintenance worker indicated the fumes were so bad, he stated, "I hope nobody smokes, because if anybody lights a match, this place is gonna blow." "I told them I needed to talk with them but I couldn't stand it in there." The main- tenance worker was in tank number 4 for approximately 30 seconds. He noted that all three workers were wearing only their street clothing, and the only respiratory protective equipment in use was a dust mask worn by one of the workers. There was no standby person positioned outside of the tank. The maintenance worker exited tank number 4, followed by the three workers. The maintenance worker asked how do you breathe in that tank, and they replied they were used to it, but they needed some fresh air anyway. They were using chemicals that contained toluene, xylene, methylethylketone, isopropanol, and methanol for the rubber repair. The foreman advised the maintenance worker not to leave any sharp edges in tank number 3. The maintenance worker then re-entered tank number 3 to finish the metal patch work. When he left tank number 3 at 12:45 p.m. he heard the rubber workers grinding in tank number 4.

Two days later, on September 25, 1992, the plant maintenance engineer stopped by the work site (sodium hypochlorite building) at 9:30 a.m. to see how the rubber repair work was progressing. He climbed the fixed ladder to the top of tank number 4; however, the interior of the tank was dark so he borrowed a flashlight from another county employee. Looking into the tank opening, he saw the three rubber workers lying on the bottom of the tank near the ladder. He immediately telephoned 911.

The hazardous materials (hazmat) rescue team arrived on the scene within a few minutes. They tested the atmosphere in the tank and determined it was flammable. A hazmat paramedic wearing a self-contained breathing device was lowered into the tank and verified that the three men were dead. The paramedic exited the tank, and before the victims were removed, the hazmat team thoroughly ventilated the tank to eliminate the possibility of fire or explosion.

The only type of ventilation equipment at the site at the time of the incident was a 20-inch-square house fan, which was not approved for flammable atmospheres. It is not known if this fan was ever used while the workers were inside the tank.

CAUSE OF DEATH

The medical examiner listed the cause of death for all three workers as toluene poisoning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers (the contractor) should develop and implement a comprehensive confined space entry program.

Discussion: Although the employer (the contractor) had provided hazard communication training to the employees, they were not given specific training on confined space entry or the selection and use of respiratory protection. The victims were working with toxic chemicals in a confined space. They had no respiratory protection, no ventilation system, no standby person, no worker rescue retrieval system, and no emergency rescue plan. Although the county had a comprehensive confined space entry program, the contract did not require the contractor to have written confined space entry procedures, or to provide training on the selection and use of respiratory protection. Additionally, it is unclear whether the workers were familiar with the hazards of the toxic chemicals they were using in the confined space.

Employers should develop and implement a written confined space entry program to address all provisions outlined in the following NIOSH publications: Working in Confined Spaces: Criteria for a Recommended Standard [Pub. No. 80-106]; NIOSH Alert, Request for Assistance in Preventing Occupational Fatalities in Confined Spaces [Pub. No. 86-110]; A Guide to Safety in Confined Spaces [Pub. No. 87-113]; and NIOSH Guide to Respiratory Protection [Pub. No. 87-116].

A confined space entry program should include the following:

1. written confined space entry procedures

2. evaluation to determine whether entry is necessary

3. issuance of a confined space entry permit
4. evaluation of the confined space by a qualified person

5. testing and monitoring the air quality in the confined space to ensure:

   - oxygen level is at least 19.5%
   - flammable range if less than 10% of the LFL (lower flammable limit)
   - absence of toxic air contaminants

6. training of workers and supervisors in the selection and use of:

   - safe entry procedures
   - respiratory protection
   - environmental test equipment
   - lifelines and retrieval systems
   - protective clothing

7. training of employees in safe work procedures in and around confined spaces

8. training of employees in confined space rescue procedures

9. conducting regular safety meetings to discuss confined space safety

10. availability and use of proper ventilation equipment

11. monitoring of the air quality while workers are in the confined space.

Recommendation #2: Employers should provide a standby person on the outside of a confined space when work is being done inside the space.

Discussion: The employer had assigned three men to this tank repair job. All three men were working in the tank, with no one stationed outside to call for help in case of emergency. Although the atmosphere in the confined space was considered safe because the county had cleaned and tested the tank, the toxic chemicals being used in the rubber repair, changed the atmosphere from safe to hazardous. The standby person on the outside should be in constant visual or audible communication with the workers on the inside, and should assist in adjusting lifelines, airlines, and other safety equipment as necessary. In the event of an emergency, the standby person is to call for help and must not enter the confined space in a rescue attempt.

Recommendation #3: Employers should require that all contractors have a written safety program specific to the work to be performed.

Discussion: Although the employer had a written comprehensive safety program, which included confined space entry procedures, the contractor was not required to have a written safety program or confined space entry procedures. The contract language should address specific safety and health requirements for any contractors. Additionally, worker safety and health issues should be included as one of the evaluation criteria for selecting the appropriate contractor.

REFERENCES

National Institute for Occupational Safety and Health, Criteria Document for a Recommended Standard, Working in Confined Spaces. DHHS (NIOSH) Publication No. 80-106, December 1979.

National Institute for Occupational Safety and Health, Request for Assistance in Preventing Occupational Fatalities in Confined Spaces. DHHS (NIOSH) Publication No. 86-110, January 1986.

National Institute for Occupational Safety and Health, A Guide to Safety in Confined Spaces. DHHS (NIOSH) Publication No. 87-113, July 1987.

National Institute for Occupational Safety and Health, Guide to Respiratory Protection. DHHS (NIOSH) Publication No. 87-116, September 1987.

Atmospheric Hazards

Toxic Gases

FACE 84-11: Fire At A Wastewater Treatment Plant

SUMMARY

At approximately 10 a.m. on December 29, 1983, a fire occurred in the floating cover of a digestion tank at a secondary sewage treatment plant. The fire caused the asphyxiation of two laborers (54 and 34 years of age) who were preparing the tank for painting. The attending medical examiner notified DSR about this incident approximately three hours after it occurred and requested technical assistance with taking and analyzing air samples and collecting information about the circumstances.

SYNOPSIS OF EVENTS

The company employing the victims was contracted by the city government to clean and repaint two sewage digestion tanks at its wastewater treatment plants in the state. The two victims had started working for this company in August, 1981.

The company had completed work on the Number 1 digestion tank and had begun work on the Number 2 tank. In October of 1983, this tank had been taken off line and a subcontractor had cleaned the tank of sewage. The company then sandblasted, scraped, and repainted the inside of the tank. During this activity, propane cylinders and salamander heaters were used inside the tank to minimize condensation and the smoke ejector was used to ventilate this workplace. By Christmas week, the exterior surface of the floating cover was being prepared for cleaning and repainting.

The floating circular cover consisted of a confined space of approximately 6,400 cubic feet with a five-foot ceiling height at the apex (see Figure 1). The only entry into the cover was through a 30-inch diameter manhole located approximately ten feet from the apex. Due to the cold and windy winter weather, the carpenters built a temporary roof (2 by 4 studs covered with 8 to 10 mil. plastic sheeting) over the floating cover.

During the week of the incident, preparations were made for painting the exterior of the floating cover. On Monday and Tuesday (December 26 and 27), the areas above and within the cover were heated with propane fueled salamanders using 100 pound cylinders through a regulator and hose assembly. On Wednesday (December 28), it rained and one or both of the victims helped clear water from the temporary plastic roof. The job foreman was not sure if or how the heaters were used that day. On the day of the incident, the two laborers (victims) and four carpenters reported to the wastewater treatment plant at approximately 7 a.m. The victims were to heat the floating cover so that it could be painted that afternoon. The carpenters were there to erect a temporary enclosure for air compressors located on the ground by the side of the Number 2 digestion tank. At the beginning of the shift, the laborers checked the propane cylinders that had been used inside and on top of the floating cover and at other location(s) at the plant. They reported to the job foreman that six of seven 100-pound cylinders were empty. After collecting these empty cylinders, the foreman transported them for refilling and then returned them to the laborers. A morning coffee break was then taken at around 9:30 a.m. and the carpenters and laborers went back to the floating cover while the carpenters resumed work on the temporary enclosure.

At approximately 10 a.m., one of the carpenters who was working from a ladder saw flames shooting four feet above the plastic sheeting of the temporary roof. He reported hearing a noise or roar and thought the flames lasted approximately 15 seconds. By the time carpenters arrived on the top of the cover, the flame had apparently gone out but smoke was issuing from the manhole. The carpenters were uncertain about the location of the laborers. They found one salamander operating in a normal (burning) mode and two propane cylinders lying on top of the floating cover. Carrying a flashlight and with a handkerchief over his face, one carpenter entered the manhole to look for the laborers. After going only a few feet, he began to choke on the smoke and decided to leave the interior of the cover. The carpenters then placed the 24-inch diameter Super Vac smoke ejector on a scaffold section over the manhole in an attempt to remove the smoke. This ejector had a rated capacity (free air) of 10,000 cfm, and therefore, given adequate make-up air from the outside, calculations show that it could have cleared the area to 1 percent of its original concentration of smoke within approximately 3 minutes.

After being notified at approximately 10:10 a.m., fire fighters from two local fire departments arrived at the scene. The first arriving unit stretched a 1 1/2-inch water line into the cover but apparently found no fire. Also, one fire fighter and a carpenter removed one propane cylinder from inside the manhole. Two fire fighters, wearing self-contained breathing apparatus, entered the floating cover. They reported heavy smoke, low visibility and a "propane like" cloud of vapor hanging over one area of the confined space. They subsequently found and removed a second cylinder, hose and regulator assembly, and salamander from inside the cover a few feet from the manhole. Both cylinder valves were reported to be closed and there was some question as to whether or not one cylinder was attached to the salamander.

After entering the cover, the two fire fighters made a counterclockwise sweep from close to the center of the tank. One hard hat was found approximately 20 feet from the manhole. During a second sweep more towards the outside of the cover, a helmet liner was found and then the two bodies. Both victims were found lying face down and no vital signs were present (see Figure 2). The older victim had overalls which were singed and a cigarette lighter was found near his body. The two victims were pronounced dead on the scene by the attending medical examiner and were transported to the morgue at a local hospital.

The responding fire fighter units also took combustible gas reading (presumably with an MSA Model 2 Explosimeter) and values of 10 to 25 (percent LFL) were reported. However, no oxygen or temperature measurements were reported nor was the calibration of the instrument known.

The area involved in the fire was confined to roughly a circular patch above the manhole. Several 2 by 4 boards used to support the plastic roof were badly burned above the manhole. Discoloration extended upward to but not beyond the crossbeams. Areas of plastic sheeting were melted around the burned board, but did not extend as far as the discoloration.

The police confiscated the two 100-pound propane cylinders, one regulator hose assembly on one salamander heater found within the floating cover. The police reported that the hose and regulator showed some previous damage and that the reset button on the automatic pilot valve stuck in the open position and appeared to be bent. The heater, regulator/hose and tanks located on the top of the floating cover were directly observed in the field by the NIOSH research team. The reset button on this pilot valve had been wired down so that it remained in the open position at all times.

MEDICAL FINDINGS

Both victims died from acute carbon monoxide intoxication. The younger victim had a blood carbon monoxide saturation of 78 percent while the older victim's blood carbon monoxide saturation was 73 percent.

The younger victim had no cutaneous burns. The hair at the sides and back of the head (in a distribution which would be of the hair not covered by a cap), the eyebrows, and the mustache were singed. Toxicologic analysis of the blood was negative for ethyl alcohol and drugs. Urine analysis was negative for common acidic, basic, neutral and narcotic drugs and positive (trace amounts) for benzodiazepines. The endotracheal air specimen was positive for propane.

The older victim had second degree burns on the backs of his hands and his face. His scalp was lacerated and there were abrasions on one side of his face. Toxicologic analysis of blood and urine samples were negative. The endotracheal air specimen was positive for propane.

CONCLUSIONS

Combustible gas measurements and oxygen reading taken at the incident site by the research team showed no concentration of combustible gas and 21 percent oxygen at all locations. Air samples taken after cover ventilation by the smoke ejector and the next day after the tank had been allowed to "sit" overnight without ventilation, failed to show any significant concentration of flammable gas. Infrared analysis of the grab samples indicated hydrocarbons present in only ppm concentrations similar to those found as background in room air. More sensitive charcoal tube analysis failed to find methane but indicated the presence of propane.

Given these lab results and the toxicologic findings of propane in the endotracheal samples from both victims, the probable fuel source was propane. Both tanks removed from inside the cover after the incident were weighed (gross) and seem to contain most, if not all of the contents. Therefore, the probable source of propane was one (or more) of the empty cylinders that had been refilled the morning of the incident.

Consideration was given to a probable ignition source. Operations of sand blasting, scraping or painting had not begun the morning of the incident as evidenced by the failure to find equipment on the scene for any of these operations. Witnesses stated that the younger victim smoked. A cigarette lighter (possibly belonging to the younger victim) was found near the body of the older victim. A co-worker stated that the older victim frequently asked to borrow lighters or matches to start the heaters. Smoking material (discarded cigarette packs and butts) were found on top of the cover and in the digestion tank but not inside the floating cover. The salamander, if burning, would provide an adequate source of ignition for a flammable atmosphere. It is uncertain that it was burning at the time of the fire. Other than the lighter or salamander, no other credible source of ignition could be found.

Since the fire occurred in a confined space, the presence of oxygen throughout the tank cannot be taken for granted. Oxygen measurements were reportedly not taken until at least 3 1/2 hours after the fire and then only after extensive ventilation efforts with the smoke ejector. Oxygen deficiency could result from either consumption (chemical reaction) or displacement. Chemical reaction with the steel tank walls (rusting) seems unlikely since 21 percent oxygen was found in all measurements taken after the fire. In a confined space with the volume of the floating cover, oxygen depletion and the concurrent displacements by the products of combustion would not allow complete combustion of 100 pounds of propane. Therefore, if a full cylinder attached to a salamander heater had been placed inside the cover and left to provide continuous heat, both the burner and pilot flames would eventually extinguish.

The heater's control valve along with the heater, cylinder and regulator are currently being tested by an independent laboratory. If the reset button on the valve was defective (stuck in the open position) and the flame extinguished from the lack of oxygen, propane would continually be released until the cylinder was emptied. Subsequent mixing with the confined space environment would be incomplete with a higher oxygen level around the only opening, the manhole. Propane concentrations would vary nearly inversely with oxygen concentrations from low around the manhole to very high in stagnant pockets, especially near the floor of the cover. This incomplete mixing may be one explanation of why one or both victims did not react to the odor of the mercaptan in the propane while standing near the manhole.

A factor in the occurrence of this fatal incident was the cold weather. The painting of floating covers of other digestion tanks had been successfully completed by the company in warmer weather without the need to provide supplemental heating. The company had never before needed nor attempted to heat the inside of a floating cover.

Another factor was the lack of recognition of the floating cover as a confined space, both in terms of a limited environment and limited entry/escape. All company employees interviewed (from the co-workers, job engineer and job foreman to the president of the company) did not fully understand the hazards associated with this confined space.

Insufficient information precludes conclusion about the location of both victims at the time of the fire. Either both were inside the cover or the older victim was inside and the younger victim, a member of a local rescue squad, could have attempted a rescue and entered the confined space after the fire.

Apparently equipment was not available for the workers to assess the combustible nature of the environment. Neither were emergency respirators readily available. Had either of these items been accessible, the fatal outcome might have been averted. No confined space entry procedures or precautions were followed (for example, testing of the atmosphere, life support equipment, rescue, etc.).

In conclusion, and based upon available information, the major elements of a hypothetical reconstruction are as follows:

1. Day(s) before the fire, workmen place a salamander and propane cylinder(s) inside the floating cover for space heating.
2. The salamander burns until the available oxygen for combustion is depleted and the products of combustion become partially inert within the confined space. Also, based upon alleged previous damage, the regulator and/or hose may have leaked propane.
3. The pilot and burner flames go out.
4. The flame-out safety device does not prevent unburned propane from being fed through the burner and the tank contents are depleted.
5. The workmen return and find the cylinder empty and remove it for refilling.
6. The workmen lower two refilled 100-pound propane cylinders through the manhole.
7. One or both workmen enter the confined space.
8. One or both workmen connect or attempt to connect the full cylinder.
9. Ignition occurs in the area around the manhole, burning one workman and igniting his clothing. Ignition may have resulted while attempting to light the salamander.
10. Based upon alleged fire damage, fire may have flashed to the leaking regulator and/or hose and damaged them.
11. Fire propagates (approximately 15 seconds) until areas with concentrations outside the flammable range are reached.
12. Flame extends outside the manhole and impinges on plastic roof, melting the plastic and igniting the 2 by 4's.
13. One or both men crawl to escape flames and both are overcome by oxygen deficiency and carbon monoxide (note carboxyhemoglobin level).
14. The burning clothes of one workman are extinguished by the oxygen deficiency.

RECOMMENDATIONS

It is important for all employees (including management) in an organization to be able to recognize work environments which are confined spaces and to fully comprehend the potential hazards associated with those environments. In organizations where such recognition and comprehension are not sufficient, further education and reinforcement efforts are needed.

Once a confined space is identified, any work activity associated with that space should follow the guidelines recommended by NIOSH in its document, "Criteria for a Recommended Standard...Working in Confined Spaces: (DHEW (NIOSH) Publication No. 80-106, December 1979). These recommendations include specific procedures for entry and rescue, permit systems, training, testing and monitoring, work practices, etc.

Future efforts should evaluate the feasibility of designing and/or providing automatic pilot valves whose reset buttons cannot be intentionally or unintentionally made inoperative.

Finally, victims of confined space incidents are often rescuers who attempt to save a worker(s). In this case, there was a near-miss with one carpenter. Also, the possibility exists that the younger victim could have died as the result of a rescue attempt. All organizations that have employees who work in confined spaces should increase educational efforts dealing with entry and proper rescue responses.

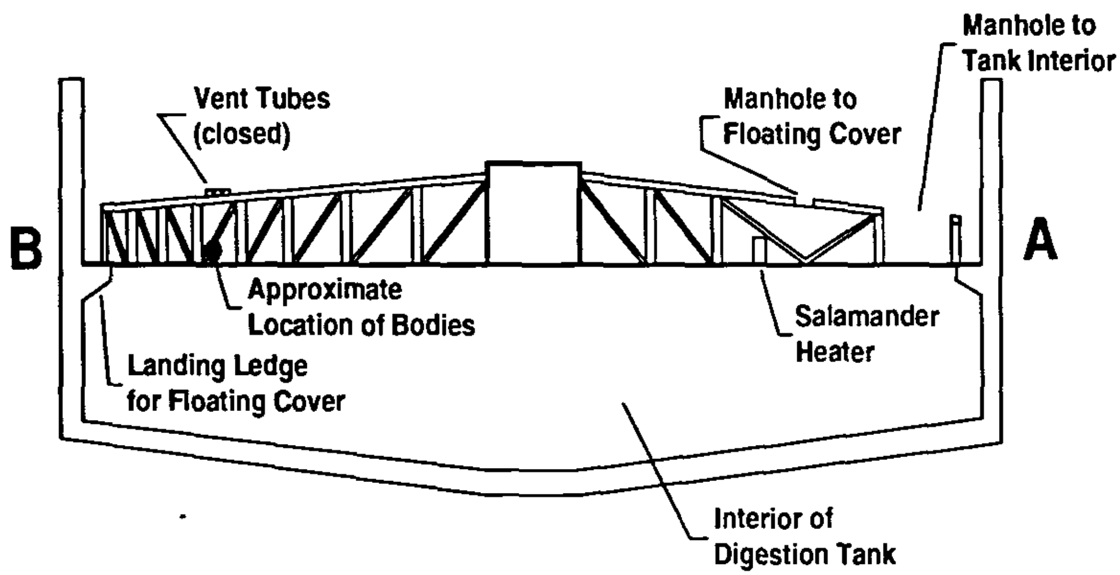


Figure 1 (84-11). Side view of digestion tank with floating cover.

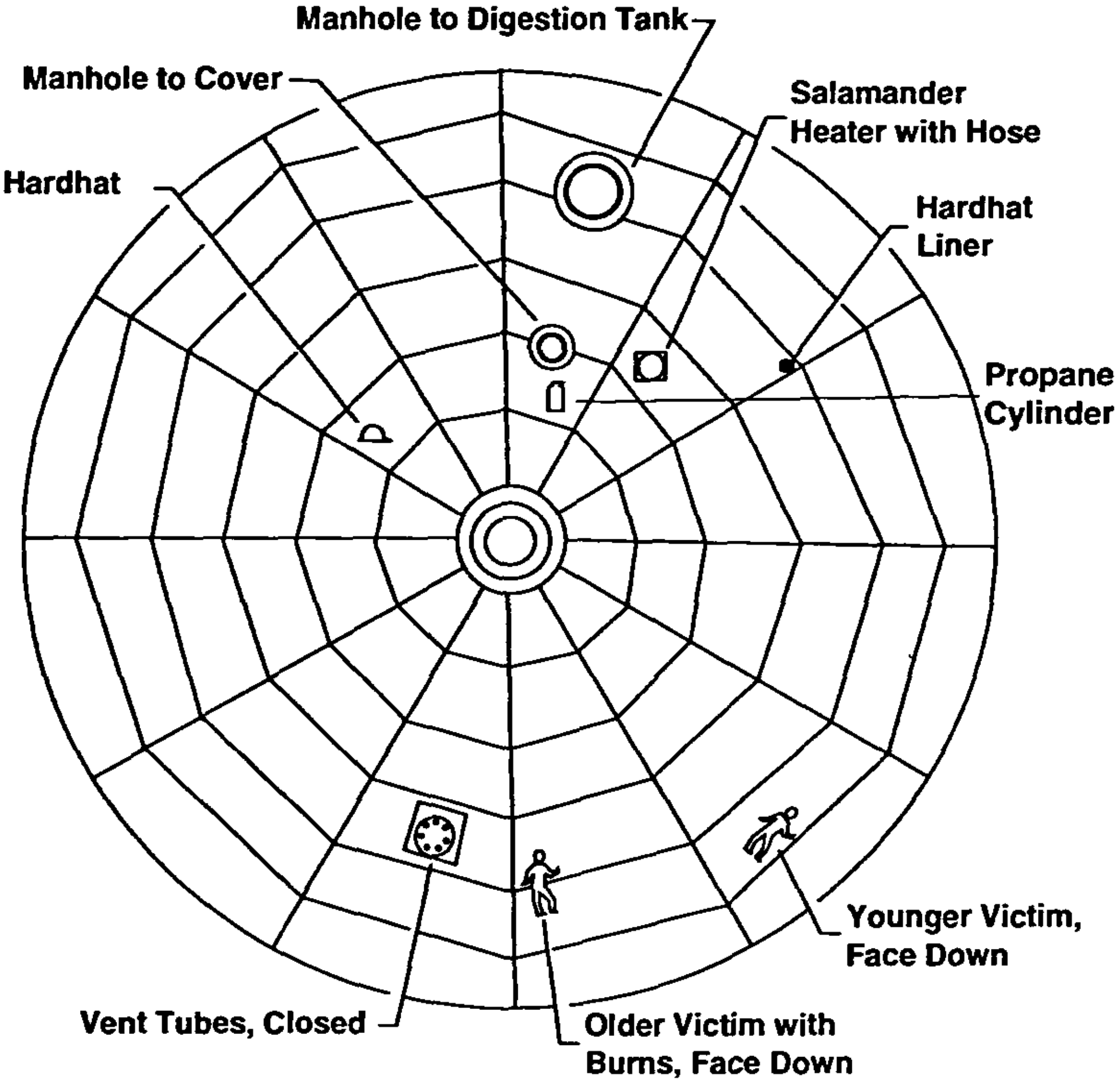


Figure 2 (84-11). Top view of digestion tank showing location of victims.

FACE 84-13: Two Confined Space Fatalities During Construction of a Sewer Line

INTRODUCTION

At approximately 3:26 p.m. on March 8, 1984, a city fire department received a report that a man was down at a sewer construction site. When the firemen arrived on the scene, they learned that two workers were down in the newly constructed sewer. One worker was an employee of the company contracted to construct the sewer. The other worker was a state inspector with the State Department of Transportation. The two workers were removed from the sewer and pronounced dead at the scene. Subsequent autopsy indicated cause of death to be carbon monoxide (CO) poisoning. As a result of the rescue effort, 30 firemen and 8 construction workers were treated for CO intoxication and/or exhaustion.

SYNOPSIS OF EVENTS

In the process of constructing the interstate highway, the contractor had to construct several thousand feet of sanitary sewer line composed of 66 inch ID by 16 feet long sections of concrete pipe. This new line had to tie into an existing line. The upstream portion of the existing line would be abandoned after completion of the new line. (Figure)

The existing line had to be kept in service during construction. A by-pass line had to be built around the connection point of the new and existing lines. This was done by tapping a 30 inch by-pass line into the existing line, upstream of the connection point, and tying the by-pass line into a newly constructed manhole (No. 1) at the connection point. In order to keep sewage from entering the construction area of the connection point, the pipe was diked by sand bags several feet upstream of Manhole No. 1. The dike was left in place for approximately 1 month while the contractor continued to lay pipe.

During this time, sewage seeped/flowed past the dike and extended approximately 480 feet (30 sections) into the newly constructed line. This sewage had to be removed before the contractor could proceed with grouting the pipe joints.

The contractor replaced the sand bag dike with a steel plug to eliminate further seepage. A gasoline engine driven pump was placed upstream of the plug so that the existing sewage could be removed from the pipe. The pumping procedure required a laborer to enter the new line at Manhole No. 2, walk downstream approximately 1,200 feet to the pump, fuel the gasoline engine, start it and exit back through Manhole No. 2. This procedure was performed on a 3-day cycle. At no time was the atmosphere in the pipe tested prior to entry, nor was there mechanical ventilation to remove air contaminants.

This procedure was not removing the sewage quickly enough and it was decided to increase this cycle to three times per day. On March 8, 1984, at 8:30 a.m., the labor foreman and one worker (his son) followed the procedure of starting the pump.

Around 3 p.m. on the same day, the same two workers returned to Manhole No. 2 to repeat the procedure of refueling the pump. However, Manhole No. 2 had been covered with plywood and framed over in order to have concrete poured the following day. So the two had to enter the pipe from the point of construction. Each carried a flashlight and the worker carried a can of gasoline. They began walking the 3,000-foot distance to the pump. After passing Manhole No. 3, they took a short break and proceeded past Manhole No. 2 toward the pump. Approximately 750 feet past Manhole No. 2, the two came to the board used to mark the water line. While the foreman was moving the board and counting the pipe length to determine how far the water had receded, the worker went on ahead to fuel the pump and start it. After noticing haze in the sewer, the foreman told the worker to keep talking so he could tell if anything was wrong. Shortly the foreman heard the worker attempt to start the pump four times and then say "I feel dizzy." The foreman ordered the worker out of the pipe. The worker started to leave, dropping his flashlight and stumbling in his unsuccessful attempt. By the time the foreman reached the worker, the worker was down and unresponsive. After failing to carry the worker out, he propped him up out of the water and told him he was going for help. The foreman walked, crawled, and stumbled 3,000 feet to the outside to report the worker was down near the pump. The only ill effect experienced by the foreman was a severe headache.

Seven workers went into the pipe in an attempt to remove the downed worker. At the same time the state inspector got into his truck and drove to Manhole No. 2, where he removed the plywood cover and entered the sewer. The state inspector proceeded towards the area where the worker had been reported down. The underground superintendent also entered the sewer at Manhole No. 2 but exited after 2 or 3 minutes. Six of the seven workers who entered the pipe at the portal exited at Manhole No. 2. The seventh man reached the worker but was unable to remove him. The company safety director entered the sewer at Manhole No. 2 and reported passing the seventh worker and reaching the deceased. Shortly after 3:30 p.m., the seventh worker and the safety director exited the sewer Manhole No. 2.

At this time three firemen arrived at the scene and entered Manhole No. 2. The firemen were equipped with 30-minute self-contained breathing apparatus (SCBA). In addition to the bulkiness of the SCBA, they were hampered by the curved and slick inner surface of the sewer. Initially, the firemen were told the victims were down approximately 150 feet into the sewer. However, they had to travel 500 to 600 feet to reach the victims. As their air supply decreased, the firemen placed one SCBA on the victim (the state inspector) who was still breathing, and resorted to buddy breathing to exit. The state inspector was removed through Manhole No. 2 at approximately 4 p.m. He was pronounced dead at the scene. Subsequent autopsy indicated his carboxyhemoglobin level was 50 percent and his pO_2 was 0 percent. The laborer was removed through Manhole No. 2 at 5 p.m. He was also pronounced dead at the scene. His carboxyhemoglobin level was 56 percent and pO_2 level was not available.

CONCLUSIONS /RECOMMENDATIONS

Combustible gas measurements, oxygen and carbon monoxide levels were taken 22 hours later at the incident site by an industrial hygienist. Oxygen level was 19 percent and concentrations of CO were 600 ppm. The industrial hygienist estimated that concentration of CO next to the pump on the day of the incident was 2000 ppm. An air sample taken the following day revealed readings of 19 to 20 percent oxygen. Trace amounts of H_2S were also recorded.

Given the industrial hygiene survey results and the toxicologic findings, the cause of death was determined to be exposure to high concentrations of CO, a by-product of the gasoline-powered pump, in an area with no natural ventilation, i.e., a confined space.

While the following list of recommendations is not exhaustive, it does cover some of the salient points which, if implemented, could have prevented this fatal incident:

1. When the existing sewer was activated (passing through Manhole No. 1), no plans were made to prevent the sewage from flowing into the newly constructed sewer.

Recommendation: An analysis of the conditions surrounding the connection at Manhole No. 1 should have generated several safe alternatives for an effective temporary barrier in the new sewer which also considered safe atmospheric conditions.

2. A gasoline-powered pump was installed inside the sewer (a confined space) which was known to have almost no ventilation. Neither workers nor pump could have operated efficiently in the sewer. The rich mixture created by depletion of O_2 increased the levels of CO.

Recommendation: The pump should have been located on the outside of the sewer with a hose running to the sewage via an access hole or an electric motor driven pump should have been considered.

3. A static ventilating condition was created when the plug was installed in the new sewer next to Manhole No. 1.

Recommendation: Since it was necessary for workmen (either those servicing the pump or those planning to do the grouting) to enter the sewer, adequate ventilation should have been provided. If ventilation could not create a safe atmosphere, the use of SCBA should have been mandatory.

4. Workers were permitted to enter an untested atmosphere of a confined space.

Recommendation: The atmosphere should have been tested by a qualified person prior to entry by workers.

5. Both fatal victims lacked experience in working in confined spaces.

Recommendation: If workers are expected, as part of their job, to work in confined spaces, they should be given appropriate training.

6. The established corporate safety procedures for work in confined spaces was not implemented.

Recommendation: Management, including local supervisors, should comply with approved corporate policy and procedures for confined space entry as well as other rules and regulations approved by the corporate president. The policy and procedure should include entry into confined spaces for rescue efforts.

7. Workers were not able to adequately assess their risk of personal injury of the tasks they were required to perform, much less the additional hazards associated with rescue efforts.

Recommendations: Management should develop a safe job procedure for all routine tasks starting with high risk tasks and specifically establish a policy and procedure regarding rescue efforts.

EMERGENCY RESPONSE RECOMMENDATIONS

As a result of evaluation of the rescue events at the scene and the actual response by the fire personnel in this emergency, five recommendations have been made. These recommendations are meant to help improve overall response and practices in terms of buddy breathing, training, optimal selection and deployment of long duration SCBA, and use of short duration ESCBA during rescue efforts.

1. The fire department should reassess the issue of buddy breathing in regard to the specific confined space pipe incident.

   In view of the actual field actions of fire personnel and the performance of the SCBA under these conditions, the following questions are appropriate:

   - Was previous training provided the firemen adequate or should training be modified to cope in a more efficient manner in a future incident?

   - Should buddy breathing be used at all?

   All the information gained from this incident should be explored and used in arriving at and setting a policy for the use of buddy breathing.

2. The fire personnel who used buddy breathing during this incident should share their personal experience with all other fire personnel in the Department.

   These firemen should relate their experiences with training academy practices. This should be related to the rescue of civilians as well as other fire personnel and all problems encountered. This experience sharing will result in increased awareness of the dangers involved, the appropriate methods or technique to use in a confined space entry situation, and recommendations to other fire personnel based on actual field exposure. Education of fire personnel in the use of buddy breathing under emergency situations based on actual field experience gained in this specific incident, should be a beneficial mode of training.

3. Fire department officials should consider the variety and types of long duration SCBA available for emergency response requiring extended rescue time and efforts.

   Although one-hour closed-circuit compressed oxygen SCBAs are available, it may be desirable to use newly approved one-hour open-circuit, compressed-air SCBAs if the oxygen units are to be used in a potential fire/flame exposure situation. Also, the breathing air temperature would be cooler utilizing open-circuit units vs. the closed-circuit units. The low profile and fit of the closed-circuit SCBA are advantageous over the large profile type open-circuit where confined space entry is necessary. Such consideration of available, alternative units can optimize selection and availability of specific long duration SCBA, which can contribute to the efficient and safe use of various types of respiratory support on a specific application basis.

4. The deployment of long duration SCBA at specific fire fighting companies in relation to their location within the city is important.

   Consideration should be given to those exposures (confined spaces, shopping centers, high rises and others) where emergency response could be required at any time. Identification of such exposures should assist the department in the strategic deployment of long duration SCBA in relation to the risks involved.

5. Consideration should be given to the potential use of short term ESCBA for rescue purposes.

   Use of the various types of ESCBA should be based on expected emergency situations and conditions found in confined spaces, structural fires and others. The choice of oxygen vs. air units should be based on specific rationale to optimize their safe use. This effort would accomplish refined rescue techniques and minimize the need for use of buddy breathing in certain dangerous circumstances, potentially increasing the chance of victim survival as a result.

NOTE: The fire department that responded to this emergency is one of the best equipped and trained in the country. As a result of this preparedness, potential injury and fatalities to their personnel were avoided.

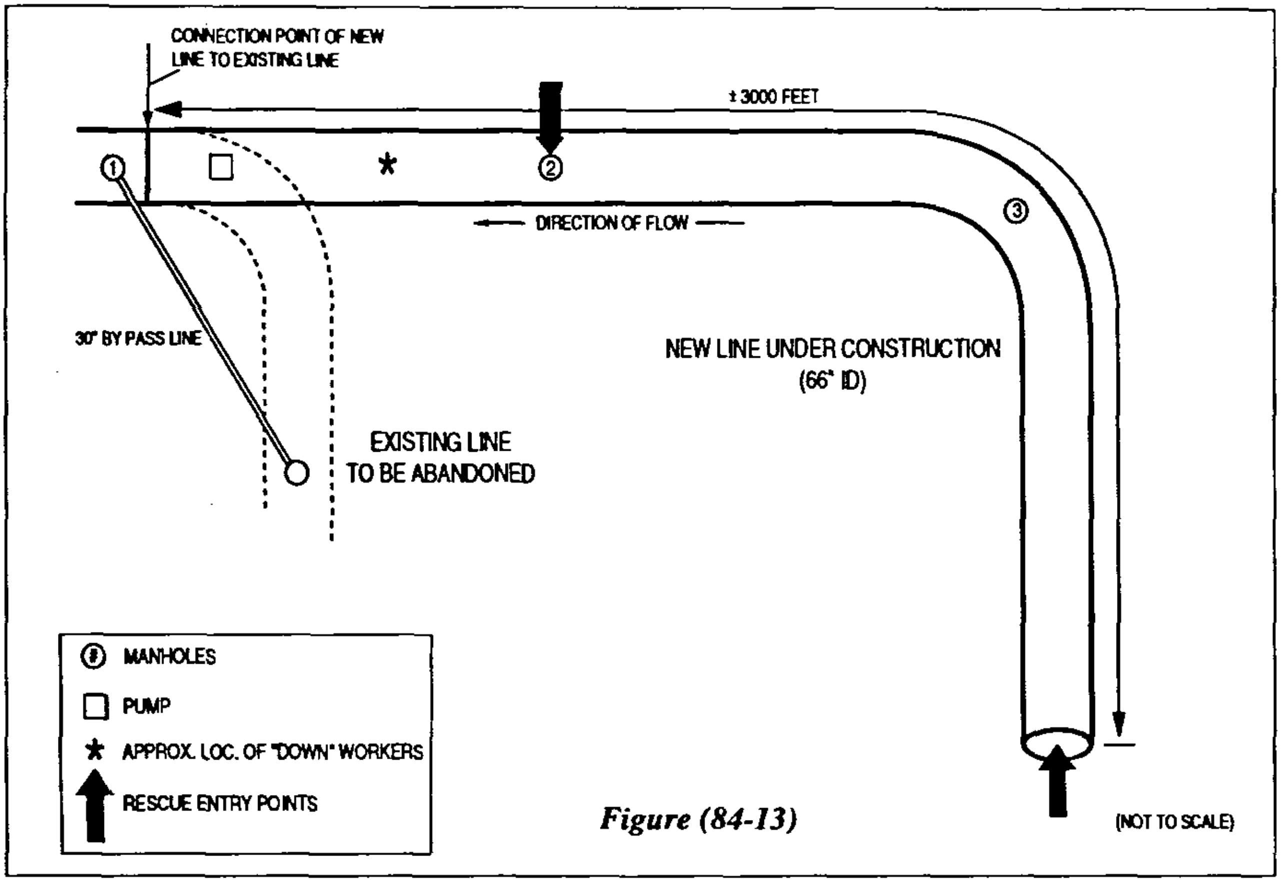

CONNECTION POINT OF NEW
LINE TO EXISTING LINE
± 3000 FEET
DIRECTION OF FLOW
30" BY PASS LINE
NEW LINE UNDER CONSTRUCTION
(66" ID)
EXISTING LINE
TO BE ABANDONED
MANHOLES
PUMP
APPROX. LOC. OF "DOWN" WORKERS
RESCUE ENTRY POINTS
(NOT TO SCALE)

Figure (84-13)

FACE 85-23: Use of Sulfuric Acid Results in Two Deaths in Waste Water Holding Tank in Pennsylvania

INTRODUCTION

On May 13, 1985, two 21-year-old men employed by a plumbing and heating company were unclogging two floor drains that carried water from a residence into a waste water holding tank. The two men had poured two gallons of sulfuric acid down the basement floor drains in an attempt to unclog the drains. After they poured acid into the drains, victim A entered the underground, cylindrical waste water tank (4 feet by 8 feet) to replace an elbow joint that had broken off. Victim A was overcome by gases and fell into the water. The homeowner then called a local ambulance service. Victim A was pronounced dead at the scene. Victim B died two weeks later.

SYNOPSIS OF EVENTS

On May 13, 1985, at 12:30 p.m. two men from a plumbing and heating firm located in southeastern Pennsylvania drove to a client's house to unclog a floor drain that carried water into a waste water holding tank. The property owner was experiencing repeated problems with a clogged drain. The workers were attempting to do two things: unclog the floor drain and replace an elbow joint, which had broken off inside the waste water holding tank. The elbow joint, located about 12 inches from the bottom of the tank, served as a trap to prevent back flow into the basement via the floor drains.

Shortly after arriving at the site the workers poured 1 1/2 gallons of sulfuric acid (66 Deg Be) into the basement floor drains. Not having success in unclogging the drains to the holding tank and from the holding tank to the floor drains, the drains remained clogged. The workers returned to their shop, picked up an elbow joint, and returned to the holding tank. Apparently, they felt that the time it took to get the elbow joint and return to the residential site would be sufficient time for the sulfuric acid to work through the clog in the drain. Upon returning to the accident site, the employees poured the remaining two quarts of sulfuric acid into the floor drain. Victim A then entered the tank with the replacement elbow joint. After working for a short period of time to install the elbow joint, victim A stopped working and started up the ladder. However, he was unable to climb out of the tank and fell from the ladder to the bottom of the tank. The head of victim A was resting in the water in the bottom of the holding tank. Seeing this, victim B climbed down the ladder to rescue victim A. The owner of the residence witnessed the incident and offered his hand to victim B through the 18-inch opening located at the top of the tank. Victim B started up the ladder, but apparently was overcome and the owner was unable to hold onto him. Victim B fell off the ladder to the bottom of the tank.

After victim B fell into the tank, the owner of the residence called the county emergency system. Two fire departments, two hospitals, and four rescue crews responded to the accident site. One fireman entered the holding tank while another fireman handed down the tanks of the self-contained breathing apparatus to the rescuer through the 18-inch opening. The firemen extricated victim B first and then pulled victim A to the surface. Approximately 20 minutes elapsed from the start of the accident until the two men were extricated from the tank. The ambulance crew said neither worker showed vital signs, but the EMS was able to raise a pulse on victim B by the time they began to transport him to a local hospital. Victim A was dead at the scene.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Workers should be assigned tasks commensurate with their training and experience.

Discussion: Workers required to work in confined spaces should be trained to do work in this environment. Victim B had been employed by the company for 2 1/2 years; victim A worked for the company for approximately 6 months. Neither worker had been trained in confined space entry, hazard recognition, use of personal protective equipment (PPE), or rescue procedures. Workers should never enter a confined space before it has been tested from the outside by a qualified person and declared safe for entry, (i.e. the space is gas free, O_2 level of 19.5%, flammability range less than 10% of the lower flammability level (LFL), etc.). Additionally, required PPE should be identified, provisions should be taken to provide a standby person, and rescue procedures should be established. Recommendations presented in the NIOSH Criteria Document 80-106 "Working in Confined Spaces" could help prevent accidents such as this, if implemented.

Recommendation #2: Workers should wear appropriate personal protective equipment, including respirators, while working in a confined space.

Discussion: Sulfuric acid was used to unclog floor drains leading to a waste water holding tank. The workers were exposed to indeterminate amounts of sulfuric acid when they spent time in the tank attempting to unclog the drain and to connect a 90 degree elbow on the terminal end of the floor drain. Workers entered this untested atmosphere without respiratory protection.

FACE 85-27: Rescue Effort Results in Fatality for a Wire Manufacturing Plant Worker in Illinois

INTRODUCTION

June 7, 1985, a 43-year-old production foreman of a wire processing company was summoned to aid a maintenance crewman (his son), who had collapsed at the bottom of an open top clarifying tank. The 18-year-old summer employee had been overcome by fumes liberated from chemical sludge that he was removing from inside the tank. In a rescue attempt the production foreman collapsed upon entering the tank. He was later removed from the tank by the fire/rescue team and pronounced dead. The fire/rescue team also removed the crewman. He was admitted to the intensive care unit of a local hospital and later released.

SYNOPSIS OF EVENTS

The victim was a production foreman employed by the company for 20 years. He was alleged to have undergone major heart surgery within the past 5 years and was apparently taking medication for a related condition.

On June 5, 1985, three employees (two summer hires and a lead man) began cleaning an above-ground, open top clarifier tank (6 feet wide, 6 feet long, 10 feet deep). The steel structure is an integral part of the company's wastewater treatment system that is used primarily for handling spent acids from pickling tanks (used to descale steel-alloy wire). After the spent acid solutions (which contain metal scale from the wire) have been neutralized in a neutralization tank and processed through a bag entrainment system, the clarifier tank serves as a settling tank for sludge fines. The tank has a small drain at the bottom that is used to pump sludge out of the tank on a weekly basis. However, as there are not scrappers or other means of agitation in the tank, the sludge builds up in the bottom of the tank. As a result the tank's capacity decreases through use. It has been necessary to clean the tank once a year for the past several years. The tank was approximately three-quarters full when the cleaning operation began (pumping out the sludge from the tank via a portable pump with a hose inserted into the sludge at the top of the tank). Discharge was into 55-gallon containers. One crew member held the end of the pump hose into the sludge from a 2-by-12-inch plank that had been laid diagonally across the top of the tank. This is the same cleaning procedure that had been followed in previous years. Previous cleaning activities stopped before the tank was fully emptied of sludge because the tank was needed for production. This year a decision was made to remove all the sludge from the tank.

Pumping operations resumed on June 6 and continued until the sludge became too thick to pump. At this point approximately 3 feet of sludge remained in the tank. When the sludge got down to a level where it couldn't be reached from the 2-by-12 plank on top, a crew member entered the tank via wooden ladders that had been propped against the outside and inside of the tank. From the ladder the crew member held the hose from the pump into the sludge. A second crew member, who stood on the 2-by-12 plank, stirred the sludge with a 2 by 4. The stirring action was intended to keep the fines suspended in the fluid. When the pump could no longer be used, a manual removal system was devised. This involved scooping sludge with a shovel into buckets and hoisting the buckets on a rope with a block and tackle that was affixed to the ceiling. The rope was operated by a crew member on the ground on the exterior of the tank. After four buckets were filled and hoisted, the two crewmen exchanged jobs. The lead man supervised this operation and made sure the workmen were supplied with 55-gallon drums in which to dump the sludge. Additional lights were installed on the ceiling above the tank to provide illumination inside. A box window fan was used to provide ventilation inside the tank. It was positioned either to blow air in or out depending on how the crew member in the tank felt most comfortable. Crew members entering the tank were required to wear chemical resistant suits, boots, gloves, safety glasses, and face shield. Respirators were optional. Upon entering the tank, both crewmen apparently informed the lead man that the odor inside was making them feel "high"; however, scooping operations continued for the rest of the day.

On June 7, 1985, the crew started working at 8:30 a.m. At this time approximately 1 1/2 feet of sludge remained in the tank. The crewmen again told the lead man that the odor in the tank was making them "high" and that it was much more intense than the day before, however, scooping operations continued. Two buckets (instead of four) were filled before switching jobs. One crewman volunteered to go into the tank more often because the odor was affecting the other crewman more. The lead man left the plant at approximately 10:40 a.m. on personal business. Before he left, he had a discussion with the maintenance superintendent (who was in charge of this cleaning operation) concerning the cleaning of the tank. A decision was made at that time to allow the work to continue. At approximately 11 a.m. the crewman on the outside of the tank heard a thud from inside. He climbed the ladder and observed the other crewman staggering around inside the tank and then collapse into the sludge. The second crewman entered the tank and attempted to revive the first. Failing, he climbed out of the tank and ran into the yard of the plant. He explained the situation to a forklift driver, who ran to the clarifier tank, climbed the ladder, and went inside in an attempt to rescue the first crewman. The second crewman continued through the plant and alerted the production foreman (father of the collapsed crewman). The production foreman ran to the clarifier tank, climbed the ladder, and jumped inside. Some shouting was heard inside the tank as various other plant personnel arrived. The forklift driver then came to the top of the tank and had to be helped out by a maintenance man. The maintenance superintendent arrived and began directing operations. He ordered several people to go get additional fans, ropes for hoisting, and respirators or oxygen masks. Then he and another maintenance man twice attempted to rescue the people in the tank. Both times they had to abandon their efforts due to the intense atmosphere in the tank. At this point the maintenance superintendent would permit no one else to enter the tank. Portable fans and a high speed blower were directed into the tank in an attempt to ventilate the area while waiting for the rescue squad to arrive.

Minutes later, the rescue squad arrived. Members of the rescue squad donned chemical protective suits and self-contained breathing apparatus (SCBA) and entered the tank. The crewman was removed first. As the rescuers and the crewman reached the top of the ladder, the crewman began to aid himself in getting out of the tank. He was brought down, his clothing removed, and oxygen administered. Two other rescuers suited up and went into the tank. The production foreman was unconscious and he had to be lifted out of the tank via a rope. He was administered CPR. However, he was pronounced dead on arrival at the local hospital. The crewman was admitted to the intensive care unit of the hospital, but later released.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The method of descaling and the method of cleaning out the clarifier tank should be evaluated to determine if either could be changed to minimize/eliminate the exposure to the acids or the need to enter the confined space.

Discussion: The descaling process should be evaluated and less hazardous chemicals substituted, where possible. To clean the sludge build-up inside the clarifier tank, entry was necessary. If removal methods were mechanically incorporated inside the tank, sludge build-up would not occur and manual cleaning of the tank would not be necessary.

Sludge was pumped out of the tank until it became too thick to pump. Other methods should have been investigated for the removal of sludge from the tank before resorting to manual methods. One possible solution, which has worked in the past, is to fill the tank part way with water and then place an air hose in the tank. Air agitation would then help to liquefy the sludge to a point where it could once again be pumped out. Prior to using this method of removal, the sludge should be evaluated to assure that it is not reactive with water. A basic pH indication within the range of 5.5 to 8.5 will provide this assurance.

Recommendation #2: Employers should develop comprehensive policies and procedures for confined space entry and emergency exit.

Discussion: Prior to confined space entry, all hazardous operations should be explained by written procedures that address all types of emergencies. These procedures should minimally include the following:

1. Air quality testing;

2. Identification of chemicals, possible chemical reactions, and chemical exposures;

3. Hazard communication of potentially hazardous chemicals and chemical reactions;

4. Personal and supervisory training in usage of respiratory protection;

5. Development of site specific work plans and procedures that address the task being performed, emergency access, and egress;

6. Training for proper selection of personal protective clothing, based on exposures;

7. Emergency rescue training;

8. Availability, storage, and maintenance of emergency rescue equipment;

9. Availability and usage of life lines, harnesses, and man lifts.

Job safety analysis procedures should be developed for all operations. Workers who enter confined spaces should complete training designed to inform them of the hazards they may encounter.

From the information obtained by the OSHA compliance officer, the employer in this case did not address any of the above items prior to the accident. Employer rescue efforts were not the result of preplanning or forethought.

Recommendation #3: Fire fighters, paramedics, and others responsible for emergency rescue should be trained for confined space rescue.

Discussion: The volunteer fire/rescue team made several unsuccessful attempts to remove the victim from the confined space. Adequate exit means (such as life lines, harnesses, or man lifts) were not available. Emergency rescue teams should be cognizant of all hazards of the confined space, including rescue hindrances, and should wear proper personal protective equipment and devices for emergency egress.

Recommendation #4: Hazardous exposure monitoring and control should be established.

Discussion: The employer appeared to have no written program to identify and evaluate existing hazardous conditions. Additionally, the facility did not have a ventilation system. During the tank cleaning process, portable household fans were being used to provide air circulation. Ventilation rates should meet industrial hygiene standards for areas where there is an exposure to potentially hazardous chemicals. Ventilation should be maintained close to maximum efficiency. Adequacy of a system can only be determined through environmental monitoring.

Recommendation #5: All chemicals in use and those being stored should be clearly identified and compliance with exposure limits should be enforced.

Discussion: Supervisory personnel apparently did not identify the chemicals present in the confined space and the crewmen were unfamiliar with the chemicals to which they were being exposed. One crewman had recognized some adverse effects of those chemicals and removed himself from the exposure; however, corrective action was not initiated by supervisory personnel or the other crewman. Poor hazard awareness was displayed by both supervisory personnel, who did not question the air quality in the presence of an unknown chemical exposure, and by the overcome crewman.

Chemicals known to be used for pickling (descaling of steel-alloy wire) are nitric, phosphoric, sulfuric, hydrochloric acid, and combinations of these acids. Water in contact with these acids and mixed acids will cause considerable evolution of heat and may evolve toxic fumes.

Chemicals used for neutralization of spent acids are lime, phosphate, and copper sulphate.

FACE 85-31: Three Sanitation Workers and One Policeman Die in an Underground Pumping Station in Kentucky

INTRODUCTION

On July 5, 1985, one police officer and two sewer workers died in an attempt to rescue a third sewer worker, who had been overcome by sewer gas at the bottom of an underground pumping station. All four persons were pronounced dead upon removal from the station.

SYNOPSIS OF EVENTS

On July 5, 1985, at approximately 10 a.m. two sewer workers (27 and 28 years of age) entered a 50-foot-deep underground pumping station. The station is 1 of 12 that pump sewage to the city's waste water treatment plant. The workers entered through a metal shaft (3 feet in diameter) on a fixed ladder that lead to an underground room (8 feet by 8 feet by 7 feet). The ventilating fan was not functioning. Neither worker was wearing personal protective clothing or equipment.

The two workers proceeded to remove the bolts of an inspection plate from a check valve. The plate blew off allowing raw sewage to flood the chamber, overwhelming one of the workers. The second worker exited the pumping station and radioed the police department requesting assistance. He again entered the station and was also overcome. Two police officers responded to the call at approximately 10:09 a.m. and one officer entered the pumping station. Later the sewage systems field manager arrived on the scene and followed the officer into the pumping station. None of the rescuers returned to the top of the ladder. A construction worker, who was passing by the site, stopped and entered the station in a rescue attempt. After descending approximately 10 feet into the shaft, he called for help. The second police officer assisted the construction worker out of the shaft. None of the responding men wore respirators.

Fire department personnel arrived at the accident site at approximately 10:11 a.m. One fireman, wearing a self-contained breathing apparatus (SCBA), entered the shaft, but could not locate the four men. By this time sewage had completely flooded the underground room. The fireman exited the pumping station. A second volunteer fireman (6'8", 240 lbs.) entered the shaft wearing a SCBA and a life line. As he began his descent he apparently slipped from the ladder and became wedged in the shaft approximately 20 feet down. (His body was folded with his head and feet facing upward.) Not being able to breathe, he removed the face mask and lost consciousness. Rescuers at the site extricated the fireman after a 30 minute effort. No further rescue attempts were made, until professional divers entered the station and removed the bodies. Autopsy results revealed a considerable amount of sewage in the lungs of the sewer workers and only a trace of sewage in the lungs of the field manager and police officer.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop proper work procedures and should adequately train employees to maintain and repair the sewage system. This training should include recognition of potential hazards associated with failures within those systems.

Discussion: The sewer workers did not have an understanding of the pumping station's design; therefore, mechanical failures and hazards associated with those failures were not adequately identified. Records were not kept of mechanical failures or repairs. The sewer workers "believed" that a malfunctioning valve had previously been repaired. This valve permitted the pumping station to flood. The lack of training resulted in the employee not being able to properly isolate the work area from fumes and sewage seepage.

Recommendation #2: Employers should develop comprehensive policies and procedures for confined space entry.

Discussion: Prior to confined space entry, all procedures should be documented. All types of emergencies and potential hazardous conditions should be addressed. These procedures should minimally include the following:

1. Air quality testing to assure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;

2. Employee and supervisory training in the selection and usage of respiratory protection;

3. Development of site-specific working procedures and emergency access and egress plans;

4. Emergency rescue training;

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

The air quality was not determined before the sewer workers entered the confined space and the ventilation system was not functioning properly. One respirator was available for use; however, it was not appropriate for the chemical contamination (sewer gas) present. Life lines were not available. Once confined space pre-entry procedures are developed, employees should be trained to follow them.

Recommendation #3: Fire fighters, police officers, and others responsible for emergency rescue should be trained for confined space rescue.

Discussion: A police officer died in the rescue attempt of the sewer workers. The police officer was not trained in confined space rescue techniques and did not recognize the hazards associated with the confined space. The volunteer fireman, who attempted the rescue and wedged himself inside the shaft, should not have been allowed to enter. His size alone created a potential hazard for himself and the incident delayed possible rescue of the victims. Emergency rescue teams must be cognizant of all hazards associated with confined spaces, including rescue hindrances, and they should wear proper personal protection and devices for emergency egress.

FACE 85-44: Two Sanitation Employees Die in Confined Space in Kentucky

INTRODUCTION

On August 24, 1985, two workers died in a sludge distribution chamber at a wastewater treatment plant. Since there were no witnesses, it is presumed they were attempting to remove pieces of a broken Plexiglas cover which had fallen into the sludge at the bottom of the chamber. They were discovered at approximately 4:35 p.m. by a co-worker. The emergency squad was summoned, and both victims were removed and transferred to local hospitals where they were pronounced dead by attending physicians.

OVERVIEW OF THE EMPLOYER'S SAFETY PROGRAM

Training at the facility is primarily on-the-job instruction. Employees are provided with a safety manual that they are expected to read. Monthly training sessions are conducted, but are not held regularly during the summer, due to vacation schedules.

SYNOPSIS OF EVENTS

Both victims had been employed by the wastewater treatment plant for approximately 7 years. The 25-year-old shift foreman and the 32-year-old operator reported to work on the day of the accident at 3:30 p.m. (the second shift). The operator was to take a sludge sample from the distribution chamber, a routine task performed at the beginning of each shift. The chamber is approximately 8 feet wide, 9 feet long, and 9 feet deep and is used to distribute primary sludge to different holding tanks. The sludge level in the chamber typically is 12 inches deep. The procedure for taking this sample was to remove the clear, Plexiglas cover from the 29-by-30-inch opening located on top of the chamber and use a sample cup attached to a rod that would reach the bottom of the chamber, without requiring the operator to enter the chamber. The Plexiglas cover was to protect the lens of a closed-circuit TV camera that was used to monitor this chamber from the plant control room.

After the sample was taken, the Plexiglas cover was to be replaced; however, the cover, which was reportedly cracked, broke upon replacement and the pieces fell into the chamber. The operator notified a co-worker of the problem and the co-worker suggested that the shift foreman be notified. The operator then notified the shift foreman that the cover had broken and fallen into the chamber. A decision was made to enter the chamber by using an extension ladder, lowered through the opening to retrieve the cover. Since there were no witnesses, it is assumed that the monitoring camera had to be moved aside to make room for the ladder. Therefore, the control room operator could not observe what was going on in the chamber. A co-worker in the area noticed the unattended ladder protruding from the chamber opening, and approached to investigate. He saw both workers face down in the sludge at the bottom of the chamber and immediately notified the control operator, who notified the emergency squad.

The emergency squad from a local volunteer fire company arrived, and with the use of SCBA retrieved the victims from the chamber. On September 3, state officials performed atmospheric tests for hydrogen sulfide and flammability levels within the chamber. At the time of the sampling, hydrogen sulfide was in excess of 500 parts per million and the flammability readings were less than 10 percent of the lower flammability limit (LFL).

CAUSE OF DEATH

Coroner's report not available at this time.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop comprehensive policies and procedures for confined space entry.

Discussion: Prior to confined space entry, all procedures should be documented. All types of emergencies and potentially hazardous conditions should be addressed. Confined space entry procedures should minimally provide for the following:

1. Air quality testing to ensure adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;

2. Site-specific confined space entry and work procedures, emergency access and egress plans, and emergency rescue procedures;

3. Availability of properly stored and maintained respiratory protective devices, protective clothing, and emergency rescue equipment;

4. Thorough supervisor and employee training in the entry and working procedures, atmospheric testing methods and test equipment, selection and use of respirators and protective clothing, and emergency rescue procedures.

Although the employer provided each employee with a general safety manual, and written procedures for confined space entry were available, a minimum level of caution was not achieved prior to the fatal entry. The air quality was not determined before the workers entered the sludge distribution chamber, and no means for ventilating the space were in place. Gas detection meters and self-contained breathing apparatus were available at the facility, but were not used. The control room operator was not notified in accordance with standard policy that the workers were going to enter the confined spaces and potential confined space hazards throughout the wastewater treatment facility.

Recommendation #2: Employers should train supervisors and employees in the application of confined space entry procedures. In particular, this should include training in recognition of confined spaces and potential confined space hazards throughout the wastewater treatment facility.

Discussion: Although the employees of the wastewater treatment facility had received training recently in confined space hazards, the victims apparently did not recognize the potential hazards within the sludge distribution chamber. The workers must have believed that they could enter the chamber safely, since neither respiratory protective equipment nor protective clothing were worn. A lack of adequate training in hazard recognition resulted in two employees failing to follow existing confined space entry procedures. The lethal consequences of this unnecessary entry might have been avoided had a level of precaution and planning been employed that was commensurate with the level of hazard that could be anticipated within such a confined area.

Recommendation #3: Employers should affix Caution/Warning signs at or near points of access to potentially hazardous areas.

Discussion: Employers should identify potentially hazardous areas within their facilities, and provide Caution/Warning signs to be affixed at or near the points of access to the hazardous areas (e.g., at or near the opening to a confined space). Such warning signs should be easily visible to anyone approaching the area; should contain specific information of procedures, notification, and/or authorizations required in the event entry becomes necessary; and should be periodically inspected on a routine basis.

Recommendation #4: The employer should design and install an improved opening cover (i.e. non-breakable) for sludge distribution chambers.

Discussion: Although the presence of the pieces of the Plexiglass cover within the chamber did not constitute an emergency situation (the cover was not actually removed from the chamber until several days after the fatalities occurred), it may have been perceived as such. Therefore, the use of a breakable, Plexiglass cover contributed to the accidental deaths. The employer should, as a result, design a cover made from a sturdy, non-breakable material with limited access openings to allow for the sampling cup to be inserted and removed without disturbing the cover. A wrought iron grid or similar cover might allow both routine sampling and video monitoring while, at the same time, inhibiting nonessential cover removal. An alternative means of protecting the lens of the video camera should be concurrently developed.

FACE 86-38: Three Dead, One Critical in Industrial Septic Tank in Georgia

INTRODUCTION

On July 16, 1986, four employees of a liquid waste hauling company were pumping out an industrial waste tank at a chicken hatchery when the accident occurred. The liquid waste had been pumped out and one of the workers entered the tank to loosen and remove sludge from the bottom and sides of the tank when he was overcome by toxic fumes. In an effort to rescue the downed worker, a second workman entered the tank and was overcome. The third and fourth workers entered the tank and were overcome in a similar manner. Before the fourth worker entered the tank he ran inside the hatchery to get help. When employees of the hatchery arrived at the opening of the tank, the fourth worker was found in the tank semiconscious and the other three were unconscious.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is a small local septic tank service company that pumps, cleans, and repairs residential and commercial waste and septic tanks. The company consisted of the owner and four employees. The company had no written safety policy or program. Safety was the responsibility of the individual worker.

SYNOPSIS OF EVENTS

A hatchery had contracted with the septic tank service company to pump out a 2,000-gallon waste water holding tank (5 feet by 7 feet by 10 feet) and to clean out any accumulated sludge on the bottom and sides of the tank every 2 months. The waste tank received waste water from the hatchery which contained chlorinated caustic cleaners (dilute potassium hydroxide and sodium hypochlorite), residue from egg disinfectant (a formulated quaternary ammonium compound), chick down, and some afterbirth and egg shells. No human waste went into this tank. A separate tank was used for employees' wash rooms in the hatchery. The waste water tank was cleaned every 2 months on a Wednesday when the hatchery is operating with a reduced workforce. On Wednesdays no waste water should be going into the tank.

Four workmen for the septic tank service company arrived at the hatchery shortly after 9 a.m. on July 16, 1986. The steel cover was removed from the tank, exposing the 25-inch square opening into the concrete waste water holding tank. The liquid waste was vacuum drawn from the tank into a tank truck. After the liquid was drawn down to the sludge level (approximately 14 inches), a hoe-like tool was used to loosen the sludge. A workman was lowered through the 25-inch square opening via a hose tied to a 5-gallon bucket. The workman, once inside the tank, filled the bucket with sludge which was then pulled out and dumped. This procedure was repeated until all of the sludge was removed from the tank. This same procedure had been used to clean this tank for the past 5 years. At approximately 10 a.m. one of the workmen reported to the office manager of the hatchery that the workmen were in trouble and was down (overcome) in the tank. The fire department was called immediately and arrived on the scene within 10 minutes. It is doubtful if any of the victims recognized this as a confined space with its associated life threatening hazards. The workmen did not test the atmosphere prior to entry, did not use isolation procedures or forced air ventilation. None of the workmen were wearing personal protective equipment or respiratory protection and apparently only one worker used the ladder.

Workmen from the hatchery went outside to assist the downed workmen and found an unattended ladder protruding from the tank opening. Apparently, the worker who requested help secured a ladder from the hatchery. The office manager stated, upon looking into the tank, that all four men were down, of which three were unresponsive. A fan was brought from the hatchery and used to blow fresh air into the tank. The fire department and EMS personnel arrived on the scene and immediately initiated rescue procedures. Two fire department rescuers donned protective gear and self-contained breathing apparatus to remove the men from the tank. All four men were transported to a local medical center. Two were pronounced dead on arrival, and two remained critical. One of the two critical died a week later. Investigation of the incident and tests performed by the OSHA compliance officer at the site revealed no appreciable amounts of chlorine. However, the atmosphere contained 2,500 ppm CO_2 and 50 ppm ammonia. Tests were negative for H_2S.

The medical examiner reported a strong chlorine odor on one of the victims while performing an autopsy.

Note:

The tank had been cleaned the same way for 5 years without incident. The following aspects of this incident may have varied from previous occasions and could have contributed to this accident:

a. The tank was not isolated from the hatchery and if anything was flushed down the drain, it would enter the tank where a man was working.

b. The chemicals used in the plant are not compatible if mixed. There exists the possibility of chlorine gas being liberated in the tank if the chemical cleaners were mixed in the right concentration.

c. Toxic gases are also liberated when sludge material is disturbed. Cleaning the sludge in the bottom of the tank could have released toxic gases.

d. The ambient temperature on July 10, 1986, was 104 degrees F.

CAUSE OF DEATH

The medical examiner stated the men died of hemorrhagic pneumonitis as a result of chlorine exposure.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Companies contracting to have a service performed on their property should implement and enforce a safety program to be followed by the contractor.

Discussion: The company that contracts out work to be performed on their property and assumes the contractor is an expert and adheres to safety procedures can be operating on a dubious assumption. Especially when hazardous tasks such as confined space entry are contracted out, outside contractors should be required to comply with a written safety policy that includes safe work procedures, and these requirements should be enforced by the company. For confined space entry, the recommendations in NIOSH Publication No. 80-106, "Working in Confined Spaces" should be used.

Recommendation #2: The septic tank service company should develop comprehensive policies and procedures for confined space entry, where confined space entry is required.

Discussion: All employees who are required to work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. Prior to entry into a confined space, the following should be addressed:

1. Is entry necessary? Can the tank be cleaned from the outside?

2. Has a permit been issued for entry?

3. Has the air quality in the tank 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. Is ventilation equipment available and/or used?

FACE 87-20: Two Workers Die in Digester Unit in New Mexico

INTRODUCTION

On December 1, 1986, four workers at a wastewater treatment plant were attempting to repair a leak and clean out a pump in the pipe gallery (a small room containing pipes and valves between two digester units) when the accident occurred. The workers were in the process of removing the bolts from an inspection plate when the plate was forced open by raw sewage which flooded the room. Two workers died in the unit; one was hospitalized, and one was treated at the hospital and released.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident was a small municipality. The victims worked for the wastewater treatment plant which is under the public works department. The public works department has 60 employees in several different divisions; parks and recreation, library, airport, water treatment, solid waste disposal, and wastewater treatment. Each division has a supervisor which reports to the city public works department supervisor. The wastewater treatment plant has five employees; a supervisor, two operators, one laboratory technician, and one trainee.

New employees are given a brief orientation which consists of a discussion of benefits and operating policy. New employee training is the responsibility of their supervisor. On-the-job training is also provided by the supervisor or experienced/certified operators. No safety training or safety meetings are conducted at the wastewater treatment plant. The employees are not trained in confined space hazards or safe entry procedures. Confined space entry procedures are included in the operating manual.

SYNOPSIS OF EVENTS

On December 1, 1986, the employees of the wastewater treatment plant reported for work at 8 a.m. and proceeded with routine daily operations. One of the first things done each day is a walk-through inspection of the plant. The two plant operators were doing the walk-through inspection when they discovered a pump was leaking in the pipe gallery. The operators reported the leak to the plant supervisor immediately. The supervisor instructed both operators and a trainee to accompany him to the digester unit to check and repair the leak. The men proceeded to the pipe gallery (approximately 13 feet by 15 feet by 13 feet deep), which was located between the primary and secondary digesters. The four workmen descended the spiral staircase into the pipe gallery to repair the leaking pump. The supervisor instructed the trainee to remain on the stairs because of the tight working conditions around the pump. One of the operators closed the two valves to the secondary digester. However, the two valves to the primary digester remained open. It was assumed all four valves were closed. The supervisor was in the process of removing the eight bolts from the inspection plate (located between the valves for the primary and secondary digesters) when the plate popped up. Some raw sewage was discharged; however, this discharge stopped. Apparently the pump, which was clogged, moved and this movement caused this momentary sewage discharge. The supervisor continued to remove the bolts from the inspection plate. All but three bolts had been removed from the inspection plate when raw sewage began spraying into the room. The trainee stated, "when the raw sewage began spraying into the room it was difficult to see because of the heavy spray and the discharge sounded like a jet engine." The supervisor and the two operators frantically attempted to locate the open valves. However, the room was beginning to flood with raw sewage. The sewage level was 3 feet deep within a few minutes and the men decided to get out. The operators and the trainee climbed the stairs and exited to the outside before they noticed that the supervisor did not follow them. All three returned immediately to the pipe gallery and found the supervisor slumped over in the sewage at the bottom. One of the operators attempted to pull the supervisor out of the sewage. The operator was overcome and fell into the sewage. The other operator and trainee attempted to rescue the downed workers; however, they realized they were in trouble so they exited immediately.

Upon leaving the unit, they notified the lab technician who called the fire department and rescue squad. Within 5 minutes the fire department and rescue squad arrived on the scene. The pipe gallery had now flooded completely (13 feet deep) and raw sewage was running out the doorway. The fire department pumped the sewage level down in the room and removed the downed supervisor and operator. Both men were pronounced dead at the scene by the coroner.

CAUSE OF DEATH

The coroner's report listed both deaths as drowning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should develop proper work procedures and should adequately train employees to maintain and repair the sewage system. This training should include recognition of potential hazards associated with failures within those systems.

Discussion: The workers were not provided with safe operating procedures (i.e., equipment malfunction) or training in hazard recognition. Without adequate work procedures, each worker assumed the other had shut down the digester valves. No one was assigned specific responsibilities or tasks. Therefore, only two of the four were closed.

Recommendation #2: The employer should develop comprehensive policies and procedures for confined space entry.

Discussion: All employees who are required to work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures that are to be followed. Prior to entry into a confined space, the following should be addressed:

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

2. Has a permit been issued for entry?

3. 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. Has the confined space been isolated/locked out from other systems?

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

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

6. Have employees been trained for confined space entry?

7. Is ventilation equipment available and/or used?

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

Recommendation #3: Employers should provide some type of pressure sensing device(s) on lines to determine if the line is under pressure when valves are closed.

Discussion: A pressure sensing device on the sewage lines would have alerted the workers to the pressure on the line thereby requiring a check to determine what valves were not closed. Without some type of pressure sensing device on the lines it is impossible to determine line pressure, if valves are functioning properly, etc.

FACE 87-26: Worker Dies After Lifting Access Cover on Acid Reclaim Storage Tank in Virginia

INTRODUCTION

On December 14, 1986, a shift supervisor (the victim) at a synthetic fiber manufacturing plant was in the process of thawing out a frozen pipe to a 6,100-gallon acid reclaim storage tank. After lifting the tank access cover the victim collapsed on top of the tank with his head down inside the adjacent tank. Resuscitation efforts were attempted by the fire department rescue squad. The victim was pronounced dead at the scene by the local medical examiner.

Another confined space-related fatal accident occurred within the same plant approximately 1 month prior to this accident. A separate evaluation of that accident is given in FACE report 87-25.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a synthetic fiber manufacturing plant that has approximately 1,200 employees consisting mainly of maintenance and production workers, pipefitters, mechanics, and machinists.

The company has a plant safety program. New employees receive a basic plant safety orientation from the safety training supervisor and a handbook which discusses general employee safety. All production employees receive fork lift truck safety training. New employees also receive on-the-job training for specialized procedures required in certain manufacturing processes. There is a written hazard communication (i.e. right-to-know) program that addresses various department-specific hazards throughout the plant and a written policy on confined space entry procedures. All employees working in or near confined spaces are expected to be familiar with the confined space entry procedures; however, there does not appear to be an effective means to make employees aware of the potential hazards associated with these tasks.

Safety meetings are conducted monthly among company management to discuss problems and to reinforce existing safety programs; however, safety meetings are not conducted regularly within the various plant departments.

SYNOPSIS OF EVENTS

On December 14, 1986, at about 9:30 a.m. two workers, under the direction of the shift supervisor (the victim), were attempting to thaw an above-ground pipe line. The frozen line ran from an acid sump tank at ground level to a 6,100 gallon fiberglass acid storage tank at the top of a six-story building. This closed system contained a "raw acid" solution (approximately 9 percent sulfuric acid, 23 percent sodium sulfate, 1 percent zinc sulfate, and 66 percent water) which comes from the spinning operation of synthetic fiber production. Also present in the tank are hydrogen sulfide (by-product) and carbon disulfide (used in the manufacturing process) gases. Starting from the acid sump tank on the ground and working towards the acid storage tank on the roof, the two workers and the victim began thawing the frozen solution in the pipe by opening the pipe at various access points and running steam lines through the pipe. During this procedure, the acid storage tank was still in use, receiving acid from the fiber spinning process from other pipe lines.

The victim and a worker climbed on top of the storage tank in an attempt to thaw the section of pipe entering the storage tank. Although the workers and victim had been instructed previously that day by a management official of the company not to go on top of the acid storage tanks without the protection of safety harnesses and respirators, neither employee was equipped with a respirator or a safety harness. The victim removed the tank access cover and stuck his head down inside the hole, apparently to determine if the pipe was frozen where it entered the tank. One of the workers pulled the victim back by the collar and warned him not to lean into the tank. The victim and worker then climbed down from the tank and began disconnecting and thawing other sections of the pipe. A short time later the victim climbed back up on top of the storage tank and, although there were no eyewitnesses, apparently attempted to thaw the pipe where it entered the storage tank from inside the tank. Approximately 15 minutes later the two workers noticed that the victim was not present and after a brief search they found the victim lying on top of the storage tank with his head down in the tank access hole. One of the workers pulled the victim from the top of the storage tank to the top of an adjacent tank and checked him for a pulse, but found none. The other worker called the local fire department rescue squad which arrived approximately 8 minutes later and attempted to resuscitate the victim. The victim was pronounced dead at the scene by the local medical examiner.

An atmospheric test of the acid storage tank was conducted by the employer shortly after the accident. This test revealed levels of hydrogen sulfide greater than 1000 parts per million.

CAUSE OF DEATH

The medical examiner's autopsy report lists the cause of death as hydrogen sulfide and carbon disulfide poisoning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should initiate <u>comprehensive</u> policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. Although the employer does have written policies and procedures for confined space entry, they should be expanded to include all required aspects of a confined space entry program. These procedures should minimally include the following:

1. Posting of all confined spaces.
2. Air quality testing to determine adequate oxygen supply, adequate ventilation, and the absence of all toxic air contaminants;
3. Monitoring to determine a safe oxygen level is maintained inside the confined space;
4. Employee and supervisory training in confined space entry;
5. Employee and supervisory training in the selection and usage of respiratory protection;
6. Emergency rescue procedures;
7. Availability, storage, and maintenance of emergency rescue equipment.

Current written confined space procedures of the employer do address items #2 and #3 above; however, these procedures were not followed in this incident. Current written confined space procedures do not adequately address the other requirements listed above. The present procedures should also be carefully reviewed and modified as necessary in order to reflect sound confined space entry practices.

Recommendation #2: The employer should insure that employees are trained in hazard recognition and safety awareness for all potentially hazardous tasks.

Discussion: Although the employer has a written hazard communication program and safety policy (including confined space entry procedures) there appears to be no effective means of communicating hazards recognition and safety awareness to employees. When confronted with potential on-the-job hazards, employees should be able to recognize these hazards and take appropriate corrective actions.

Recommendation #3: The employer should implement and enforce its safety program.

Discussion: Although the employer has a written safety policy (including written confined space entry procedures), it appears that these policies and procedures were not being followed by supervisory personnel. Management should ensure that its safety policies and procedures are put into practice by all department supervisory personnel as well as plant laborers and enforcement procedures should be implemented to improve employee compliance with the safety program.

Recommendation #4: The employer should implement an improved housekeeping program.

Discussion: Section 5.5 of the employers safety policy states, "Housekeeping is often a barometer of attitudes concerning safety, quality and cost." Maintaining work areas in a clean and orderly condition will improve worker safety. Procedural references to housekeeping in the safety policy should be strictly followed.

FACE 87-45: One Dead, One Near Miss in Sewer in Kentucky

INTRODUCTION

On May 15, 1987, two laborers for the city sewer department entered a 15-foot-deep sewer manhole into an oxygen deficient atmosphere. When help arrived, both men were unresponsive. The men were removed from the manhole and transported to a local hospital. Prolonged resuscitation efforts were unsuccessful and one worker was pronounced dead by an attending physician 2 hours later. The second worker was treated and released.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a small municipality which has 474 employees. The victim worked for the sewer department which has 14 employees: a superintendent, assistant superintendent, 2 crew leaders, 2 brick masons, 2 pipe layers, 3 operators, and 3 laborers. The municipality had no written safety policies or confined space entry procedures at the time of the accident. Safety on the job has been handled on an informal basis and left up to the individual worker.

Since the accident, the municipality has drafted up basic confined space entry procedures. These procedures aren't all inclusive for confined space entry; however, they are in writing and confined space training was initiated.

SYNOPSIS OF EVENTS

On the morning of May 15, 1987, two laborers (the victim and a co-worker) were assigned the task of cleaning out a drainage ditch. After completing this assignment, the men reported back to the sewer department. At 11:30 a.m. the superintendent informed the two workers that the engineering department had reported a blockage in a sewer manhole adjacent to a sewage lift-station. The two laborers were instructed to take the sewer cleaning machine (a tank truck with a vacuum cleaning system and water jet) to the stopped up manhole and wait for the engineering department workers to arrive. The two laborers drove the sewer cleaning machine to the location of the manhole. They arrived at the manhole at approximately 1 p.m. and positioned the truck so that the manhole could be cleaned. One of the workers (the victim) removed the 22-inch diameter manhole cover, while the other worker was preparing equipment on the truck. After removing the manhole cover, the victim observed two boards stuck in the sludge (the sludge level was up 3 feet in the 12-foot-deep manhole and had formed a crust). The victim descended via an attached steel rung ladder into an untested, oxygen deficient atmosphere and attempted to remove the two boards stuck in the sludge." The co-worker noticed the victim had entered the manhole and went to investigate. The co-worker stated that "the victim was staggering, gagging, vomiting, and then fell face down on the sludge. The co-worker called the sewer department and reported a man was down in the manhole and was in trouble. The superintendent told the worker to wait for help, not to enter the manhole. The co-worker entered the manhole in a rescue attempt and passed out, falling backwards, face-up.

When the engineering crew arrived (shortly before the emergency squad and fire department) both men in the manhole were unresponsive. The engineering crew lowered an 8-inch-diameter vacuum line from the sewer cleaning machine into the manhole and turned on the vacuum system.

The vacuum system quickly evacuated the air in the manhole, causing fresh make-up air from the exterior of the manhole to enter the manhole. The co-worker regained consciousness and stood up. A rope was lowered into the manhole and he was pulled out. Two firemen entered the manhole (with SCBA) and removed the victim. All four men (the victim, the co-worker, and the two firemen) were transported to a local hospital. Resuscitation efforts were continued on the victim for 2 hours, but were unsuccessful. The co-worker and the two firemen were treated and released.

CAUSE OF DEATH

The coroner listed the cause of death as "prolonged acute exposure to sewer gas—aspiration of foreign material."

NOTE: While conducting this evaluation, the sewer manhole was tested for O_2, H_2S and CH_4. The results of these tests:

O_2	7%
H_2S	Negative
CH_4	Negative

RECOMMENDATION/DISCUSSION

Recommendation #1: The employer should develop a comprehensive safety program for confined space entry that clearly documents procedures for safe entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should include, but not be limited to:

1. Air quality testing to determine adequate O_2 level.

2. Ventilation of the space to remove air contaminants.

3. Monitoring of the space to determine a safe oxygen level is maintained.

4. Employee training in confined space entry, testing, and use of personal protective equipment (respirators, clothing, etc.).

5. Emergency rescue procedures.

Air quality was not tested prior to entry. Testing devices should be ordered and used for testing the atmosphere for O_2, H_2S, and CH_4. Training on correct use of these devices, plus calibration of each should be stressed. Respirator training, fitting, and proper maintenance procedures should be required of all employees.

FACE 87-67: Two Construction Workers Die Inside Sewer Manhole in Indiana

INTRODUCTION

On July 21, 1987, a worker for a construction company entered a 7-foot-deep sewer manhole that had a toxic and oxygen deficient atmosphere. When the worker collapsed, another worker entered the manhole in a rescue attempt and also collapsed. Both workers were pronounced dead at the scene.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a family-owned construction company with approximately 50 workers (mostly laborers and heavy equipment operators). The majority of the company business involves general excavation and the construction of water systems, sewers, and roads. The company has a written, 1-page safety policy which addresses employee responsibility, general safety guidelines, confined space safety, and reporting injuries.

It is the responsibility of each employee to read this policy. All management level employees are trained in cardiopulmonary resuscitation (CPR). Other than the CPR training, there is no formal classroom safety instruction for employees. Tool box meetings are held monthly to discuss basic safety issues. On-the-job safety is the responsibility of each employee.

No training is given on confined space entry; however, company policy requires that each manhole be tested and ventilated prior to entry. The company has gas monitoring devices available at the main office to test confined spaces for oxygen (O_2), hydrogen sulfide (H_2S), and methane (CH_4). It should be noted that the company also experienced a confined space fatality 5 years prior to this incident.

SYNOPSIS OF EVENTS

On July 21, 1987, at approximately 11 a.m. a company work crew (a 36-year-old foreman with 17 years' experience with the company, a 50-year-old heavy equipment operator with 21 years' experience with the company and two laborers) began clearing brush in a vacant field in preparation for setting grade stakes to extend an existing sewer line for a new housing subdivision. At 11:30 a.m. when the two laborers broke for lunch, the foreman and equipment operator both left to look for an existing sewer manhole.

Although there were no eye witnesses to the incident, it is presumed (based on circumstantial evidence) that the following occurred: The foreman and equipment operator, upon locating the sewer manhole, removed the manhole cover. In an effort to check the existing sewer grade, the foreman then entered the 7-foot-deep manhole through a 24-inch diameter "manway" opening, and collapsed at the bottom. In an attempt to rescue the downed foreman, the equipment operator entered the manhole and also collapsed.

After lunch, when the foreman and equipment operator did not return to the field that was being cleared, the two laborers began to search for them. At approximately 1:30 p.m. the two laborers found the foreman and equipment operator at the bottom of the manhole with their heads submerged in about 12 inches of water. One of the laborers told two other company workers (who had just arrived at the scene) to call for an ambulance. When the rescue squad from the local fire department arrived (after approximately 15 minutes), two fire department rescuers donned self-contained breathing apparatus (SCBA's), entered the manhole and, using ropes and harnesses, removed the two victims from the manhole.

Fire department and emergency medical service (EMS) personnel noted that the two victims were "obviously dead," and they were pronounced dead at the scene by the county coroner. After the victims were removed from the manhole, the atmosphere of the manhole was tested by a private analytical laboratory and by the City Water Pollution Control Maintenance Department. Results of these tests are as follows:

O_2	at depth of 3 feet	15.7%
O_2	at depth of 6 feet	7.2%
CH_4	at depth of 6 feet	2%
H_2S	at depth of 6 feet	0.1 and 0.2%
CO	at depth of 6 feet	>5%

Investigator's Comment:

The foreman and equipment operator were both employed by the company 5 years previous to this incident when the company experienced its first confined space fatality.

CAUSE OF DEATH

Autopsies were performed on both victims. The cause of death for both men was listed as asphyxiation.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers engaged in the business of sewer construction or maintenance should assure that workers are trained sufficiently in recognition and awareness of confined space hazards they may encounter in the daily performance of their duties.

Discussion: According to the employer, the work being performed at the construction site did not require the workers to enter any sewer manhole. However, the foreman did enter the manhole without testing and ventilating the atmosphere of the manhole prior to entry as required by company safety policy. The fact that this is the second confined space fatality incident within the past 5 years (resulting in three confined space fatalities) underscores the importance of employee training in safe confined space work practices.

Recommendation #2: The employer should develop and implement a more comprehensive safety policy with specific procedures for confined space entry.

Discussion: The 1-page safety policy devotes one paragraph to confined space entry: "Employees shall not enter manholes, underground vaults, chambers, tank, silos, or other similar places that receive little ventilation, unless it has been determined that the air contains no flammable or toxic gases or vapors. Ventilate thoroughly, detectors are available at office."

Phrases such as "...unless it has been determined..." and "ventilate thoroughly..." should be expanded and clarified to describe a detailed confined space entry procedure. Also, the individual(s) responsible for testing the atmosphere and making recommendations for safe entry should be identified. Minimally, the following confined space safe work practices should be addressed in the company safety policy and 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 line
   - 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 recommendation 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 88-33: Electroplater and Four Co-Workers Die from Asphyxiation in Metal Plating Vat

INTRODUCTION

On June 28, 1988, a 25-year-old male electroplater (victim) died after entering a metal plating vat he was cleaning. Four male co-workers also died when they entered the vat in rescue attempts.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is an electroplating company with 31 employees, most of whom are electroplaters. Employees with at least 1 year of experience had attended a one-time training session on chemical hazards from a hazard communication training company. New employees receive a brief orientation on the chemicals used in the plating operation and the location of Material Safety Data Sheets (MSDS), and then take a "chemical awareness test" which is a review of the information received. Electroplaters are required to wear personal protective equipment (boots, gloves, aprons and safety glasses). Acid-mist cartridge-type respirators had been issued to two electroplaters and the wastewater treatment operator, but were available for use by any of the workers.

At the time of the incident the employer had no written safety program, no plant emergency procedures, no on-going safety training, no confined space safe entry procedures, and did not conduct safety meetings with employees.

SYNOPSIS OF EVENTS

The company uses a series of open-top steel tanks to acid treat metal parts with a metal finish of either zinc, chrome, nickel, brass, copper, or cadmium. Two parallel lines of tanks, separated by a 5-foot-wide removable metal grating walkway, are located in the zinc plating room. Below the walkway is a concrete drainage pit. The only ventilation the zinc plating room receives is from two exhaust fans on the ceiling about 20 feet above the tanks, five open windows (at the time of the incident the windows were closed), and one open door.

The end tank (4 feet wide by 5 feet deep) on the south side of the zinc plating line is used as a holding tank for excess zinc cyanide that drips from the finished metal parts suspended above the tank. Approximately once a year the tanks are cleaned out by an industrial cleaning and waste hauling company. One day prior to the incident the waste hauling company had completed pumping out the tanks; however, the holding tank still contained about 2 inches of zinc cyanide sludge on the bottom.

During the night shift, the plating company employees were cleaning and rinsing the tanks in preparation for changing from cyanide process to acid plating process. Chemicals for the new process were to be added to the tanks and the plating operation was to resume the following morning. During the cleaning process, the metal grating between the two tank lines was removed. This resulted in the top of the end holding tank being 8 feet above the surface of the drainage pit floor. A ladder was used to reach the top of the tank.

In a cleaning procedure that had never been attempted before, the victim manually pumped between 1 and 2 gallons of 1 percent muriatic acid solution from a 55-gallon drum (which the victim had placed nearby for cleaning and rinsing purposes) into the zinc cyanide holding tank, and then climbed into the tank. The tank had not been tested or ventilated before entry. The victim was not wearing any respiratory protective equipment and the only personal protective equipment (PPE) he was wearing were gloves, boots and an apron. Within a few minutes hydrogen cyanide vapor formed in the tank due to a chemical reaction between the muriatic acid and zinc cyanide. About 4 minutes after he had entered the tank, co-workers observed the victim trying to climb out but then falling back into the tank. Four co-workers entered the tank in an attempt to rescue the victim. They were wearing varying amounts of PPE but no respiratory protective equipment. They all collapsed inside the tank. Other co-workers, seeing these workers collapse, also made varying rescue attempts. By this time, as the chemical reaction continued, most of the co-workers who entered the zinc plating room were unable to even get close to the holding tank because of the hydrogen cyanide vapor. However, one co-worker (without respiratory protection) removed one of the four collapsed co-workers (who was bent over the top of the tank with his head down inside) and administered cardiopulmonary resuscitation.

The city police, state police, and fire department were notified. Personnel from these departments arrived within approximately 15 minutes and began removing the workers from the zinc cyanide holding tank. Fire fighters were wearing full turnout gear (standing PPE for fire fighters) with self-contained breathing apparatus (SCBA). Police officers were not wearing any respiratory protective equipment or PPE.

The rescue effort was hampered because police and fire department personnel were initially unaware that hydrogen cyanide vapor was involved. During the rescue effort they became suspicious that hydrogen cyanide vapor might be involved after learning from plant employees that zinc cyanide and acids were used at the plant. The hydrogen cyanide vapor permeated the exposed skin and the leather protective "turnout gear" when they removed the victims from the tank. As a result, 17 police officers and fire fighters received toxic exposures, and the turnout gear became contaminated. A further complication was the uncertainty between responding agencies as to who should take command of the rescue effort, including administering emergency medical care and securing the contaminated area from unauthorized entry. This disorganization continued for nearly 2 hours before the premises were finally sealed off.

The county coroner pronounced the electroplater (victim) and three of the co-workers attempting rescue dead at the scene. The fourth co-worker was taken to the local hospital where he died 2 days later. In addition to the 5 fatalities, 30 individuals received medical treatment for toxic exposure to hydrogen cyanide vapor:

2	company workers hospitalized
10	company workers treated and released
1	police officer hospitalized
3	police officers treated and released
13	fire fighters treated and released
1	medical examiner treated and release
TOTAL	30

Seven hours after the incident began, a private environmental and hazardous waste consulting firm (contracted by the employer) collected air samples at the plant for analysis of toxic air contaminants. Concentrations of hydrogen cyanide vapor measured 1.0 milligram per cubic meter (mg/m^3) immediately outside the plant door, and 6.0 mg/m^3 immediately outside the zinc cyanide holding tank. Analyses for other toxic air contaminants were negative. Sample collectors were unable to obtain air samples from inside the holding tank at that time. After collecting these samples the consulting firm added a chemical to neutralize the chemical reaction inside the holding tank and then ventilated the building using portable blowers. The following day the consulting firm analyzed the air inside the holding tank; hydrogen cyanide vapor was present at a concentration of 2.0 mg/m^3.

It is assumed that the concentration of hydrogen cyanide vapor inside the holding tank was at least 60.0 mg/m^3 (the level immediately dangerous to life) at the time of the incident. This is based on the acute effect of the vapor on the workers.

CAUSE OF DEATH

The county coroner listed the cause of death for all five electroplaters as asphyxiation due to overexposure to hydrogen cyanide vapor.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The company should develop and implement a written safety and training program. This program should include the recognition of hazards and safe work methods.

Discussion: The company had no written safety program or policy. Any training at the plant was on-the-job, with little emphasis on safety and health. The victim (age 25) was an electroplater with 3 1/2 years experience. All four co-workers who died (ages 19, 21, 29, and 29) were electroplaters with less than 8 months experience. Using muriatic acid to clean out the zinc cyanide holding tank had never been attempted before because vapor would be produced by adding muriatic acid to zinc cyanide. (In fact, two active chemicals such as zinc cyanide and muriatic acid should never be kept in the same area.) Additionally, entry into the tank without adequate ventilation, PPE, and respiratory protection implied the employees generally did not recognize the hazards associated with the plant operation, the use of Material Safety Data Sheets (MSDS), the reactivity and toxicity of chemicals, methods of working safely, plant emergency procedures, and the proper use of PPE, including respiratory protection.

A preliminary hazard analysis of the entire operation should identify hazardous areas (physical, chemical, environmental, etc.), conditions, and tasks that are performed. This is especially important when a new work task is initiated. In this case, a new cleaning procedure was attempted without identifying potential hazards. Based upon the hazard analysis, safety procedures can be developed and implemented. For example, the method of plating metal parts and cleaning out the zinc cyanide holding tank should be evaluated to determine if either process could be changed to minimize or eliminate exposure to cyanide or the need to enter the tanks. Less hazardous chemicals should be substituted where possible. Tank entry was considered necessary to clean the sludge build-up inside the zinc cyanide holding tank after the level became too low to pump. If removal methods were mechanically incorporated inside the tank, sludge build-up would not occur and manual cleaning of the tank would not be necessary. Other methods should be used for the removal of sludge and liquid waste from the tank before exposing workers to this hazard.

Environmental monitoring and control should be established. The facility did not have an effective ventilation system and during the tank cleaning process only two ceiling fans were used to provide air circulation. Ventilation rates should meet industrial hygiene standards for areas where workers are exposed to potentially hazardous chemicals. Ventilation should be maintained close to maximum efficiency and the adequacy of the system should be evaluated by monitoring of the work environment.

Recommendation #2: The employer should develop and initiate comprehensive policies and procedures for confined space entry.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should minimally include the following:

1. Posting confined space warning signs on all tanks in the plant
2. Air quality testing to determine adequate oxygen supply, adequate ventilation, and the absence of all toxic and flammable air contaminants
3. Monitoring to ensure a safe oxygen level is maintained inside the confined space
4. Employee and supervisory training in confined space entry
5. Employee and supervisory training in the selection and usage of respiratory protection
6. Identification of chemicals, possible chemical reactions, and chemical exposures
7. Hazards communication of potentially hazardous chemicals and chemical reactions
8. Development of site specific work plans and procedures that address the task being performed, emergency access, and egress
9. Training for proper selection of personal protective clothing, based on exposures.
10. Emergency rescue procedures
11. Availability, storage, and maintenance of emergency rescue equipment

The air was not monitored for toxic air contaminants and oxygen level before the workers entered the zinc cyanide holding tank. 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".

Recommendation #3: The employer should develop and implement a comprehensive respirator program, including either quantitative or qualitative fit testing and training in the use and limitations of air-purifying respirators.

Discussion: The employer did not have any SCBA's or supplied air respirators in the plant. The employer did provide acid-midst cartridge-type respirators; however, employees were not trained on their use and limitations. Employees were also not given physical examinations to determine if they were capable of wearing a respirator. The cartridge-type air-purifying respirator used by some of the workers in this incident was not the proper respirator for entering and cleaning a tank. A positive pressure SCBA should have been used. Adequate respirator selection should be according to criteria in the NIOSH Respirator Decision Logic (NIOSH publication #87-108) for assigning respirators in the plating operation; following these criteria will prevent workers from wearing inappropriate respirators for the task assigned.

Recommendation #4: Fire fighters, police personnel and others responsible for emergency rescue should be trained in confined space rescue and hazardous material emergencies.

Discussion: Fire and police department rescuers in this incident were not adequately trained in confined space rescue procedures. Many were also unaware of the hazards of hydrogen cyanide vapor. A "level A" totally encapsulated protective suit should have been worn in the rescue effort. Additionally, adequate means of exit from the confined space (such as life lines, harnesses, or man lifts) were not incorporated into the rescue attempts. Emergency rescue teams should be cognizant of all hazards associated with confined spaces, including rescue problems, and should wear proper PPE and devices for emergency egress. The conventional leather turnout gear worn by the fire fighters did not give adequate protection against hydrogen cyanide vapor.

City and county fire departments should establish a registry of confined spaces and toxic/explosive substances for specific companies within the area in which they serve. Such a registry should provide not only the name of the substance, but also sufficient information so that emergency response personnel will have sufficient information to plan a safe rescue. The development of a chemical hazard emergency plan should be coordinated with other involved agencies so that combined rescue efforts are organized and effective.

FACE 89-28: Two Maintenance Workers Die After Inhaling Hydrogen Sulfide in Manhole

INTRODUCTION

On January 31, 1989, a 29-year-old male maintenance worker (the victim) entered a sewer manhole to repair a pipe, and collapsed at the bottom. In a rescue attempt, a 43-year-old male maintenance worker (co-worker victim) entered the manhole and also collapsed. Both workers (hereinafter referred to as initial victim and co-worker victim) were pronounced dead at the scene.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer is an animal hide tanning company with 24 employees. The company operates a plant which has been in existence for 27 years (4 years under its present ownership). Most of the employees are tanning laborers (12 employees), drum operators (3 employees), and maintenance workers (2 employees). The victim had been with the company for nearly 4 years. Two months before the incident he had been promoted to the position of maintenance worker. The co-worker had been with the company for 6 years. He had been a maintenance worker for the last 4 years.

The company has a safety committee consisting of the two department heads, a union steward, and a foreman. The committee meets each week to discuss and follow up on needed safety improvements at the plant. Material safety data sheets (MSDS) on the various chemicals used in the plant are available throughout the plant. The company has a written safety policy consisting of plant safety rules and procedures for machine safety, chemical safety, and manhole entry. However, none of these rules and procedures was implemented. In addition, regular safety meetings for plant workers were not held.

SYNOPSIS OF EVENTS

The plant uses up to 120,000 gallons of water per day to process animal hides. After primary treatment, the wastewater is discharged into a series of lagoons approximately 400 yards from the plant. A gate valve located in a concrete manhole between a retention lagoon and a discharge lagoon regulates the flow of wastewater discharged. The manhole is 10 feet deep with an inside diameter of 4 feet. The top of the manhole has a 2-foot-square opening with a locked steel cover. Steel rungs on the inside of the manhole provide access to the bottom.

The manhole normally operates with about 3 feet of wastewater at the bottom. Rising vertically from a horizontal pipe at the bottom of the manhole is a 12-inch-diameter plastic overflow pipe. This pipe extends to 18 inches below ground level. The wastewater discharge volume was periodically adjusted by a worker who would partially enter the manhole (to about shoulder height and without entering the water), reach over and turn the gate valve This adjustment was made on a routine basis without testing or ventilating the manhole atmosphere. (Since the incident, the company has extended the valve stem to a level above the ground, thereby eliminating the need for workers to routinely enter the manhole to adjust the valve.)

On the day of the incident the maintenance foreman assigned the two maintenance workers (initial victim and co-worker victim) the task of repairing a crack in the top of the overflow pipe. Although there were no eyewitnesses, evidence suggests that at about 11 a.m. the initial victim entered the manhole without first testing and ventilating the inside. Presumably, the initial victim, while standing on the steel rungs inside the manhole, began to repair the broken pipe with the co-worker victim observing the work from the top, handing down tools and supplies as needed. Hard hats and steel toe boots were the only personal protective equipment worn by the workers. While repairing the broken pipe, the initial victim was apparently overcome by hydrogen sulfide gas. He fell into approximately 3 feet of wastewater and sludge at the bottom of the manhole. Presumably in a rescue attempt, the co-worker victim entered the manhole, also lost consciousness, and fell to the bottom.

At about 11:45 a.m., the maintenance foreman came to the manhole to tell the two workers it was lunchtime. When he looked into the manhole, he saw the co-worker victim at the bottom facedown in the water. The foreman did not see the initial victim, who was totally submerged in the wastewater. The foreman entered the manhole in an attempt to pull the co-worker victim out, but could not move him. The foreman became dizzy and felt like he was losing consciousness, so he climbed out. He then fell unconscious on the ground next to the manhole. When he regained consciousness approximately 15 minutes later, he ran to the plant office and notified plant personnel of the emergency. A call was placed to the emergency medical service (EMS) and the local fire department while four plant workers ran to the site. Another plant worker, who had been a local volunteer fire fighter, grabbed a self-contained breathing apparatus (SCBA) from the plant office and drove to the manhole site. The four plant workers who had arrived on foot each briefly entered the manhole in unsuccessful rescue attempts. None of these workers wore respiratory protection. They were all able to exit the manhole without any noticeable ill effects. The worker who arrived with the SCBA entered the manhole wearing the SCBA, but was also unsuccessful in his rescue attempt.

Fire fighters from the local fire department arrived at the scene approximately 15 minutes after being notified. One of the fire fighters donned an SCBA, entered the manhole and tied a rope around the co-worker victim's chest. Rescue personnel then hoisted him up out of the manhole. The initial victim's body was located and removed from the manhole in the same manner. When local EMS personnel arrived, they noted that the initial victim and co-worker victim were obviously dead for some time. Therefore, cardiopulmonary resuscitation was not attempted and the county coroner pronounced both workers dead at the scene. The foreman was hospitalized, treated for hydrogen sulfide exposure, and released 2 days later. The other five plant workers and the fire fighter who entered the manhole were treated for hydrogen sulfide exposure and released the same day.

Six days after the incident, a compliance officer from the state OSHA office conducted an investigation. During the investigation the atmosphere of the manhole was tested for hydrogen sulfide (H_2S). At first, a gas monitoring device capable of measuring concentrations up to 100 parts per million (ppm) was used. When measurements indicated that the concentration of H_2S at the bottom of the manhole exceeded 100 ppm, a gas monitoring device capable of measuring H_2S concentrations up to 500 ppm was used. A measurement of 200 ppm H_2S was obtained just inside the manhole opening.

CAUSE OF DEATH

The medical examiner listed the cause of death for both workers as anoxia due to hydrogen sulfide inhalation.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: All employers should develop and implement a safety program to protect their employees.

Discussion: The company did not have a formal safety program established. Although the company had written safety rules and procedures, they were not implemented. There were also no safety training or safety meetings conducted for plant workers. A logical first step in developing a safety program is to identify all potential hazards. One way is by analyzing the sequential steps in routine operations to identify potential hazards, and attempting to develop procedures or other control analysis is known as job hazard analysis. Additionally, each specific job involves hazards particular to that job or the working environment. The company should therefore develop and implement a safety program as outlined in NIOSH publications 77-101, "Health and Safety Guide for the Tanning Industry," and 76-157, "Good Work Practices for Tannery Workers."

Recommendation #2: The employer should develop and implement specific confined space entry procedures for each type of confined space.

Discussion: Although the company had confined space procedures for entering the sewer manhole, they were not implemented. Also, the company's existing confined space procedures do not fully address every basic procedure; however, if the existing procedures had been closely followed, the two fatalities in this incident may have been prevented. The company has other types of confined spaces (i.e., drums, pits, tanks, etc.) with no written entry procedures. Although these types of confined spaces are not entered on a routine or even an occasional basis, they should still be covered by specific procedures for entry. 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 Space." 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?

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

3. Are confined spaces posted with warning signs and are 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 based on the following criteria:

   - 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:

   - Protective clothing
   - Respiratory protection
   - Hard hats
   - Eye protection
   - Gloves
   - Lifelines
   - 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. Is ventilation equipment available and/or used?

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

Recommendation #3: The employer should develop and implement a comprehensive respirator program as required by 29 CFR 1910.134, including either quantitative or qualitative fit testing and employee training in the use and limitations of SCBA and air-purifying respirators.

Discussion: Although the company had an SCBA in the office and provided escape only hydrogen sulfide gas masks (not for confined space entry) for plant workers and drum operators, employees are not trained in their use to determine if they are capable of wearing and respirator. It should be noted that 3 months prior to this incident, a state OSHA compliance officer had cited the company for failure to provide an employee respirator program. The absence of a respirator program contributed to the fatalities and the potential hazards associated with the unsuccessful worker rescue efforts in this incident. Respirators should be selected according to criteria in the "NIOSH Respirator Decision Logic" (DHHS (NIOSH) Publication No. 87-108). Additional information on the characteristics and use of respirators is available in the "NIOSH Guide to Industrial Respiratory Protection" (DHHS(NIOSH) Publication No. 87-116).

FACE 90-30: Carbon Monoxide Kills Three Volunteer Fire Fighters Inside Well in Pennsylvania

SUMMARY

Three volunteer fire fighters 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 fire fighters 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 fire fighters decided to first pump the water out of the well (approximately 12 feet of water). One fire fighter climbed down into the well on an aluminum ladder and built a wooden platform at the 15-foot level. A second fire fighter climbed down into the well to help position a 9-horsepower gasoline engine-powered pump being lowered down to the platform. The two fire fighters started the engine but were unable to prime the pump. Within a few minutes the first fire fighter became dizzy and exited the well. The second fire fighter remained in the well and became unconscious. In a rescue attempt the first fire fighter 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 fire fighters responding to radio emergency calls arrived at the scene. Over the next 3 hours, eight volunteer fire fighters entered the well in rescue attempts. Only two of the rescuing fire fighters wore supplied-air respirators (SCBA type). The first fire fighter was rescued and revived. The second fire fighter and two other fire fighters 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 fire fighters from respiratory hazards
- ensure that fire fighters 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 fire fighters recognize and control hazards affecting themselves.

INTRODUCTION

On May 1, 1990, a 39-year-old male volunteer fire fighter died inside a 33-foot-deep water well in Pennsylvania while attempting to pump water out of the well. Also, two male volunteer fire fighters (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 fire fighters involved in the incident, and obtained reports from the police and coroner. Photographs of the incident were obtained during the investigation.

The three fire fighters 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 receives pay for services performed. The initial fire fighter victim (the second fire fighter to enter the well) had 9 years' experience as an active volunteer fire fighter. The other two fire fighter victims had 3 and 4 years' experience, respectively, as active volunteer fire fighters. The volunteer fire department has no written safety policy, no documented fire fighter 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 volunteer fire fighters 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. To remove the remains of the dead animal from the well, the fire fighters decided to pump approximately 12 feet of water out of the well.

The day before the incident, the fire fighters 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 fire fighters 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:

- Fire fighters lowered two aluminum ladders (tied end to end) into the well.
- A fire fighter (first fire fighter) climbed 15 feet down into the well on the ladder and wedged two boards across the well shaft to set the pump on.
- Another fire fighter (second fire fighter) climbed down into the well to help position the gasoline pump.
- The gasoline pump was lowered down to the platform, and the two fire fighters started the engine but were unable to prime the pump.
- Within a few minutes, the first fire fighter became dizzy, exited the well, and collapsed on the ground near the well opening.
- Fire fighters, who remained outside the well noted that the second fire fighter in a crouching position on the platform next to the pump was unresponsive.
- The first fire fighter 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 fire fighter then apparently fell off the platform face down into the water (6 feet below the platform).
- A third fire fighter climbed down into the well in a rescue attempt, but was unable to lift the first fire fighter and climbed back out.
- A fourth fire fighter 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 fire fighter's torso, and collapsed unconscious, falling facedown into the water.
- By this time, other volunteer fire fighters arrived at the scene in response to the radio emergency call, and began pulling on the rope that was attached to the first fire fighter. They were unable to lift him.
- A fifth fire fighter climbed down into the well, placed the first fire fighter on his shoulder and hoisted him out of the well with the help of fire fighters pulling on the rope at the well opening.
- Fire fighters began cardiopulmonary resuscitation (CPR) on the first fire fighter, who regained consciousness. (Up to this time, none of the fire fighters who entered the well wore any type of respiratory protective equipment.)

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

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

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

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

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

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

- An eighth fire fighter donned an SCBA, climbed down into the well, tied the end of a rope around the torso of the sixth fire fighter, and, with the help of fire fighters pulling on the rope at the well opening, began hoisting the sixth fire fighter 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 fire fighter sounded, so the eighth fire fighter climbed out of the well.

- The fifth fire fighter reentered the well (without any respiratory protective equipment), climbed down to where the sixth fire fighter was hanging, untangled the rope from the ladder, placed the sixth fire fighter on his shoulder, and, with the help of fire fighters pulling on the rope at the well opening, hoisted the sixth fire fighter 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 fire fighter at the site and in route to a local hospital. Efforts to resuscitate the sixth fire fighter were unsuccessful and he was pronounced dead in the hospital emergency room.

- A ninth fire fighter 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 fire fighter 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 fire fighter and began hoisting the fire fighter out of the well using the same technique as before. Again, the rope became entangled in the ladder when the fourth fire fighter was a few feet above the platform.

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

- An EMS rescuer then donned an SCBA, climbed down into the well, and hoisted the second fire fighter 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 fire fighter had initially begun.)

- EMS personnel administered CPR to both the fourth and second fire fighters immediately after they were removed from the well and while in 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 fire fighter and sixth fire fighter as carbon monoxide inhalation, and the cause of death for the fourth fire fighter 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 fire fighters 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 fire fighters 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 fire fighters and fire fighter supervisors being continuously trained in the selection and use of appropriate rescue equipment such as:

   - SCBA's
   - lifelines
   - human hoist systems offering mechanical advantage
   - protective clothing?

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

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

9. Are fire fighters 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 fire fighters 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 fire fighters should be trained in the use and limitations of gasoline-powered pumps and the hazards of carbon monoxide in a confined area.

Discussion: The fire fighters in this incident operated a gasoline-powered pump while inside a confined space without providing any exhaust ventilation. According to interviews with the fire fighters 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 fire fighters 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." Fire fighters are often requested by residents to perform non-emergency tasks that can endanger the fire fighter'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.

FACE 92-28: Hog Farm Co-owner and Employee Die of Hydrogen Sulfide Poisoning in Manure Pit

SUMMARY

A 27-year-old male hog farm employee (victim #1) died as a result of hydrogen sulfide poisoning when he entered a manure- waste pit to extract a pump. The 46-year-old farm co-owner, the victim's uncle (victim #2), also died from hydrogen sulfide poisoning when he entered the pit in a rescue attempt. The manure pit was a holding facility for manure that drained from five holding barns on the property before being pumped to a holding pond 150 feet away. When victim #1 and a co-worker tried to pump the manure from the pit, they discovered that the pump intake was clogged. A tripod-mounted come-a-long was positioned directly over the pit so the pump could be extracted for servicing. A 1/4 inch wire rope was attached to an eye bolt at the top of the pump. As the workers tried to raise the pump from the pit, the wire rope broke. The following morning victim #1 went to one of the barns to get a length of rope with a hook at its end to attach to the pump's eye bolt. As he prepared to descend the ladder into the pit, he was warned by his co-worker that poisonous gases might be present in the pit. Victim #1, explaining to the co-worker that he had entered the pit several times in the past and that he would be fine, descended the ladder into the pit. As he reached for the pump, he collapsed and fell into the manure. The co-worker ran to the farm office and called the rescue squad, then contacted the co-owner by two-way radio and told him what had happened. When the co-owner arrived, he decided to enter the pit with a rope to tie around the victim. The co-worker tried to restrain the co-owner from entering the pit, but the co-owner insisted that he had to go into the pit and help his nephew. The co-owner (victim #2) then entered the pit, and, as he attempted to tie the rope around the victim, collapsed on top of the victim. The rescue squad, equipped with self-contained breathing apparatus, removed the victims from the pit. NIOSH investigators concluded that, to prevent future similar occurrences, employers should:

- *identify manure-waste pits as confined spaces and post hazard warning signs at all entrances*
- *instruct farm employees never to enter manure-waste systems unless absolutely necessary, and only when following safe entry procedures*
- *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*
- *periodically inspect equipment for physical damage, especially equipment located or used in corrosive environments*
- *equip manure-waste systems with some type of powered ventilation system.*

Additionally, manufacturers of equipment designed for use in manure-waste pit systems should:

- *include warnings on the potential hazards associated with these systems.*

INTRODUCTION

On August 8, 1992, a 27-year-old male farm worker (victim #1) died of hydrogen sulfide poisoning when he entered a manure-waste pit to attach a rope to a pump so that the pump could be removed from the pit. The 46-year-old farm co-owner (victim #2) also died from hydrogen sulfide poisoning when he entered the pit in a rescue attempt. 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 2, 1992, a DSR safety specialist and two FACE field investigators from the state of Minnesota traveled to the incident site to conduct an investigation. The investigative team reviewed the incident with the farm co-owner and county extension agent, photographed the incident site, and obtained reports from the sheriff, coroner and emergency rescue squad.

The employer was a multi-farm hog-farming operation that processed approximately 10,000 hogs annually. These hogs, separated by different stages of growth, were housed on nine farms in the area. The farm employed 10 workers and had been in operation for 18 years. The employer had no written safety program or safe work procedures. The employer had no previous fatalities.

INVESTIGATION

The manure-waste pit in this incident was 12-feet deep and 49 inches in diameter. It was covered by a 7-inch-thick circular concrete slab with a 28-inch diameter opening in its center. The interior of the pit was accessed by a ladder anchored to the side of the pit. The manure entered the pit through five gravity-fed drains leading from five holding barns. Occasionally, the pump intake, located within the pit, would become clogged with debris from one of the barns. When this occurred, the pump was extracted from the pit using a tripod-mounted come-a-long that was positioned directly over the pit. A 1/4 inch wire rope from the come-a-long remained attached to the eye bolt on the top of the pump at all times.

On the afternoon before the incident, the farm worker (victim #1) and a co-worker went to the manure pit to pump it out, but found that the pump intake was clogged with debris. The men tried to raise the pump from the pit but the 1/4 inch wire rope attached to the eye bolt at the top of the pump broke. The two men then decided to wait until the following morning to repair the pump and replace the wire rope.

On the following morning, victim #1 told the co-worker that he was going to climb down the ladder to attach a new wire rope and hook to the eye bolt on the pump. The co-worker warned the vic-tim not to enter the pit because of the possibility of poisonous gases in the pit. The victim told the co-worker that he had entered the pit several times in the past and had never experienced any problems. He then descended the ladder approximately 9 feet into the pit. As the victim bent over to attach the hook to the eye bolt he collapsed into the manure. The co-worker immediately ran to the office and called the emergency rescue squad, then contacted the co-owner by two-way radio and told him what had happened. The co-owner (victim #2) arrived at the farm, found some rope to tie around the victim, then ran to the pit. The co-worker repeated his warning about the presence of poisonous gases to the co-owner, but the co-owner insisted that he had to try to rescue his nephew. The co-worker tried to physically restrain the co-owner from entering the pit but failed. The co-owner then descended the ladder into the pit, and as he tried to tie the rope around victim #1, he was overcome and collapsed on top of victim #1. The emergency rescue squad arrived 10 minutes after the co-owner entered the pit and approximately 20 minutes after victim #1 was overcome. Using self-contained breathing apparatus, the rescue squad removed the victims from the pit. The victims were transported to the hospital where they were pronounced dead.

Gas readings taken by the FACE team during their investigation showed no measurable levels of hydrogen sulfide or methane, and an oxygen level of 20.4%. It should be noted that on the day of the incident and the preceding day, the temperature was in the mid 90s and the humidity was about 95%; the barometric reading was 30.2 and there was no wind. These conditions would have been favorable for a buildup of hydrogen sulfide and/or methane inside the pit. At the time of the investigation, the temperature was 65 degrees and the conditions were windy.

CAUSE OF DEATH

The coroner listed the cause of death for both victims as hydrogen sulfide poisoning.

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 confined spaces, as described in this incident, are 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 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 equip- ment and training in the use of this equipment may not be readily available to many farm workers, these workers should, at a minimum 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 might not be able to speak or read English. In some areas, signs in more than one language might 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-waste pit system 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 of removing 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 substantial anchor point 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 resolved and understood 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 to be 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 periodically inspect equipment for physical damage, especially equipment located or used in corrosive environments.

Discussion: In this incident, the unwritten standard operating procedure called for the pump to be raised from the manure pit for maintenance. A wire rope was connected to the pump for this purpose; however, when the workers attempted to raise the pump, the wire rope broke. Since the pump was raised from the pit at least once a month for maintenance or repair, a visual inspection for physical damage to the pump, wire rope, or any other components could have been conducted at this time. Any damaged component should be repaired or replaced immediately. This would be especially important for components used in a corrosive environment such as a 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. Information (such as diagrams, etc.) about installing 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.

Physical Hazards

Engulfment

FACE 86-19: Truck Driver Suffocates in Sawdust Bin in Pennsylvania

INTRODUCTION

On February 21, 1986, a 22-year-old self-employed truck driver died after entering the top of a 22-foot-high by 15-foot-square sawdust bin. He was suffocated when the sawdust inside the bin collapsed and buried him.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The facility at which the fatality occurred has been in operation for the past 115 years and has been under the present ownership for the past 4 years. The facility employs six full-time workers. Fifty percent of the business at the facility involves the manufacturing of wooden gauge (measuring) poles for the local oil industry while the other 50 percent of the business is devoted to surfacing lumber for the local lumber industry. Safety rules exist that cover the work performed in the wood shop. No written safety rules exist that outline precautions to be taken when entering the sawdust bin; however, when the victim began hauling sawdust away from the facility 1 1/2 years ago, the owner and the victim discussed the hazards that might be encountered upon entering the sawdust bin. Both men were aware of the potential hazards. A safety line was present in the sawdust bin, but was not utilized by the victim on the day of the incident.

SYNOPSIS OF EVENTS

The victim had hauled sawdust away from the facility for the past 1 1/2 years. The owner did not receive payment from the victim for the sawdust, nor did the victim bill the owner for hauling the sawdust away from the facility. The only stipulation in the agreement was that the victim would keep the level of sawdust inside the bin at such a level that production would not have to be interrupted. The sawdust bin was located outside and to the rear of the facility. At 10:30 a.m. on the day of the incident, the victim pulled his truck underneath the auger that dispensed the sawdust. This auger was mounted 5 feet above ground level on the side of the sawdust bin at approximately a 45-degree angle from ground level. The control switch was mounted adjacent to the auger. The victim turned the auger on, but very little sawdust came out of the auger. The victim then turned the auger off. It was not unusual for the sawdust to accumulate on the sides of the bin. When this occurred the victim or the owner (the only two workers allowed in the bin) would climb the ladder to the entrance, which was located on the side of the bin 22 feet above ground level. The owner or victim would then utilize a section of pipe to knock sawdust from the sides of the sawdust bin into the auger attachment. Since it was sometimes necessary to enter the sawdust bin to accomplish this task, a safety line was present inside the entrance. The owner stated that he had to remind the victim to use the safety line on several occasions.

At approximately 11 a.m. the victim entered the sawdust bin and was in the process of knocking the sawdust down into the auger attachment when the surface beneath him gave way and he was buried by the sawdust. He had not attached the safety line to himself. To compound the problem, sawdust from the wood planers in the shop continued to be blown into the sawdust bin.

At 11:15 a.m. the owner had to move the victim's truck so that a truck hauling gravel could pass through. The owner was not alarmed when he did not see the victim since it was commonplace for the victim to ride into town with someone to get coffee or something to eat. The owner then left for a doctor's appointment. When the owner returned from his doctor's appointment at 1:15 p.m. he noticed that the victim's truck had not been moved. He climbed the ladder and saw that the sawdust bin was filled to capacity. The owner also saw the end of the pipe protruding from the sawdust in the center of the bin. The owner descended the ladder, entered the facility, and asked the workers if they had seen the victim; they hadn't. The owner ordered all operations to be stopped. He then exited the facility with one of the workers and turned the auger on. The owner and worker then climbed the ladder. The owner entered the sawdust bin without utilizing the safety line and quickly sank into the sawdust up to his chest. The worker was able to rescue the owner. As the level of sawdust in the bin dropped, the victim was uncovered. At approximately 1:30 p.m. the victim was removed from the sawdust bin and was pronounced dead at the scene by the county coroner.

CAUSE OF DEATH

The county coroner listed asphyxiation as the official caused of death.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: All safety equipment provided at a worksite should be utilized.

Discussion: The owner and the victim in this case both realized the inherent dangers of the unstable material inside the sawdust bin. For this reason a safety line was installed inside the upper entrance of the sawdust bin. Workers should not allow themselves to be lulled into a false sense of security when working in a confined space containing unstable material (i.e., sawdust). Had the victim used the provided safety line in this instance, the likelihood of a fatality occurring would have been greatly reduced.

Recommendation #2: When work is being performed in a confined space containing unstable material, a standby person must be utilized.

Discussion: A standby person stationed outside the confined space containing unstable material (i.e., sawdust) should maintain constant communication with the worker inside the area. If visual contact cannot be maintained, the standby person should at least maintain voice contact. The use of a standby person by the victim might have prevented the fatality; the use of a standby person by the owner prevented a rescue attempt fatality.

Recommendation #3: The feasibility of installing an electrical interlock system in the facility should be examined.

Discussion: An electrical interlock system could be installed in the facility. This system would disconnect the power to the auger, the blowers, and the planers inside the facility when the entrance to the sawdust bin was opened. This would eliminate the possibility of sawdust being drawn down into the auger causing the surface beneath a worker to collapse, and without the blowers and planers operating, additional sawdust would not be blown into the bin. In addition, this safeguard would alert plant personnel that someone was entering the storage bin.

Recommendation #4: Facilities whose operations include entrance into a confined space should develop comprehensive policies and procedures for confined space entry and emergencies.

Discussion: Prior to confined space entry, a hazardous operation should be explained by written procedures that address the hazards associated with entry. Several areas normally addressed by procedures such as this are permit systems (notification of other personnel), standby personnel, and procedures to be followed in an emergency. In this case all of the above areas were not initiated in accordance with generally accepted and established procedures. (The NIOSH Confined Space Document, "Working in Confined Spaces," Publication 80-106, discusses these procedures in detail.)

FACE 87-49: Farmer Dies in Indiana

INTRODUCTION

On May 26, 1987, a farmer suffocated when he was engulfed in shelled corn inside a grain storage bin. The storage bin had a capacity of 12,000 bushels.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was the owner of a 100-acre grain farm. There was no written safety program or safety policy. The farmer was aware of the hazards associated with grain storage bins. He often instructed fellow farmers and family members never to enter a grain storage bin without wearing a harness attached to a lifeline.

SYNOPSIS OF EVENTS

The farmer had rented a grain storage bin with 12,000 bushels capacity at a nearby farm. He had stored approximately 8,000 bushels of shelled corn in the storage bin. The temperature of the corn was beginning to rise and the farmer was afraid it was going to spoil. On the day of the incident he was going to load a portion of the grain onto a truck. He was planning to use a grain auger to load the corn onto a truck and to stir the corn remaining in the storage bin. He was doing this in an effort to lower the temperature of the corn. The farmer had diabetes and had recently suffered from "dizzy spells" associated with the disease. He was warned by his daughter as he left the house at noon not to enter the storage bin, and he said he would not.

The farmer drove to the bin and pulled the truck under the loading chute. He then started the auger, using the controls at the base of the storage bin. There were no witnesses to the accident, but it is assumed he climbed the ladder attached to the side of the bin (20 feet) and entered the door at the top. The farmer's son arrived at the storage bin at approximately 2 p.m. He noticed the auger running and only a small amount of corn coming out of the loading chute. Assuming that his father was visiting neighbors, the son opened the chute, but left the auger running and returned home.

At approximately 4:30 p.m., the son was notified by his wife that his father had not returned home. The son and a friend drove to the grain storage bin. The truck had not been moved and the auger was still running. In order to remove the shelled corn, the door on the side of the bin was opened. Cutting torches were used to cut holes at the base of the storage bin. The shelled corn was shoveled away from the storage bin by hand for approximately 2 hours before the farmer's body was found.

CAUSE OF DEATH

The coroner listed "suffocation" as the cause of death.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: When work is being performed in a confined space containing unstable material, a standby person should be utilized.

Discussion: A standby person stationed outside of confined spaces containing unstable material (i.e. shelled corn) should maintain constant communication with the worker inside the area. If visual contact cannot be maintained, the standby person should at least maintain voice contact. The use of a standby person would have greatly reduced the amount of time before rescue procedures began and may have prevented this fatality.

Recommendation #2: Confined spaces containing unstable material should be equipped with life lines and harnesses at their entrance point(s).

Discussion: Life lines and harnesses should be present at the entrance(s) of confined spaces containing unstable materials and should be utilized by all persons entering the confined space. If these are not provided by the manufacturer they should be installed by the user prior to entry into the confined space. A life line and harness may have prevented this fatality.

FACE 89-33: Grain Elevator Leadman Suffocates After Being Engulfed in Shelled Corn Inside Silo

INTRODUCTION

On April 5, 1989, a 54-year-old male grain elevator leadman died when he was engulfed in corn stored inside a 76-foot-high, 33-foot-diameter grain silo. The victim was using a pneumatic conveyer to clean the inside of the grain silo.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was employed as an elevator leadman at a grain processing facility that has been in operation for 47 years. The facility employs a total of 80 workers, and has no written safety policy or safety program. Workers receive on-the-job training. Since the incident, the facility has instituted a comprehensive confined space entry program.

SYNOPSIS OF EVENTS

On the afternoon prior to the incident, the victim and a co-worker were assigned the task of removing the remaining grain (shelled corn) from a concrete silo. Most of the grain had been removed by a 16-inch-wide gravity-fed auger-transfer unit incorporated into the floor of the silo. When the grain had reached a level approximately 6 feet above floor level, it would no longer feed into the conveyor. An estimated 10,000 bushels of corn remained in the silo. Until 6 months previous to this incident, procedures called for the remaining grain to be shoveled from the silo by hand. However, the employer purchased a pneumatic conveyor which was powered by the power take-off system of a tractor. Using this device, the remaining grain could be transferred from the silo into a truck by means of a 5-inch diameter suction hose. This pneumatic conveyor had the capacity to transfer between 2,500 and 3,000 bushels of corn per hour.

On the day prior to the incident, the victim and his co-worker positioned the pneumatic conveyor outside the silo. The victim and the facility manager entered the silo by means of a door (16 inches by 18 inches) located on the side of the silo. The bottom of the door was 6 feet above the floor level of the silo. The shelled corn that remained in the silo was level with the bottom of the door. The two men inspected the surface of the grain at that time and felt confident that the surface was not crusted and that no bridging (crusted surface covering a hollow space) was present in the remaining grain. The men then exited the silo. The victim re-entered the silo later with the suction hose of the pneumatic conveyor and began transferring the grain to a truck outside. A co-worker remained outside the silo to operate the tractor and the pneumatic conveyor. After enough corn was removed to determine the machinery was working properly, the two men then shut off the equipment and left it in position for the following day.

The following morning the men resumed the transfer operation. At 10 a.m., the co-worker heard the victim yell from inside the tank to turn the pneumatic conveyor off. After not seeing or hearing from the victim for a few moments, the co-worker looked through the door into the silo. When the co-worker did not see the victim inside the silo, he assumed that the victim had exited the silo and gone inside the office building. Discovering that the victim had not been seen in the area, he called the facility manager. A decision was made to begin cutting holes around the perimeter of the silo in order to remove the grain. In addition, the pneumatic conveyor was restarted and the facility manager entered the silo to operate the suction hose. At 2 p.m., after some of the grain had been removed, the victim was found lying on his back on the floor of the silo. He was removed from the silo by facility personnel and was pronounced dead at the scene by the county coroner.

The rapid removal of the grain by the pneumatic conveyor may have created a quicksand-like effect at the feet of the victim causing him to be engulfed by the shelled corn before he could exit the silo.

CAUSE OF DEATH

The county coroner ruled suffocation as the cause of death.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop a comprehensive safety program that clearly documents procedures for safe entry into confined spaces such as those contained in the NIOSH criteria document on "Working in Confined Spaces" (NIOSH Publication 80-106) and "A Guide to Safety in Confined Spaces" (NIOSH Publication 87-113).

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to working in a confined space. These procedures should include, but not be limited to:

1. testing air quality to determine adequate oxygen level and the presence of flammable and/or toxic gas/vapors
2. ventilating the space to remove air contaminants
3. monitoring the space to determine a safe oxygen level is maintained
4. training employees in confined space entry, testing, and use of personal protective equipment, safety harnesses, respirators, clothing, etc.
5. stationing a standby person(s) outside the space for communication and visual monitoring
6. providing for emergency rescue procedures
7. identifying and controlling of the hazards associated with unstable surfaces.

Since the incident the employer has implemented a comprehensive confined space entry program.

Recommendation #2: Confined spaces containing unstable material should be equipped with life lines and harnesses at their entrance point(s), and workers should be trained in their usage.

Discussion: Life lines and harnesses should be present at the entrance(s) of confined spaces containing unstable materials and should be utilized by all persons entering the confined spaces. If these are not incorporated into the design of the silo by the manufacturer, they should be installed by the user prior to worker entry into the confined space. Workers should then be trained in the proper use of this equipment.

Recommendation #3: When work is being performed in a confined space containing unstable material, a standby person should be utilized in a manner such that constant communication with the worker inside the confined space can be maintained.

Discussion: A standby person, e.g., stationed outside of confined spaces containing unstable material (i.e., shelled corn), should maintain constant communication with the worker inside the area. If visual contact cannot be maintained, the standby person should at least maintain constant voice contact. In this instance, although there was a person outside the silo, he was not a designated standby person and did not maintain constant contact with the person inside. The co-worker outside the silo was operating noisy machinery that made it difficult to hear a worker inside the silo. Although the co-worker heard the victim yell to turn the pneumatic conveyor off, he may not have heard other calls from the victim. If a designated standby person had been stationed at the door of the silo, quicker action may have been taken that may have prevented the fatality.

Recommendation #4: Employers should perform a hazard analysis on each new piece of equipment or machinery and associated tasks to determine if potential hazards exist.

Discussion: A proper hazard analysis involves three distinct steps:

(1) outline each step of a task or activity that involves the equipment or machinery

(2) identify all potential hazards presented by the equipment or machinery during each step

(3) develop measures for controlling each hazard.

Had such an analysis been performed, the employer may have identified the danger associated with rapidly transferring unstable material when someone is standing on the surface of that material.

Recommendation #5: Employers should instruct workers to enter confined spaces only when absolutely necessary and to strictly adhere to established confined space entry procedures.

Discussion: In this instance it was not absolutely necessary for the worker to enter the silo when the job began. A significant amount of the corn could have been removed while a worker maneuvered the 5-inch flexible hose from outside the silo. Enough corn could have been transferred in this manner to allow the victim to stand on the floor of the silo to complete the job. This would have eliminated the hazard of performing work while standing on an unstable surface.

Recommendation #6: Employers should not allow workers to stand on or work from the surface of loose, granular materials, even when the surface appears to be stable.

Discussion: Employers should not only prohibit workers from standing on unstable surfaces while performing their assigned tasks, but should also require employees to wear safety harnesses or safety belts attached to lifelines when working in the vicinity of unstable surfaces. Workers should be made aware of the hazards, such as engulfment, bridging, and crusting, associated with unstable surfaces. Workers should be instructed in the identification of these hazards and appropriate methods needed to avoid them.

Recommendation #7: Equipment manufacturers should recognize potential hazards inherent in the operation of their products, and provide appropriate warnings and safety information in product advertising and packaging.

Discussion: At the time of the investigation, advertising literature for two manufacturers of pneumatic conveyor systems was obtained. Neither pamphlet contained any warning of the hazards associated with entering confined spaces or the hazards associated with unstable surfaces such as stored grain. A photograph in one pamphlet actually shows a worker inside a silo standing on shelled corn while performing his task. No safety devices or stand-by persons are visible in the photograph.

Both manufacturers were apprised of the situation and alerted to the hazard presented by standing on grain while using the pneumatic conveyor system. The manufacturers are considering including a warning in the advertising literature that addresses the hazards associated with confined spaces and unstable surfaces. Additionally, copies of NIOSH publications 87-113 (A Guide to Safety in Confined Spaces) and 88-102 (Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials) were sent to the manufacturers for consideration as supplementary information to be included with advertising literature. Responsible advertising could contribute to the prevention of these fatalities.

FACE 91-04: Maintenance Worker Suffocates From Engulfment After Falling Into Sawdust Silo

SUMMARY

A maintenance worker (victim) for a furniture manufacturing company fell headfirst into a sawdust storage silo and suffocated. The silo is 17 feet in diameter, 36 feet high, and has a 24-inch diameter manhole on top near the edge. Although there were no witnesses, evidence suggests that the victim did the following: a) climbed to the top of the silo to check the sawdust level inside, b) removed the manhole cover, c) stuck his head inside the manhole and noted that the silo was nearly full of sawdust, d) reached inside the manhole with a hoe-like tool to "rake down" the sawdust pile, e) slipped from this position, and f) fell headfirst into the sawdust 7 feet below. The upper half of the victim's torso became submerged in the sawdust and the victim suffocated in an upside down position. NIOSH investigators concluded that, in order to prevent future similar occurrences, employers should:

- *provide appropriate fall protection equipment to all workers who may be exposed to a fall hazard*
- *develop and implement safe work procedures for employees who work in, or near, confined spaces containing unstable materials*
- *develop and implement a comprehensive confined space safety program*
- *consider retrofitting silos and similar storage facilities with mechanical leveling/raking devices, or other means to minimize the need for workers to climb and enter silos.*

INTRODUCTION

On September 21, 1990, a 52-year-old male maintenance worker died after falling headfirst into a sawdust silo. On September 25, 1990, officials of the Virginia Occupational Safety and Health Administration notified the Division of Safety Research (DSR) of the death, and requested technical assistance. On November 15, 1990, a research industrial hygienist from DSR traveled to the incident site and conducted an investigation. The DSR investigator reviewed the incident with company representatives and employees, the medical examiner, and the Virginia OSHA compliance officer assigned to this case. Photographs of the incident site were obtained during the investigation.

The employer in this incident is a furniture manufacturer that has been in business for 60 years. Most of the work performed by the company involves machining hardwood and the assembly of furniture components. The company employs 275 full-time employees, including 6 maintenance workers. The victim had been employed by the company for 8 years as a maintenance worker. The company has a written safety program consisting of hazard communication, lockout/tagout, respiratory protection, and confined space entry components. A safety committee composed of supervising laborers and management is responsible for the safety program. New employees receive on-the-job safety training from supervisors and co-workers.

INVESTIGATION

Wood scraps and sawdust from the plant production areas are removed by a system of mechanical conveyors and suction ducts. The sawdust is stored in one of two steel silos, then burned in the plant boiler. The sawdust is drawn into each silo through an 8-inch diameter duct at the top center of the structure. The larger silo, measuring 25 feet in diameter and 55 feet high, operates about 80 percent of the time. When it is full or being emptied, sawdust is diverted to a smaller silo (measuring 17 feet in diameter and 36 feet high). The smaller silo will fill up in about 5 days when the plant is in full operation.

The victim was responsible for keeping the scrap wood conveyers, sawdust removal ducts, and the two silos operating. Whenever the smaller silo was in operation, the victim would visually check the sawdust level inside the silo twice a day. The victim would climb a staircase attached to the side of the silo, remove the cover to a 24-inch-diameter manhole located at the top near the edge, and peer inside. If the tip of the sawdust pile or cone was close to the inlet duct, the victim would "rake it down." This was done by reaching inside the manhole with a tool resembling a garden hoe with a 10-foot-long aluminum handle. The victim kept this tool on top of the silo near the manhole.

The smaller silo was in operation on the day of the incident. At 1:15 p.m., the victim entered the boiler room and informed the maintenance supervisor that he believed the smaller silo was nearly full, and that he was going to check the sawdust level. Although there were no eyewitnesses to the incident, based on the circumstances and evidence, it is presumed that the following sequence of events occurred:

- the victim climbed the stairs to the top of the small silo and opened the manhole cover
- the victim crouched, or laid down, stuck his head inside the manhole and noted that the silo was nearly full of sawdust
- the victim reached inside the manhole with the hoe to rake down the sawdust pile
- the victim slipped from his position and fell 7 feet, headfirst into the sawdust
- the upper half of the victim's torso became submerged in the sawdust and the victim suffocated in an upside-down position.

About 30 minutes later, a co-worker entered the boiler room and asked the maintenance supervisor if he had seen the victim. The maintenance supervisor told the co-worker that the victim had gone to check on the sawdust level in the smaller silo. The co-worker climbed to the top of the silo and peered inside the manhole. He saw the victim's legs sticking out of the sawdust, and the hoe lying on top of the sawdust. The co-worker yelled to the victim, but there was no response.

The co-worker ran back to the boiler room and told the maintenance supervisor what had happened. The maintenance supervisor radioed the plant superintendent, who called the emergency medical service (EMS). The plant superintendent, maintenance supervisor, co-worker and several other workers ran up the stairs to the top of the silo. The superintendent tied a rope around his waist, the other workers lowered him into the silo through the manhole, and he tied a rope around the victim's waist. The workers pulled the victim out while the superintendent assisted from inside the silo. After the superintendent was pulled out of the silo, he carried the victim down the stairs to the ground. By this time, EMS personnel had arrived at the scene (about 10 minutes after the emergency call was received). EMS personnel administered cardiopulmonary resuscitation to the victim at the scene and in route to the local hospital. The victim was pronounced dead on arrival by the attending physician.

CAUSE OF DEATH

The medical examiner listed the cause of death as suffocation due to submersion in sawdust.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should provide appropriate fall protection equipment for all workers who may be exposed to a fall hazard.

Discussion: Employers should provide appropriate fall protection equipment for all workers exposed to fall hazards, and should provide worker training in the proper use of this equipment. Once this training is provided, employers should initiate measures to ensure the use of this fall protection equipment. A safety belt and lanyard, suitably anchored, would be appropriate fall protection equipment for use on top of sawdust silos. This type of fall protection equipment has an additional life-saving benefit. When properly installed, such fall protection equipment will prevent workers from being engulfed if they fall into a silo or other confined space containing unstable materials.

Recommendation #2: Employers should develop and implement safe work procedures for employees who work in, or near, confined spaces containing unstable materials.

Discussion: OSHA construction safety standard 29 CFR 1926.250(b)(2), General Requirements for Storage, requires workers to use safety belts while working on stored materials in silos, bins, or other similar storage areas. The Mine Safety and Health Administration (MSHA) has requirements for storage of materials in the mining industry (39 CFR 56). These requirements address the storage of loose, unconsolidated materials, safe access, and the use of safety belts and lines. In the absence of general industry standards covering such work, these requirements are appropriate for application to similar situations in general industry. Life lines and harnesses should be present at the entrances of confined spaces containing unstable materials, and should be used by all workers (including rescuers) entering confined spaces. Optimally, lifelines and harnesses should be incorporated into the design of the silo by the manufacturer. Silos without this design feature should be provided with appropriate safety equipment, by the employer, and use should be mandatory. Workers should be trained in the proper use of this equipment. Some lifelines, harnesses, and human hoisting devices designed for confined space entry are also rated for fall protection (Recommendation #1). A NIOSH Alert entitled "Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials" provides additional recommendations pertaining to work on or around silos.

Recommendation #3: Employers should develop and implement a confined space safety program.

Discussion: Employers should ensure that employees are aware of the potential hazards, possible emergencies, and specific procedures to be followed prior to working in, or around, a confined space. At a minimum, as discussed in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces," the following items should be addressed:

1. Testing the air quality to determine adequate oxygen level and the presence of combustible and toxic air contaminants
2. adequate ventilation to remove air contaminants
3. monitoring the space to determine that a safe atmosphere is continuously maintained
4. training employees in confined space entry, testing, and the use of personal protective equipment, safety harnesses, respirators, clothing, etc.
5. stationing a standby attendant outside the space for communication and visual monitoring
6. emergency rescue procedures
7. identifying and controlling the hazards associated with unstable surfaces.

Recommendation #4: Employers and manufacturers should consider retrofitting silos and other similar storage facilities with mechanical leveling/raking devices, or other means to minimize the need for workers to climb or enter silos.

Discussion: Silos, bins, hoppers, tanks, transport vehicles, and surge piles where loose materials are stored, handled, or transferred should be equipped with mechanical leveling/raking devices or other means for remotely handling materials. Such devices would minimize the need for workers to climb or enter such storage facilities. Usually cone shaped piles of loose material can be leveled, and bridging of material prevented, by mechanical agitation or vibration of stored materials.

REFERENCES

1. Office of the Federal Register, Code of Federal Regulations, Labor, 29 CFR 1926.250(b)(2), U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C., July 1989.

2. Office of the Federal Register, Code of Federal Regulations, Labor, 39 CFR 56.16002, 39 CFR 56.11001, and 39 CFR 56.15005, U.S. Department of Labor, Mine Safety and Health Administration, Washington, D.C., July 1989.

3. National Institute for Occupational Safety and Health, Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials, DHHS (NIOSH) Publication Number 88-102, December 1987.

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

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

FACE 91-12: Truck Driver Suffocates After Being Engulfed in Shelled Corn Inside Grain Storage Bin in Ohio

SUMMARY

A truck driver (victim) was engulfed in shelled corn inside a grain storage bin and suffocated while trying to clear an obstructed grain auger. The grain bin was 32 feet in diameter, 20 feet high, and contained approximately 8,000 bushels of corn at the time of the incident. The bin had a 36-inch by 20-inch hatch at the top near the edge, another hatch on the side, 2 feet above the bin floor, and steel access ladders anchored to the exterior and interior of the bin wall. The victim and two farm laborers were transferring corn from the bin to a truck, using two augers. One auger, placed horizontally in the bottom of the bin, pushed the corn through a pipe into a small hopper outside the bin. The second auger lifted the corn from the hopper to the truck. When each truck was loaded, the corn was hauled to a commercial grain storage silo. When the third truckload had been loaded, the corn stopped flowing into the hopper. The victim and one of the laborers entered the grain bin through the top hatch and tried to get the grain flowing again. The victim stood on the surface of the corn in the middle of the bin, and probed the corn with a 15-foot-long section of 1-inch-diameter galvanized pipe. The laborer stood on the corn near the ladder at the side of the bin. When the corn began to flow, the victim was quickly engulfed, sank to the bottom of the bin, and suffocated. The laborer hung onto the ladder and escaped injury. NIOSH investigators concluded that, in order to prevent future similar occurrences, employers should:

- *develop and implement safe work procedures and training for employees who work in, or near, confined spaces containing unstable materials*
- *provide lifelines and harnesses, and ensure that workers wear them before entering confined spaces containing unstable materials*
- *consider retrofitting grain storage bins and other similar storage facilities with mechanical leveling/raking devices, or other means to minimize the need for worker entry.*

INTRODUCTION

On January 24, 1991, a 43-year-old male truck driver (victim) died after being engulfed in shelled corn inside a grain storage bin. On February 26, 1991, officials of the Ohio State University Agricultural Department notified the Division of Safety Research (DSR) of the death, and requested technical assistance. On March 26, 1991, a research industrial hygienist from DSR traveled to the incident site and conducted an investigation. The DSR investigator reviewed the incident with the company owner, the medical examiner, the property owner, the investigating police officer, the county agriculture extension agent, and a representative from the Ohio State University Agriculture Department. Photographs of the incident site were obtained during the investigation.

The employer in this incident, a commercial trucking company, had been in business for 23 years. Most of the work performed by the company had involved hauling agricultural products. At the time of the incident, the company owner employed only one truck driver (the victim), who had worked for the owner for 23 years. The owner had employed as many as four truck drivers at one time. The company did not have a written safety policy, safety program or established safe work procedures. Employees did not receive any type of safety training.

INVESTIGATION

On the day before the incident, the company owner contacted the victim and asked him to haul approximately 12,000 bushels of shelled corn from a grain bin on a local farm to a nearby commercial grain storage silo.

The grain bin on the farm was 32 feet in diameter, 20 feet high, and was constructed of corrugated galvanized steel. The bin had two access hatches. One hatch was on the side, 2 feet above the bin floor, and measured 30 inches wide by 60 inches high. The other hatch was located on the top near the edge, and had an elliptical shape measuring 36 inches by 20 inches across the center. Posted on the inside of the top hatch door was a 20-inch by 12-inch hazard warning sign in red and black lettering. It stated, "DANGER ... YOU CAN SUFFOCATE UNDER GRAIN IN THIS BIN ... DO NOT ENTER WHEN THIS BIN IS BEING LOADED OR UNLOADED." Also included on the warning sign were safety instructions, and diagrams depicting potential hazards of being engulfed and suffocating in grain. Access to the top of the bin was provided by a galvanized steel ladder anchored to the outside of the bin. A second ladder was anchored to the inside of the grain bin, and extended from the top hatch to the bin floor. Installed within the concrete floor of the bin was a channel with an auger shaft. The auger was connected to a horizontal, 4-inch-diameter grain discharge pipe which extended to the outside of the grain bin. When the grain was loaded from the bin to a truck for commercial transport, a portable electric motor was mounted to the discharge pipe outside the bin. A drive belt on the electric motor turned the shaft of the horizontal auger, and the grain was drawn from the bottom of the bin, through the discharge pipe, and into a small plastic hopper outside the bin. A mobile grain auger, driven by a tractor power-take-off (PTO) unit lifted the grain from the hopper to the truck.

The victim arrived at the site in the afternoon on the day before the incident. With the help of two farm laborers employed by the property owner, the victim transferred nearly 3,000 bushels of corn from the bin to the truck. When the second truckload was nearly loaded, the victim and farm laborers noticed that some of the corn appeared to be "out of condition," i.e., to have a high moisture content. This caused the grain to agglutinate, and obstructed its flow. Since it was late in the afternoon, the victim decided to transport the second load, and complete loading and transporting the rest of the corn the following day.

On the day of the incident, the victim returned to the site at 1 p.m., and worked with the farm laborers to fill the third truckload. When the truck was nearly full, the corn stopped flowing out of the bin discharge pipe. The victim transported that load, and returned at approximately 5 p.m. The victim told the farm laborers that he would enter the grain bin and probe the corn with a pole or rod to get the corn flowing again. He found a 15-foot-long, 1-inch-diameter section of galvanized pipe to use for this purpose. He climbed the ladder to the top of the grain bin, and one of the laborers (first laborer) handed him the pipe. The victim opened the top hatch, inserted the pipe, and entered the bin with the grain bin auger still running. There was approximately 12 feet of corn remaining inside the bin. The first laborer entered the bin and stood on the corn near the ladder to help the victim probe the corn. The victim stood on the corn near the center of the bin and pushed the pipe to the bottom of the bin in several places, but the corn still would not flow.

Suddenly, the corn began to flow, pulling the victim down with it. Almost instantly the victim was buried up to his knees, and continued to sink into the corn. The victim immediately yelled to the first laborer, "Turn off the auger!" The first laborer hurriedly climbed up the ladder, stuck his head out the top hatch, and shouted to the laborer who was on the ground near the hopper (second laborer) to turn off the grain bin auger. The second laborer immediately pulled the electric power cord to the auger motor, and the first laborer climbed back down into the bin in an attempt to rescue the victim. The first laborer could not see very well because of the dust in the air, so he yelled the victim's name several times, but could not hear any response. The first laborer climbed back up the ladder inside the bin, and told the second laborer to "Get help!"

After calling the emergency medical service (EMS) from a phone at a nearby residence, the second laborer climbed to the top of the grain bin, and the two laborers entered the bin to look for the victim. The grain had stopped flowing but the dust in the air restricted the laborers' visibility to only a few feet. The laborers searched for the victim for approximately 10 minutes. They walked across the surface of the corn several times, thrusting their hands into the corn in various places, and calling out the victim's name. However, they were unsuccessful in locating the victim, and did not hear any response from him.

Two police officers, followed by several local volunteer fire fighters, arrived at the scene approximately 10 to 15 minutes after receiving the emergency call. They opened the side hatch on the bin, and began shoveling corn away from the bin. Fire fighters cut several openings in the side of the bin with the bucket on a front end loader and a metal-cutting power saw. Other emergency responders shoveled corn away from all the openings in the bin. The victim was found on the bottom of the bin after having been engulfed for approximately 90 minutes. The victim received cardiopulmonary resuscitation (CPR) at the scene and in route to a local hospital where the attending physician pronounced him dead on arrival.

CAUSE OF DEATH:

The medical examiner listed the cause of death as mechanical asphyxiation due to inhumation in corn.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should develop and implement safe work procedures and training for employees who work in, or near confined spaces containing unstable materials.

Discussion: Farm workers, truck drivers, and other employees who work with agricultural products are regularly exposed to confined space hazards. Employers should ensure that they and their workers are familiar with the hazards of grain bins, silos, manure pits, and other farm-related confined spaces. Additionally, they should be aware of possible emergencies, and specific procedures to follow, prior to working in confined spaces. Grain storage bins, by their design, meet the NIOSH criteria for the definition of a confined space. Entrance into these bins should be in accordance with the guidelines in NIOSH Publication 80-106 ("Criteria for a Recommended Standard ... Working in Confined Spaces"). Four other publications, designed to increase worker awareness of confined space hazards, and to provide specific recommendations for safe work procedures are available: (1) A grain bin hazard alert, developed and published by the Ohio State University Cooperative Extension Service, "Suffocation Hazards in Grain Bins," (2) NIOSH Publication 88-102 (NIOSH Alert, "Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials"), (3) NIOSH Publication 86-110 ("Request for Assistance in Preventing Occupational Fatalities in Confined Spaces"), and (4) NIOSH Publication 87-113 ("A Guide to Safety in Confined Spaces"). During the on-site investigation, the NIOSH/DSR investigator gave a copy of each NIOSH publication to the employer, the farm owner, and the agriculture extension agent. The publications do not address all safety concerns and recommendations for every situation. However, they do provide useful information in developing safety training and safe work procedures specific to the engulfment hazards associated with storing and transporting grain. Some of these issues which should be addressed are included in the appendix of this report.

Recommendation #2: Employers should provide lifelines and harnesses, and ensure that workers wear them before entering confined spaces containing unstable materials.

Discussion: OSHA construction safety standard 29 CFR 1926.250(b)(2), General Requirements for Storage, requires workers to use safety belts while working on stored materials in silos, grain bins, or other similar storage areas. The Mine Safety and Health Administration (MSHA) has requirements for storage of materials in the mining industry (30 CFR 56). These requirements address the storage of loose, unconsolidated materials, safe access, and the use of safety belts and lines. Although OSHA and MSHA have no jurisdiction in this incident, their standards serve as appropriate guidelines in this instance. Life lines and harnesses should be present at the entrances of confined spaces containing unstable materials, and should be used by all workers (including rescuers) entering confined spaces. A standby person should tend the lifeline when silos, bins, tanks, or other confined spaces are entered. If the manufacturer does not incorporate lifelines and harnesses into the design of the storage bin or silo, then the employer should provide the equipment. The use of this equipment should be mandatory, and workers should be properly trained in how to use it. Some lifelines, harnesses, and human hoisting devices designed for confined space entry are also rated for fall protection (Appendix item #1).

Recommendation #3: Employers should consider retrofitting grain storage bins and other similar storage facilities with mechanical leveling/raking devices, or other means to minimize the need for workers to enter grain storage bins.

Discussion: Grain bins, silos, hoppers, tanks, transport vehicles, and surge piles where loose materials are stored, handled, or transferred should be equipped with mechanical leveling/raking devices or other means for remotely handling materials. Such devices would minimize the need for workers to enter such storage facilities. Usually cone-shaped piles of loose material can be leveled, and bridging of material prevented, by mechanical agitation or vibration of stored materials.

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. Ohio State University Cooperative Extension Service, Suffocation Hazards in Grain Bins, August 1975.

3. National Institute for Occupational Safety and Health, Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials, DHHS (NIOSH) Publication Number 88-102, December 1987.

4. National Institute for Occupational Safety and Health, Request for Assistance in Preventing Occupational Fatalities in Confined Spaces, DHHS (NIOSH) Publication Number 86-110, January 1986.

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

6. National Institute for Occupational Safety and Health, Guidelines for Controlling Hazardous Energy During Maintenance and Servicing, DHHS (NIOSH) Publication Number 83-125, September 1983.

7. Office of the Federal Register, Code of Federal Regulations, Labor, 29 CFR 1926.250(b)(2), U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C., July 1989.

8. Office of the Federal Register, Code of Federal Regulations, Labor, 39 CFR 56.16002, 39 CFR 56.11001, and 39 CFR 56.15005, U.S. Department of Labor, Mine Safety and Health Administration, Washington, D.C., July 1989.

APPENDIX

Confined Space Safety Checklist for Grain Storage Bins:

1. Is entry necessary? Can the assigned task be accomplished from the outside? Under certain conditions, a worker could use a non-conductive pole (such as fiberglass or wood) of sufficient length to probe the grain in a bin from immediately above the top hatch, without entering. However, to prevent electrical injury, workers should first verify that there are no overhead electric powerlines near the grain bin that a pole might contact. Also, for fall protection, workers should wear a harness with a lifeline tied off to a secure anchorage point on top of the bin.

Employers should address the following items (beginning with # 2) only if entry into a grain bin has been determined necessary:

2. Are grain bins and other confined spaces posted with warning signs where workers will notice them? In this incident, a warning sign was posted on the top hatch where the victim entered.

3. Has the grain bin auger been de-energized and locked out/tagged out prior to entry?

4. Has consideration been given to testing the air quality to determine an adequate oxygen level and the presence of flammable and/or toxic dust, gas, or vapor?

5. Is ventilation equipment of explosion-proof design available and used before and during entry? Some grain storage bins, like the one in this incident, have an electric fan built into the side of the bin at the bottom. The fan can be operated to pull air from the top of the bin and out the bottom. In this incident, the fan was not used.

6. Do workers know how and when to use the following personal protective equipment?:

   - Respirators (air-supplying and air-purifying)
   - Lifelines/harnesses
   - Emergency rescue equipment (SCBA, human hoist, etc.)
   - Protective clothing
   - Eye protection
   - Hard hats
   - Gloves

7. Can workers recognize confined spaces (grain bins, tanks, silos, etc.), and are they aware of their hazards?

8. Do workers discuss confined space safe work practices with employers and co-workers before attempting entry?

9. Is there a confined space rescue plan, and do workers know how to respond safely in an emergency?

FACE 92-34: Mill Worker Dies in Feed Storage Bin

SUMMARY

On August 31, 1992, a 56-year-old male millworker (the victim) died of suffocation after becoming engulfed in soybean hulls in a grain mill storage bin. The victim and two co-workers were unloading the soybean hulls from an open-topped indoor storage bin compartment when the material became lodged in the compartment. The victim positioned himself on the upper level of the multilevel feedmill building to attempt to dislodge the material with a flexible sewer tape. After load out operations had been completed, the co-workers could not locate the victim. He was later found dead inside the bin compartment, engulfed in the soybean hulls. The victim either entered or fell into the open-topped storage compartment and was engulfed when the bridged material collapsed during load out operations.

NIOSH investigators concluded that, to prevent future similar incidents, employers should:

- *develop, implement, and enforce a written safety program which includes confined space entry and rescue procedures and training to ensure that workers assume that all stored materials are bridged and that the potential for entrapment and suffocation associated with stored grain and other loose materials is constant*
- *ensure that workers are protected from the engulfment hazards of open-topped bins by installing bin covers to prohibit entry*
- *consider installation of devices which will prevent stored granular materials from lodging on the inside of bins*
- *install standard railings with toeboards and intermediate rails around all openings where persons may be exposed to hazards of falls*
- *ensure that workers entering storage areas wear safety belts or harnesses equipped with properly fastened life lines*
- *ensure that safety signs are posted to warn workers of the hazards of working with stored grains and other loose materials.*

INTRODUCTION

On August 31, 1992, a 56-year-old male millworker (the victim) died of suffocation after becoming engulfed in soybean hulls. On September 14, 1992, the Virginia Occupational Safety and Health Administration (VAOSHA) notified the Division of Safety Research (DSR) of the incident and requested technical assistance. On September 23, 1992, a DSR safety engineer traveled to the site and conducted an investigation of the incident. The investigator interviewed the general manager of the feedmill, a co-worker, and the VAOSHA compliance officer assigned to the case. Measurements and photographs of the site were obtained as well as copies of the death certificate and medical examiner's report.

The employer was a regional farm bureau established in 1913, employing a total of 40 employees at various locations through- out the region, 5 of whom were millworkers employed at the feed- mill where the incident took place. According to the general manager, the facility had been in existence in various capacities for about 80 years. Safety issues were the responsibility of the general manager, who reported to a board of directors. The employer did not have a written safety program; however, safety policies were communicated verbally from the general manager to employees. There was no formal training program and specific job duties were learned on the job. The victim had been employed as a millworker for 10 years, all at the incident site. This was the first fatality experienced by the farm bureau since its inception.

INVESTIGATION

The incident occurred in a 10-compartment open-topped storage bin, which was approximately 47 feet long, 20 feet wide, and 18 feet deep. The top of the bin was accessed by a 27-inch-wide walkway around two sides and one end. The compartments were arranged in two rows of five, with an auger-type conveyor centrally located along the top of the bin. The conveyor loaded material into each compartment through individual discharge chutes dropping from the side of the conveyor trough. Load out was accomplished by another auger-type conveyor system located under the compartment hoppers. At the time of the incident, a nonstandard railing had been installed around one side of the bin, 36-inches above the walkway.

On the day of the incident, the victim and co-workers started work at the normal 7 a.m. start time. Throughout the morning the victim and his co-workers had been engaged in loading trucks with material from the bin compartments. At about 11 a.m. they began loading a truck with soybean hulls. They had almost completed loading the truck when the compartment was emptied.

They then switched load out to the end compartment, which had been filled 3 weeks earlier with 18.6 tons (37,220 lbs.) of soybean hulls. The victim and his two co-workers attempted to unload the compartment by opening the slide gate under the compartment hopper and pounding on the hopper sides to dislodge the hulls. When this failed, the victim ascended the stairs to the walkway around the top of the bin, and attempted to dislodge the bridged material by dropping the weighted end of a flexible sewer tape into the soybean hulls. Shortly after the victim left, the co-workers observed the hulls begin to flow out of the compartment. They proceeded to load out the material into 300 pound capacity wheeled boxes, to be transferred into the waiting truck. After four boxes had been loaded, the truck was full and the co-workers shut down the conveyor system. Thinking that the victim would know that the truck was loaded when he heard the conveyor machinery shutdown, they proceeded to eat lunch. After a short period, they decided to look for the victim, since he had not joined them for lunch. The area around the bin was searched without success and one of the co-workers expressed concern that the victim may have fallen into the bin. They then decided to load out the contents of the bin compartment to see if the victim was inside. The conveyor machinery was started and the contents were loaded out into boxes, exposing the victim lying on two rod braces approximately 8 feet below the top of the compartment. One of the co-workers notified the local emergency medical service, (EMS) which responded in about 10 minutes. The victim was removed from the compartment by EMS personnel, transported to a local hospital and pronounced dead at 1:15 p.m.

CAUSE OF DEATH

The medical examiner determined the cause of death as suffocation.

RECOMMENDATIONS\DISCUSSION

Recommendation #1: Employers should develop, implement, and enforce a written safety program which includes confined space entry and rescue procedures and training to ensure that workers assume that all stored materials are bridged and that the potential for entrapment and suffocation associated with stored grain and other loose materials is constant.

Discussion: The co-worker interviewed during this investigation indicated that, when the compartment had been filled 3 weeks prior to the incident, it was necessary for the millworkers to trim the top of the load to prevent material from spilling over into adjacent compartments. This had been done with shovels while the millworkers were standing on top of the material in the bin compartment. There had been no problems with this procedure at the time of loading. While it is not known whether or not the victim entered the bin compartment of his own volition, past experience of the workers with this particular material, soybean hulls, indicated to them that standing on top of the material in the compartment was an acceptable practice. NIOSH has prepared an Alert detailing the hazards associated with the storage of grain and other loose granular materials (NIOSH Publication No. 88-102). NIOSH has published other materials which can also serve as the basis for developing a comprehensive confined space entry program (NIOSH Publication Nos. 80-106, 86-116, and 87-113.) The physical properties of granular materials in bins are such that workers may easily develop a false sense of security while on top of the material, because the exact set of conditions necessary for bridging and subsequent collapse of the bridged material may only occur infrequently. Bridging occurs in storage bins that contain loose materials such as soybean hulls; it is caused by the material clinging to the sides of the bin. As the bin is emptied from the bottom, the material clinging to the bin sides lodges there, forming a bridge over the void previously occupied by the withdrawn material. The bridge may collapse without warning, entrapping workers who are standing on the bridge and who may be unaware that the surface is unstable. Workers may not be aware that the potential for engulfment is constantly present. Safety programs should prohibit entry into bins unless absolutely necessary; when entry is necessary, workers should be adequately protected from the hazards of confined spaces, such as engulfment. Workers may be protected by using properly secured safety harnesses and lanyards and by stationing standby persons outside of the bin.

Recommendation #2: Employers should ensure that workers are protected from the engulfment hazards of open-topped bins by installing bin covers to prohibit entry.

Discussion: The bin compartment in this incident was open at the top and guarded by a 36-inch-high railing. It is conceivable that the victim fell over the top or slipped under the railing while trying to dislodge material with the sewer tape. After the incident, the tape was found routed under the railing, with the weighted end in the compartment and the other end on the walkway. Bins can be covered with solid sheeting, or if necessary, a grating could be installed, to allow access for tools while prohibiting intentional or inadvertent entry by workers.

Recommendation #3: Employers should consider installation of devices which will prevent stored granular materials from lodging on the inside of bins.

Discussion: Devices are available which, when installed in a bin, can prevent material from bridging or can dislodge bridged material without the need for workers to be exposed to the hazards of confined spaces or unstable materials. These devices range in complexity from a simple chain hung down the center of the bin, to mechanical vibrators. In this incident, one of the compartments of the bin had been equipped with a chain attached to the ceiling of the building and hung down inside the compartment near its center. This compartment normally stored soybean meal, a material which readily bridges. Ambient vibration present when machinery is operated inside the building causes the chain to oscillate, thereby minimizing lodging of the surrounding material. A similar arrangement could be applied to other compartments containing granular materials.

Recommendation #4: Employers should install standard railings with toeboards and intermediate rails around all openings where persons may be exposed to hazards of falls.

Discussion: In this incident, a 36-inch-high railing had been installed around the edge of the bin compartments and the walkway. Standard 42-inch-high railings as specified in 29 CFR, 1910.23(e) should be installed around all floor openings where persons are exposed to fall hazards. Such railings should be equipped with toeboards and intermediate railings, as well as a top rail. Although this incident was unobserved, evidence suggests that the victim may have fallen through or over the railing and into the bin compartment during unloading operations. Additionally, railings could provide an anchor point for safety lines and lanyards worn by workers when working over the bin compartment.

Recommendation #5: Employers should ensure that workers entering storage areas wear safety belts or harnesses equipped with properly fastened life lines.

Discussion: Although it is not known whether the victim intentionally entered the bin compartment during the incident or fell into it, workers at this facility had entered prior to the incident without the protection of properly secured safety belts or harnesses. When entering areas where granular materials are stored, the potential for engulfment is always present. If the storage space absolutely must be entered, safety belts or harnesses secured to life lines can protect the workers by arresting their fall when bridged material collapses, and by providing a means for rescue retrieval.

Recommendation #6: Employers should ensure that safety signs are posted to warn workers of the hazards of working with stored grains and other loose materials.

Discussion: Although a nonstandard railing had been erected around the accessible sides of the open-topped bin compartment, there were no warning signs posted to alert workers to the hazard of potential entrapment and suffocation present if the compartment was entered. Employers should treat all grain bins, silos and other areas where grain is stored as confined spaces. Posting readily observable warning signs where workers may be exposed to the hazards of confined spaces can reinforce worker training and serve as a constant reminder of the hazards associated with the storage of granular materials.

REFERENCES

NIOSH Criteria for a Recommended Standard ... Working in Confined Spaces, December 1987, U.S. Department of Health, Education and Welfare, Publication No. 80-106.

NIOSH Alert, Request for Assistance in Preventing Occupational Fatalities in Confined Spaces. January 1986, U.S. Department of Health and Human Services, Publication No. 86-110.

A Guide to Safety in Confined Spaces. July 1987, U.S. Depart- ment of Health and Human Services, Publication No. 87-113.

NIOSH Alert, Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials. December 1987, U.S. Department of Health and Human Services, Publication No. 88-102.

NIOSH Alert, Request for Assistance in Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials. December 1987, U.S. Department of Health and Human Services, Publication No. 88-102.

29 CFR, 1910.23(e) Code of Federal Regulations, Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register. June 27, 1974.

Physical Hazards

Falls

FACE 87-46: Confined Space Fatality at a Wastewater Treatment Plant in Indiana

INTRODUCTION

On June 6, 1987, a maintenance worker for a city's wastewater treatment plant entered the plant's "wet well" to clean the bar screen which filters the raw sewage prior to its entry into the plant. The employee performed this duty without a co-worker or a safety harness. The event was not witnessed. The body was discovered at 12:38 p.m., approximately on hour after the victim was last seen. The victim's body was removed from the "wet well" by the local fire department and pronounced dead at the site by the county coroner.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a small municipality in Indiana with a population of approximately 23,000. The wastewater treatment plant employs 17 persons: seven certified operators (five working at the plant and two working the city's sewers), five maintenance laborers, two laboratory technicians, one process control technician, one maintenance foreman, and one plant superintendent. The plant operates three shifts providing around the clock coverage. Safety issues involving confined space entry were informally communicated to the employees during personnel meetings, occurring every 4 to 6 months. These meetings discussed the importance of:

1. Using a gas detection meter to determine the air's quality.
2. Using a safety harness and rope around the employee entering the space.
3. Positioning a co-worker at the entrance of the space.

Although the meetings reviewed these safety procedures, the procedures were rarely practiced. The only gas detection meter and harness owned by the plant was kept on the sewer maintenance truck and was unavailable for use while the truck was away from the facility. Employees frequently entered the "wet well" alone.

SYNOPSIS OF EVENTS

On June 6, 1987, three employees were scheduled to work: a laboratory technician, an operator, and a laborer (the victim). The victim and the operator arrived at work at the usual starting time for the day shift (8 a.m.); the laboratory technician, who was planning to leave his shift early, arrived at 6 a.m. Shortly after 8 a.m. it was determined that the east primary aeration tank had shut down. In response to this problem an extra laborer and the maintenance foreman were called into work. In order to repair the problem associated with the aeration tank the 14-foot-deep aeration tank had to be drained. this was accomplished by re-routing the sludge from the east aeration tank back to the "wet well" at the entrance of the plant. The "wet well" is the entry point for all industrial, commercial, and residential sewage and is 27 feet long by 18 feet wide by 26 feet deep. Access to the bottom of the well is provided by a permanent ladder which terminates on a concrete walkway at the bottom of the well. The raw sewage enters the well at the flow gate, travels through a trough (24 inches deep), and drains via gravity into a "comminuter." The "comminuter" pulverizes large debris, such as bricks, large rocks, or tree branches that find their way into sewer lines. The "comminuter," which required approximately five major repairs since its installation in 1970, had been shut down since 1984.

Thus, the primary means of preventing large objects from entering the plant was a "bar screen" which needed to be cleaned approximately three times per shift. Workers used a metal rake to scrape off debris collecting on the screen and deposited that debris into a bucket. Upon completion of the job, employees would climb to the top of the ladder, hoist the bucket of debris to the surface, and discard. Re-routing the sludge from the east aeration tank to the "wet well" increased the volume of water flowing into the "wet well" and caused a more pronounced odor (described as "rotten eggs"). Additionally, the "bar screen" clogged more often requiring more frequent cleaning. The victim had cleaned the screen four times during the first 3 hours of his shift. Each time this was performed without sampling the air, without a safety harness attached, and without a co-worker positioned at the entrance. The victim was also to mow the lawn that morning. A co-worker, who was also mowing the lawn, went to lunch at 11:37 a.m. and last saw the victim cutting grass.

When the co-worker returned from lunch at 12:38 p.m., he noticed that the rope and bucket were in the well. The co-worker walked to the "wet well" and noticed the intake gate was closed, the cleaning rake was lying on the cement platform, and the bucket was empty. He saw the victim's left leg protruding from the surface of the sewage. The rest of the victim's body was submerged in the trough.

The co-worker ran to the office where the laboratory technician was working and told him to call the emergency squad and fire department. The co-worker then returned to the "wet well" with the maintenance laborer and they both descended into the well. While trying to retrieve the body, they became nauseated and faint and exited via the ladder. Upon ascending the ladder one of the workers stated he almost slipped and fell into the well. The ambulance arrived, followed by fire fighters. Using self-contained breathing apparatus (SCBA), two firemen descended into the well. The firemen retrieved the victim and laid him on the cement platform. One of the firemen descended into the well without a breathing apparatus to take pictures. He experienced some light-headedness and eye irritation. The victim was hoisted to the surface and pronounced dead at 1 p.m. by the coroner. The five firemen involved in the incident were all taken to the local emergency room for evaluation of nausea and dizziness. No one required hospitalization; however, three of the five received tetanus shots.

CAUSE OF DEATH

An autopsy was performed by the county coroner. The official report is pending a blood toxicology screen and serum level of anti-epileptic medication. A noncompounded fracture of the victim's left knee at autopsy suggested a fall of at least five feet. The death certificate lists the cause of death to be "aspiration of foreign material."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should maintain equipment in proper operating condition.

Discussion: This facility recognized the need for an automated procedure to prevent large debris from entering the plant and installed a crushing device called a "comminuter" in 1976. This device, when working, adequately performed the task. Its use eliminated the need for operators and maintenance laborers to enter the "wet well," thus eliminating this hazardous exposure. Eliminating the need to enter a confined space completely abates any hazards associated with the confined space. The "comminuter" should be maintained and repaired in operating condition.

Recommendation #2: The employer should initiate comprehensive policies and procedures for confined space entry.

Discussion: Although the employer had outlined informal procedures for confined space entry prior to the incident, these should be expanded and formalized into a written policy. This policy should include the following points:

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

2. Has a permit been issued for entry?

3. 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. Has the confined space been isolated/locked out from other systems?

5. 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

6. Have employees been trained for confined space entry?

7. Is ventilation equipment available and/or used?

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

Recommendation #3: Employers should enforce safety procedures.

Discussion: Employees of this facility did not routinely follow the established confined space entry procedures. Employers must enforce established procedures and supervisory personnel must continuously monitor work practices.

Recommendation #4: Employees who are required to enter confined spaces should receive pre-placement and periodic physical examinations to determine that they are physically capable of performing these duties.

Discussion: During the course of employment the physical condition of an employee can change and the employee can become inadequately suited to the job's responsibilities. Employees required to enter confined spaces should receive pre-placement and periodic physical examinations to determine that they are physically capable of performing these duties. The victim had a history of epilepsy dating back to his childhood. The victim's last known seizure occurred in 1978 and his last known evaluation was done on February 29, 1984. His seizures were controlled with medication and a physician's note dated January 1984 stated the victim's seizures were under control and he could "resume normal activities." The victim was hired by the wastewater treatment plant in 1976 at the age of 16. At that time he was 5'11" and weighed 210 pounds. He listed his history of epilepsy and stated that he was on medication. At the time of the victim's death co-workers estimated his weight to be 230 pounds.

FACE 87-47: Worker Dies Inside Filtration Tank in Michigan

INTRODUCTION

On May 12, 1987, a city worker died while checking the inside of an empty filtration tank at a sewage treatment plant.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a municipality with a resident population of approximately 160,000. The victim worked at the wastewater treatment plant (in the wastewater treatment department) which has a total of 56 employees, primarily plant operators and plant maintenance personnel. Additionally, there are five lab technicians, three plant foremen, a chemist, a civil engineer, office personnel, and a plant supervisor.

New employees are given a half-day orientation concerning the operating policy of the city. Time off is provided for mandatory reading of safety booklets. All employees are given formal training in hazardous communication, material safety data sheets/"right to know," and the use of self-contained breathing apparatus. Continual on-the-job task training also addresses various hazards encountered on a day-to-day basis. Workplace safety is stressed as a responsibility of each employee. A wastewater treatment plant safety committee which consists of the plant superintendent, two union stewards (a plant maintenance worker and a plant operator), a maintenance foreman, and the civil engineer meets monthly. Accident reports, safety equipment, safety complaints from employees, the implementation of safety directives from management, etc. are discussed at these committee meetings. The two union stewards are given additional time to evaluate employee complaints and safety concerns in the plant. No training is given on confined space entry; however, plant supervisor has necessary testing equipment available to test a confined space atmosphere for oxygen (O_2), hydrogen sulfide (H_2S), and explosive gases. The plant also has several self contained breathing apparatus (SCBA) throughout the plant facility.

SYNOPSIS OF EVENTS

A 55-year-old wastewater treatment plant operator (the victim) with 25 years of experience was inspecting 1 of 12 open-top concrete filter tanks (used for tertiary wastewater treatment) when this incident occurred. Each filter tank is 15 feet wide by 24 feet long by 12 feet deep and is divided vertically in the middle by a concrete baffle. The bottom of each tank contains a filter bed (several feet of filter media composed of graduated sized stone, covered by approximately 12 inches of wheat-sized anthracite coal). Four trough-like weirs spaced equally apart span the width of each tank half, 3 feet above the top of the filter media. A concrete walkway with steel safety rails is located around the top of each tank. Each tank operates with approximately 9 feet of wastewater and is backwashed three times per day. During this process, a small amount of the filter media (i.e. coal) is washed away. In order to determine the amount of filter media lost, the victim (or other plant operators, when assigned) periodically drain each tank and measure the depth of the filter media. To do this employees are required to lower an aluminum ladder into the tank, positioning the feet of the ladder inside a weir, climb into the tank with a steel tape, measure the depth of the filter media, climb back out, and place the filter tank back in operation. This process is repeated for all the filter tanks. The victim had been assigned to inspect the depth of the filter media in all of the filter tanks (a task which he had done at least twice before). Four days prior to the day of the accident the victim had inspected six tanks. The acting plant foreman (the victim's supervisor) was not aware of the victim having experienced any ill effects from these tank inspections.

On May 12, 1987, the victim reported to work at 8 a.m. and was asked by the plant foreman if he required any assistance in the completion of the remaining six tank inspections. The victim said "no" and completed the inspection of one tank and, although there were no eye witnesses, it is presumed that he was in the process of climbing either into or out of a second tank when he fell from the ladder into the weir. The victim struck his head on a ladder rung or on an edge of the weir.

At approximately 10:55 a.m. the victim's supervisor noticed that the filter tank being inspected had no filter tank valve changes documented on the computer for several minutes. The supervisor left the control room and entered the tertiary filter tank building to check on the victim. The supervisor found the victim lying unconscious inside a weir at the bottom of the tank. The supervisor immediately notified office personnel in the plant, who notified the city fire department emergency rescue squad and then summoned a maintenance worker for help. The supervisor and the maintenance worker entered the filter tank, but did not attempt cardiopulmonary resuscitation (CPR). The rescue squad arrived on the scene approximately 2 1/2 minutes after being called, entered the tank, hoisted the victim out, and began to administer CPR. Resuscitation efforts were unsuccessful. The county medical examiner arrived on the scene at about 1 p.m. and pronounced the victim dead at the scene.

CAUSE OF DEATH

An autopsy was conducted and the cause of death listed by the medical examiner was hypertensive and arteriosclerotic heart disease. Also, according to the medical examiner: "Advanced emphysema of the lungs may have contributed to the death. The deceased was considerably overweight...", the " .....laceration of the left side of the head was sustained as the result of the terminal fall." "Yellow discoloration of the skull may have been related to diabetes mellitus."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Workers who are required to enter confined spaces to perform tasks as part of their job responsibilities should receive pre-placement and periodic physical examinations to determine that they are physically capable of performing these duties.

Discussion: Simply entering and exiting the filter bed placed a great deal of stress on the victim's cardiopulmonary system. Because of pre-existing medical problems (emphysema, arteriosclerotic heart disease, obesity, and diabetes), which were apparently unknown to the victim, he was unable to withstand this stress. This fatality underscores the advisability of pre-placement and periodic physical examinations for any strenuous work, especially in a confined space.

Recommendation #2: The employer should develop a written comprehensive safety program that clearly documents procedures for safe entry into confined spaces.

Discussion: All employees who work in or around confined spaces (wastewater treatment plant employees) should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should include, but not be limited to:

1. Air quality testing to determine adequate O_2 level.

2. Ventilation of the space to remove air contaminants.

3. Monitoring of the space to determine a safe oxygen level is maintained.

4. Employee's training in confined space entry, testing, and use of personal protective equipment (respirators, clothing, etc.).

5. Standby person outside the confined space for communication and visual monitoring.

6. Emergency rescue procedures.

Even though there were no dangerous air contaminants in the confined space and normal oxygen levels were found in air samples taken inside the filter tank by the DSR research industrial hygienist at the time of the on-site evaluation, entry into confined spaces should not be attempted until atmospheric testing of the confined space ensures that the atmosphere is safe. This testing requirement applies to all confined spaces, including the inside of open-top tertiary filter tanks. Testing must be done by a qualified person prior to entry. Specific recommendations regarding safe work practices in confined spaces can be found in the NIOSH Publication No, 80-106, "Working in Confined Spaces." This publication also defines and provides recommendations of hot work, isolation, purging, ventilation, communication, entry and rescue, training, posting, safety equipment, clothing, etc.

Recommendation #3: A trained standby person should remain outside of the confined space when a worker enters or works inside. The standby person should visually monitor the tasks being performed inside and should be able to communicate with the worker(s) inside the confined space.

Discussion: A person trained in emergency rescue procedures, assigned to remain on the outside of the confined space for communication and visual monitoring of the person inside is of utmost importance.

Recommendation #4: Employees should be trained in cardiopulmonary resuscitation (CPR).

Discussion: CPR should begin as soon as possible, minimally within 4 minutes (in accordance with American Heart Association guidelines) in order to achieve the best results. To meet this criteria for successful resuscitation, workers should be trained in CPR to support the victim's circulation and ventilation until trained medical personnel arrive. While some employees had apparently received CPR training in the past, employees who arrived at the scene of the accident (prior to the arrival of emergency medical personnel) did not begin CPR on the victim. Retraining in CPR is necessary, usually on an annual basis.

Recommendation #5: The procedure used to measure the level of filter media present in a tank should be evaluated to determine if the procedure could be modified to eliminate the need to enter the confined space.

Discussion: Prior to entry into a confined space one of the first questions that needs to be addressed is whether entry is necessary. The procedure used to measure the level of filter media present in a tank should be evaluated to determine if it could be modified to eliminate the need for entry into the tank.

FACE 88-14: Labor Foreman Falls to His Death Inside Municipal Water Tank in Indiana

INTRODUCTION

On March 21, 1988, a 28-year-old male labor foreman died when he fell 50 feet inside a 700,000-gallon municipal water tank.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this incident is a multistate corporation specializing in cathodic protection systems which provide a form of protection against electrolytic corrosion. Of the company's 250 employees, 16 perform the same type of work as the victim. The company has a written safety policy which prescribes the use of fall protection where there is potential that a worker may fall in excess of 10 feet. This policy also calls for testing the atmosphere prior to entering any confined space, and for the use of a lifeline, safety harness, and appropriate respirator when working inside a confined space. The victim was employed as a tank department foreman and served as a supervisor at various sites where work on cathodic protection systems for water tanks was being performed.

SYNOPSIS OF EVENTS

The victim and a co-worker were assigned routine maintenance work on the cathodic protection system within an elevated municipal water tank. Approximately 2 months prior to this incident, the tank developed a leak and was drained. A small amount of water remained in the tank at a level below the riser which serves as the tank drain. There was ice on the surface of the water.

The cylindrical tank is approximately 40 feet wide by 60 feet high. A ladder on one of the legs supporting the tank provides access from the ground to a catwalk on the tank. The catwalk circles the tank approximately 125 feet above the ground. A second permanently-mounted ladder extends from the catwalk to the top of the tank. At the top of the tank, a 2-foot-square door provides entry to the tank.

On the day of the incident, the victim and his co-worker arrived at the job site at 11 a.m. Prior to climbing the tank, they noticed an entry hatch on the side of the tank bowl at the level of the catwalk. They decided not to use this entry hatch because they weren't sure they could properly seal it at the conclusion of the work.

At approximately 12:15 p.m., the two men climbed to the top of the tank and found the entry door locked. The men descended the tank, obtained a key from city officials, climbed again to the top of the tank, and opened the door. They suspended a rope ladder through the door to provide access to the tank floor.

The maintenance work on the cathodic protection system required that they replace a fitting which was below the level of the water in the tank. The victim used a section of garden hose to begin syphoning the water from the bottom of the tank and routing it down the wet riser at the center of the tank bowl. Because the water would not be removed by the end of their shift, they performed other necessary maintenance work, planning to return the following day to finish the job.

At approximately 5:10 p.m., the co-worker exited the tank and stopped on the catwalk to wait for his supervisor. When the supervisor did not follow after 4 to 5 minutes, the co-worker climbed to the top of the tank in search of him. The co-worker saw the supervisor inside the tank approximately one quarter of the way up the ladder. The supervisor stated that he was tired and that his arms were numb. The supervisor then continued to climb the ladder.

The co-worker noticed that the supervisor "was climbing wrong and had a funny look on his face." (The supervisor was facing the ladder, as opposed to the standard procedure for climbing a rope ladder from the side thereby producing less swaying motion.) The co-worker asked the supervisor if he needed help. Upon receiving a positive response, the co-worker descended the ladder to assist him. The co-worker managed to grasp the supervisor's hand, however the supervisor was unresponsive to the co-worker's repeated calls to grasp the ladder. The co-worker was unable to retain his grip, and the supervisor slipped from the ladder and fell approximately 50 feet to the bottom of the tank. The co-worker descended the ladder to aid the victim and moved him slightly from the facedown position near the water where he landed. He returned to the top of the tank where he cried out for help. He got the attention of several individuals located at a business establishment across the street who, in turn, summoned help.

The local fire department received the report of the accident via telephone at 5:15 p.m. and were on the scene at 5:19 p.m. Two fire fighters and an EMT from the local ambulance company entered the tank through the manway located at the catwalk. The victim was found to be bleeding from the mouth and nose, with noticeable deformation of his forearm and right upper leg. No vital signs were detected. The victim was secured to a back board and lowered to the ground. The ambulance departed the scene at 5:54 p.m. and arrived at the local medical center at 6 p.m. where the victim was pronounced dead shortly after arrival.

Neither the co-worker nor the responding rescue personnel noted any unusual odors in the tank, nor did they experience any symptoms indicative of possible oxygen deficiency.

CAUSE OF DEATH

The medical Examiner gave the cause of death as a skull fracture and lacerations of the brain, along with contusions to the lungs.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should periodically re-evaluate company confined space work procedures to ensure that the following areas are addressed:

- ***atmospheric testing is performed prior to entry***
- ***safe climbing devices are employed where needed***
- ***safety harness and lifeline are used in all cases (for rescue as well as fall protection when working at elevations)***
- ***an observer outside of the confined space is available to summon help if needed***
- ***communication devices are available to ensure adequate communications between workers in confined spaces and those outside.***

Discussion: The company that employed this foreman has written safety procedures that require the testing of the atmosphere of any confined space prior to entry. In addition, the procedures specify that a lifeline and safety harness are to be worn while working in a confined space, and that an appropriate respirator be worn when indicated by the atmospheric testing. None of these procedures was followed in this case, nor was any provision made for the use of safe climbing devices. In addition no observer was present, nor was any means provided for communication between the tower and anyone on the ground. If an oxygen deficient atmosphere existed within the tank, it could have proved fatal to both workers.

Recommendation #2: Employers should provide periodic refresher training which stresses the hazards that exist within confined spaces to all employees who work in or around confined spaces.

Discussion: Although the victim in this case was a supervisor who had received training in confined space entry procedures, he elected to forego written company safety procedures regarding atmospheric testing and the use of safety harnesses and lifelines. His failure to follow standard written procedures concerning confined space work was an important factor in this incident.

Recommendation #3: Company management (safety) personnel should conduct periodic worksite evaluations to ensure that written procedures are being followed in the field.

Discussion: In this case a foreman apparently chose to ignore company procedures regarding work in confined spaces. Since safety is an inherent function of management, workers cannot be expected to follow safety procedures if their supervisors do not. Periodic inspection of worksites by company safety personnel would serve to show management's interest in the safety program and reinforce within all workers the need to follow company standard operating procedures.

Recommendation #4: An evaluation of the worksite should be performed prior to the start of all operations to determine potential safety and health hazards as well as concerns which would affect efficiency of the operation.

Discussion: An evaluation of the worksite prior to the start of work would permit safety hazards to be identified and plans for corrective action to be prepared prior to employee exposure. In the above case such an evaluation might have enabled the workers to avoid the initial climb up the tower to unlock the door at the top of the tank. In addition, a thoughtful evaluation might have convinced the supervisor to utilize the hatch at the catwalk rather than the opening at the top of the tank. Such action may have eliminated the need for the rope ladder and thus prevented the fall.

Recommendation #5: Rescue personnel entering confined spaces should utilize appropriate protective equipment.

Discussion: In the above case, rescue personnel entered a confined space where a victim became ill and had fallen for unknown reasons without either checking the atmosphere first or utilizing self-contained breathing apparatus. In similar situations rescue personnel themselves often become victims. NIOSH investigations of 41 confined space incidents have revealed that 18 (31%) of the 59 victims were would-be rescuers.

FACE 90-12: Painter Dies When Scaffold Falls Inside Municipal Water Tank in Indiana

INTRODUCTION

The employer, a painting contractor with 20 employees, has been in business for 7 years. The company has a designated safety officer and written safety rules and procedures, but no formal training program. The victim was hired as a journeyman painter, and had worked for the company for 1 month at the time of the incident. The victim had previously been employed as a painter by other contractors for approximately 10 years.

INVESTIGATION

The victim was a member of a three-man crew engaged in painting the interior and exterior of two 68-foot-tall by 32-foot-diameter municipal water tanks. The crew had been working on this project for 2 weeks prior to the incident, and had completed all work on one tank and most of the exterior work on the second.

On the day of the incident, the crew arrived at the worksite at approximately 11:30 a.m. The crew consisted of a foreman, the victim, and a groundman. The foreman was going to spray paint the interior of the water tank while the victim was to finish work on the exterior of the tank. The groundman was to work inside the tank handling the spray paint lines used in the operation. The victim, a journeyman painter, asked to paint the interior of the tank. The foreman agreed, and the victim proceeded to paint the interior of the tank while the foreman finished work on the exterior of the tank.

Access to the interior of the tank was provided through a manhole on the side of the tank at ground level, and a second manhole located on top of the tank. This second manhole was reached by climbing a fixed ladder on the exterior of the tank.

The interior sidewalls of the tank were reached via a swing scaffold rigged inside the tank. This scaffold consisted of an aluminum ladder secured to a steel "stirrup" (a steel bar bent into a box shape and installed perpendicular to the ladder) at each end. The ladder was thus subjected to loading while in a horizontal position, rather than in the vertical position for which it was designed. Cables from each stirrup ran to a common tie-off point. A cable from this common tie-off point then passed through a block and tackle. By pulling on this cable the entire scaffold could be raised and lowered from the ground level of the interior of the tank. The block and tackle which supported the scaffold was secured by a single cable which looped around a vertical steel pipe on top of the tank and fastened back to itself by two "U" bolts.

The entire crew entered the tank through the lower manhole. The groundman and the supervisor then raised the scaffold with the victim on it to the top of the tank. The victim was wearing a safety belt and lanyard which was secured to a lifeline, with the lifeline secured to a steel railing on the top of the tank. The victim proceeded to paint the top few feet of the tank's interior. The foreman climbed the exterior ladder to the manhole on top of the tank to help complete work near the tank's top. At approximately 1 p.m., the victim completed painting at the upper level. He then disconnected his lanyard from his lifeline and moved over to where he could hand the paint spray gun to the foreman so the foreman could finish a small area at the top of the tank. The foreman had just taken the spray gun from the victim when he heard a "pop" and saw the victim and the scaffold on which he was standing, fall to the floor of the tank 65 feet below. The victim and the scaffold struck the floor of the tank, barely missing the groundman. The foreman called to the groundman and told him to go next door and call an ambulance. The foreman then descended the ladder on the exterior of the tank and went in to assist the victim. The Emergency Medical Service (EMS) unit arrived on the scene approximately 5 minutes after the incident, removed the victim from the tank via the lower manhole, and transported him to the local hospital. The victim was pronounced dead at the hospital at 2:29 p.m.

Investigation after the incident revealed that the two "U" bolts on the cable which supported the block and tackle had allowed the cable to slip through them, causing both the scaffold and all of its supporting hardware to fall. This particular rig had been used daily for 2 weeks preceding the incident with no problems.

CAUSE OF DEATH

The cause of death was listed by the coroner as "hemorrhage from severe liver laceration and brain stem hematoma."

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Appropriate personal protective equipment should be worn at all times whenever the potential for a serious fall exists.

Discussion: In this case the victim was wearing a safety belt and lanyard, however at the moment when the incident occurred he was not hooked up to his lifeline. This failure to use PPE at all times during the job allowed the victim to experience a fatal fall when a scaffold failure occurred.

Recommendation #2: Suspension scaffold rigging should be inspected periodically to ensure that all connections are tight and that no damage to the rigging has occurred since its last use.

Discussion: The scaffold rigging in this case had been used daily for 2 weeks prior to the incident; however, no periodic inspection program was in place. It appears that the "U" bolts holding the scaffold had loosened over time, although this loosening had not been observed by workers at the site.

Recommendation #3: Equipment should only be used for the purpose for which it was designed.

Discussion: The "scaffold platform" in this incident was a simple aluminum ladder. This ladder was designed to support a load in a vertical position but was being utilized to support a load while in a horizontal position. While this did not directly contribute to this incident, the potential for a failure of the ladder while being used in this manner was certainly present.

FACE 90-16: Painter Dies Following a 40-foot Fall from Scaffold Inside Water Tank in Ohio

INTRODUCTION

On November 20, 1989, a 39-year-old male painter (victim) fell 40 feet from a scaffold, when one of the nylon suspension ropes supporting the scaffold broke. Although the incident occurred in Ohio, the victim died in a Pennsylvania hospital. On November 30, 1989, officials from a county coroner's office in Pennsylvania notified the Division of Safety Research (DSR) of the death, and requested technical assistance. On December 12, 1989, a research industrial hygienist from DSR traveled to the incident site to conduct an investigation. The DSR investigator reviewed the incident with company representatives and the OSHA compliance officer assigned to the case, and obtained photographs and diagrams of the incident site.

The employer is an industrial painting contractor who has been in business for 10 years. Most of the employer's business involves painting building exteriors and other outdoor structures. Contracted work is either done by the owner himself or with the help of one or two hired workers, depending on the job. The victim in this incident was the owner's brother, who also owned his own painting company and had been an industrial painter for 15 years. The employer has no safety program.

INVESTIGATION

The employer had been contracted by a manufacturing company to sandblast and paint the interior and exterior of a 250,000-gallon steel water tank, which measures 48 feet high by 30 feet in diameter. The tank has an 18-inch-diameter manway on the side 12 inches from the bottom, and a 3-foot-square hatch on top of the tank near the edge.

The employer hired a laborer to help him with the job. The owner and laborer had sandblasted and painted the outside of the tank 3 weeks prior to the incident, using a two-point suspension scaffold. The scaffold consisted of a platform (20 feet long and 2 feet wide) constructed of angle iron and wood planks with a metal guardrail. The top rail of the guardrail was 40 inches above the platform. The platform was suspended by two, 5/8-inch-diameter nylon ropes from a triangular framework ("stirrup") of angle iron at the ends of the platform. The nylon ropes passed through a block and tackle hoist at both ends of the platform. The other end of each rope was tied to a vent pipe on top of the tank. By pulling and letting up on the individual ropes and tying them to the platform, the scaffold platform could be positioned at the desired height.

After painting the exterior of the tank, the owner hired his brother (the victim) to help him sandblast and paint the interior. In order to remove the moisture and condensation inside the tank, the owner opened the manway and hatch, and positioned two propane salamander heaters equipped with blowers just outside the manway to blow warm air into the tank. The owner, the victim, and the laborer entered the tank through the manway and hatch with the necessary scaffold parts, and set up a suspension scaffold similar to the two-point suspension scaffold used on the outside of the tank. However, with this scaffold, three platforms were joined together by overlapping the ends of two other platforms inside the stirrups at the ends of the center platform. The resulting configuration formed a "U"-shaped, four-point suspension scaffold.

Before the suspension scaffold was raised into position, the victim climbed a ladder to weld steel brackets to the opposite side walls at the top of the tank. The brackets were used to anchor a horizontal 3/8-inch-diameter steel cable (to be used as a fall protection anchor cable). The nylon suspension ropes were lying on the floor of the tank while the brackets were being welded. After the welding, the owner inspected the suspension ropes by passing each rope length through his hands, but did not notice any apparent damage to the ropes.

The four suspension ropes and two, 300-watt portable utility lights were then tied to angle iron roof support beams at the top of the tank. Another 300-watt utility light was secured to the center scaffold platform. The entire scaffold platform was raised to approximately 40 feet above the floor and the victim began sandblasting the top portion of the tank wall. During the sandblasting, the victim wore a supplied air respirator (without an auxiliary, escape-only SCBA), a sandblaster's hood, gloves, and coveralls. The owner urged the victim to wear a safety belt, secure it to a vertical rope (lifeline) with a rope-grab device, and secure the other end of the lifeline to the horizontal steel cable at the top of the tank. The victim chose not to wear the fall protection equipment, saying that it would get in his way. After the victim had sandblasted as much of the top portion of the tank as he could reach, the platform was lowered to the floor of the tank and the nylon suspension ropes were reattached to roof support beams above the portion of the tank which had yet to be sandblasted. The three men began raising the scaffold platform by alternately raising each suspension point a few feet at a time. Again, the victim did not wear any type of fall protection equipment. The laborer, however, did wear a safety belt/lifeline tied off to the steel cable as the owner had suggested. The owner was standing at the bottom of the tank during this time.

While the victim (who was standing on the platform at one end) was pulling on a suspension rope to raise one end of the scaffold, it broke, causing that end of the platform to fall. The victim fell approximately 40 feet, landing on a horizontal, 2-inch-diameter water pipe at the bottom of the tank. The laborer managed to remain standing on the other platform leg which stayed intact. The owner rushed to the victim (who was unconscious but still breathing), placed the victim on a piece of planking, and the owner and laborer subsequently removed him from the tank through the manway. The laborer then ran to the manufacturing plant for help. The county emergency medical service (EMS) was notified and arrived at the site 12 minutes later. The victim was rushed to a local hospital and then air transported to a larger hospital where he died in the operating room 3 hours later. An OSHA investigation determined that the suspension rope broke at a point where it had been burned.

CAUSE OF DEATH

The coroner listed the cause of death as blunt force trauma to the head and trunk.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Synthetic rope used in suspension scaffolding should be protected from heat producing sources.

Discussion: Paragraph 3.25 of the American National Standards Institute (ANSI) "Safety Requirements for Scaffolding," A10.8-1977, states that "Special precautions shall be taken to protect scaffold members, including any wires, fiber, or synthetic rope when using a heat producing process." Occupational Safety and Health Administration (OSHA) standard 29 CFR 1926.451(a)(18) states that "No welding, burning, riveting, or open flame work shall be performed on any staging suspended by means of fiber or synthetic rope." An OSHA investigation after the incident determined that the rope had broken at a point where it had been burned. Exactly how the rope was burned is not clear. The victim had previously welded steel support brackets to the inside of the tank. Although the welding was not done from the scaffolding platform, it was performed above the nylon rope which was lying on the floor of the tank before the scaffolding was raised. Also, the 300-watt utility lights may have come too close or contacted the nylon suspension ropes sometime during the sandblasting operation.

Recommendation #2: Suspension scaffolding should be constructed and maintained in accordance with OSHA Standard 19 CFR 1926.451, and ANSI Standard A10.8-1977.

Discussion: The OSHA and ANSI Standards require synthetic or fiber rope used for scaffold suspension to be capable of supporting at least six times the rated load (29 CFR 1926.451(a)(19) and (i)(5), and ANSI A10.8-1977, 3.23). Due to the size and type of rope being used it is questionable whether it was capable of meeting this requirement.

Recommendation #3: Where the potential for a fall from an elevation exists, employers should ensure that fall protection equipment is provided and used by workers.

Discussion: Although fall protection equipment, consisting of a steel anchor cable secured horizontally across the top of the tank (to secure lifeline ropes), lifeline ropes, safety belts, and rope-grab devices, was available at the site during the incident, it was not used by the victim. The use of a safety belt/lanyard combination is required by 29 CFR 1926.451(i)(8) for use on two-point suspension scaffolds. The use of the safety belt or body harness/lanyard with a rope-grab device is appropriate for persons working from scaffolds at varying heights. Properly used, this type of fall protection would have prevented the victim from falling even when the scaffolding fell.

Recommendation #4: Employers should develop and implement a safety program designed to help workers recognize, understand, and control hazards.

Discussion: OSHA Standard 1926.21(b)(2) states that "the employer shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury." Even small companies should evaluate the tasks performed by workers, identify all potential hazards, then develop and implement a safety program addressing these hazards, and provide worker training in safe work procedures. Prior to starting any job, the employer should conduct a jobsite survey, identify all hazards, and implement appropriate control measures.

Recommendation #5: Employers should develop and implement specific procedures for entry and work in confined spaces.

Discussion: The owner and workers in this incident were working inside a confined space. Even though the victim died from the result of a fall, there were other potential hazards associated with the work to be performed inside the tank (i.e., painting the inside of a tank with a toxic and flammable paint). Although most of the work contracted by the employer does not require confined space entry, it is reasonable to expect that future work might require the employer and hired workers to enter other types of confined spaces. 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. 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

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

    - Fall protection
    - Respiratory protection
    - Emergency rescue equipment
    - Protective clothing

3. Have employees been trained for confined space entry?

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

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

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

Recommendation #6: The designers/manufacturers of tanks of this type should design and install appropriate anchor points for maintenance purposes.

Discussion: Permanent structures of this type are known to require extensive maintenance when they are designed. It is essential that designers/owners of these facilities incorporate appropriate anchor points on tanks to which workers can adequately secure scaffolds and lifelines. Omission of designed anchor points causes workers to improvise anchors or not use them at all. This increases the possibility that a scaffold will be erected using improper procedures and components.

Physical Hazards

Electrocutions

FACE 88-16: Power Company Worker Electrocuted in Underground Utility Vault

INTRODUCTION

On March 11, 1988, an overweight, 35-year-old male cable splicer was electrocuted when he contacted an energized pipe that was connected to a 220-volt sump pump.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The victim was a lead cable splicer employed by a power company that has approximately 14,000 employees. The victim worked in the company's Network Underground Division, which has 176 workers. Most of these workers (including 24 cable splicers) perform maintenance work on the underground components of the utility system.

The company has a safety and health department, an industrial hygiene department, a written safety policy, and specific written safety procedures for electrical work and confined space entry. Division-level and local employee safety committees conduct monthly safety meetings. A formal safety training session on electrical and confined space safety, conducted approximately 2 1/2 months prior to the incident, was attended by the victim.

SYNOPSIS OF EVENTS

The incident site was an underground transformer vault located in the downtown area of a large city. The concrete vault measuring 80 feet long, 10 feet wide, and 12 feet deep, lies beneath an alley between two large buildings. The vault is covered on top with concrete and steel grating (the grating covers approximately 20 percent of the top) which form part of the driving surface of the alley. Located on the top (at each end and in the middle) are three 27-inch-diameter manhole openings, equipped with vertical, steel ladders attached at the top and embedded in the concrete at the bottom of the vault.

The vault houses eight 480-volt transformers. Two 220-volt sump pumps (one at each end) were originally installed to remove water that accumulates in the vault. Each pump is designed to operate by means of a float valve switch mechanism, with water intake pipes submerged in a sump well 18 inches square and 18 inches deep below the vault bottom.

Electric power is supplied through an underground 220-vault cable. The power cable enters the vault and passes through two fuse boxes (located about half-way up the side of the vault), one serving the sump pumps and one serving lighting along the vault ceiling. When the pumps were installed, an effective electrical ground was not provided. Later (about 5 years prior to this incident), an electrical short circuit developed inside one of the pump motors, blowing the fuses and de-energizing the pumps. The company decided not to repair the sump pumps, but to periodically pump water from the vault with truck-mounted pumps. Despite the decision not to repair the pumps, the fuse box, wiring, pumps, and piping were <u>not</u> removed.

Over time the "moisture-proof" fuse boxes filled with condensated water and became heavily corroded. The corrosion bridge across the blown fuses re-energized the sump pumps and the pump frame and water discharge pipe of the short-circuited pump at a level of approximately 120-volts. On March 11, 1988, two power company employees, a lead cable splicer (the victim) and a winch truck operator (co-worker) were inspecting the circuit protectors on the transformers in the vault. The victim and a co-worker arrived at the vault at about 8:30 a.m. Since the vault had approximately 33 inches of water in the bottom, the victim put on rubber hip waders, removed the manhole cover at the east end of the vault, and entered the vault with a flashlight. While the victim was checking the circuit protectors on four transformers, the co-worker studied an electrical circuit map of the vault. The co-worker also directed vehicular traffic through the alley since there were no traffic cones or guard rails around the open manhole.

At about 8:40 a.m. the co-worker heard "a noise" inside the vault. When he looked into the manhole, he saw the victim facedown in the water, halfway between the ladder and the sump pump (a horizontal distance of about 4 feet). Although the co-worker did not observe the position of the victim immediately prior to seeing him facedown in the water, circumstantial evidence suggests that the victim contacted an energized component of the sump pump (either a metal pipe, part of the housing, or another connected apparatus) with his right hand, and the steel ladder (which was at ground potential) with his left hand. This would have provided the current a path to ground through the victim. Current may have entered his right hand, passed through his chest, and exited his left hand, resulting in his electrocution. Presumably, the victim then fell forward, breaking contact.

In a rescue attempt, the co-worker entered the manhole, descended the ladder, and stretched out one hand and pulled the victim's face out of the water. However, when the co-worker stepped off the ladder onto the floor of the vault he felt a shock, so he stepped back on the ladder. It is believed that since the co-worker was not wearing rubber hip waders his foot was at some level of ground potential when it touched the vault floor. While managing to hold the victim's face out of the water with one hand and the ladder with the other hand, the co-worker called out for help.

Several passersby responded and made several unsuccessful attempts to help the co-worker remove the victim from the vault. However, they were hampered by electric shocks they received from either structural steel beams that crossed the inside of the vault or the vault bottom. Another factor that made rescue difficult was the victim's relatively large size and weight. At least three attempts were made to hoist the victim out of the vault with a handline tied around the victim's chest. Each time, the victim slipped through the rope and fell to the bottom of the vault. One of the passersby made an emergency call on the company truck radio. A policeman arrived and then minutes later paramedics, each attempting to assist in the rescue effort, and each experiencing electric shocks in the process.

According to rescuers, the power company cut off the power to the vault approximately 35 minutes from the time the victim was first observed facedown in the water. Paramedics observed that the victim was "still breathing a little" and had a slight pulse. Shortly after the power was turned off, a manual respirator was lowered into the vault and used in an attempt to resuscitate the victim. Attempts to remove the victim from the vault were unsuccessful until the fire department rescue squad arrived.

Rescuers ultimately succeeded in putting a body harness around the victim and hoisting him out of the vault with the use of a truck-mounted winch. The total time from when the victim was observed unconscious in the vault to when he was removed was estimated at approximately 1 hour and 20 minutes.

Paramedics initiated cardiopulmonary resuscitation (CPR) after the victim was removed from the vault, and continued to administer CPR while in route to a local hospital. The victim was pronounced dead on arrival by the attending physician.

CAUSE OF DEATH

The cause of death is presumed electrocution. The exact cause of death has not yet been verified, pending receipt of the medical examiner's report.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The sump pump and pump wiring no longer in use should be disconnected from energized circuits and removed.

Discussion: The presence of water in the vicinity of energized electrical apparatus increases the potential for conduction of electrical energy. Also, holes, depressions, loose parts, debris, or other irregularities in the floor surface of the vault which could represent all hazards, might not be visible to a worker stepping into or walking through standing water.

Recommendation #2: The employer should ensure that each metal piece of equipment that is not designed to conduct electricity be permanently and continuously bonded to a grounding system.

Discussion: The metal sump pump appurtenances, metal vault ladders, beams, etc. were not only installed without effectively being grounded, but also remained ungrounded for 18 years. During those years workers entered the vault numerous times under damp and wet conditions, and were needlessly exposed to this electrical hazard.

Recommendation #3: The employer should develop and implement (1) a method of detecting the existence of ground faults (i.e., a defect in an electrical circuit creating an unintentional path for current to flow to ground), and (2) procedures to follow if a ground fault is detected, prior to employee entry to wet and damp locations where energized, electrical apparatus exist.

Discussion: The victim entered an electrical vault which had energized electrical components submerged in water. The victim was unaware that a ground fault existed within the vault. If ground fault indicators had been installed on the vault circuitry, the victim would have had the opportunity to check an indicator panel for existing ground faults prior to entering the vault. Knowing a ground fault existed in the vault, the victim may have chosen not to enter the area without first pumping the water and donning additional protective insulated gear.

Recommendation #4: The company should re-evaluate, implement, and enforce its confined space rescue procedures.

Discussion: The company had written confined space entry and rescue procedures; however, they were either not practiced, unenforced, or ineffective when attempted. The written procedures outline a confined space rescue method which proved to be ineffective in this case. This rescue procedure for underground utility vaults needs to be re-examined. The vault in this incident was classified by the company as a "Class C" confined space, which would not normally require auxiliary ventilation nor isolation procedures to be followed prior to entry. (NIOSH publication 80-106, "Criteria For a Recommended Standard...Working in Confined Spaces"). The company confined space entry procedures did not address any method for detecting the existence of ground faults prior to entering damp and wet locations such as underground utility vaults.

FACE 88-28: Asbestos Worker Electrocuted

INTRODUCTION

On July 6, 1988, a 23-year-old male laborer on an asbestos removal crew died when he contacted an exposed overhead conductor in a utility tunnel.

OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The employer in this case was an asbestos abatement contractor with 30 employees. The company has been in business for 3 years. Company safety training focuses on asbestos removal procedures; however, other hazards likely to be encountered in the course of this work are not addressed.

SYNOPSIS OF EVENTS

The victim and a co-worker comprised one of two 2-man teams removing asbestos from steam lines in a utility tunnel which serves a large educational facility with numerous buildings. The tunnel is approximately 55 inches high by 52 inches wide and runs in a north/south direction. The steam lines run along the east wall of the tunnel. The west wall of the tunnel is covered with numerous heavy electrical cables and signal wire sets. A walkway approximately 36 inches wide extends down the center of the tunnel. Four separate, insulated wires suspended from individual insulators run along the top of the tunnel directly above the walkway. This wiring serves as the power supply for numerous 110-volt light bulb sockets hanging down on flexible conductors ("pigtail") at intervals along the tunnel. At the time of the incident, one of the "pigtails" did not have a light socket attached. Therefore, bare, energized conductors were hanging down over the walkway from the wiring circuit.

The victim was removing insulation containing asbestos from the steam lines within the tunnel, while his co-worker was following behind him bagging the insulation. During removal activities, the victim's shoulder contacted the exposed conductors hanging from the roof of the tunnel. A path to ground was established from the victim's shoulder through his right arm which was in contact with the steel steam line. The co-worker, who heard the victim yell and saw that he was in contact with the overhead wires, used his body to knock the victim away from the wires. The victim collapsed to the floor of the tunnel.

The co-worker then called the other crew to help remove the victim from the tunnel. The closest way out of the tunnel was the entry to a basement about 57 feet from the incident site. The workers dragged the victim to this entry, took down the plastic containment wall isolating the tunnel from the basement, and removed the victim from the tunnel. A university police officer who was in the basement heard the men and reported the incident via radio to his dispatcher, who called the local fire department and emergency medical service (EMS) unit. The EMS unit and the fire department were on the scene 6 minutes later. Cardiopulmonary resuscitation (CPR) was initiated at the scene and continued while the victim was transported to the local hospital. The victim was pronounced dead at the hospital 57 minutes after the police officer initially reported the incident.

(NOTE: Co-workers and rescue personnel stated that the victim was wet with perspiration at the time of the incident. The high ambient temperature in the tunnel and the protective clothing required for asbestos removal work combined to create a hot working environment for the removal crew.)

CAUSE OF DEATH

The coroner's office reported the cause of death as electrocution.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Job site surveys should be conducted prior to the start of all construction/ demolition projects to ensure that hazards within the area are identified, employees are informed of the hazards, and methods of eliminating or controlling the hazards are implemented.

Discussion: The suspended wires for the lighting circuit should have been identified as potentially hazardous. The bare conductors on the "pigtail" involved in this incident would have been detected if a survey of the actual job site had been performed prior to the start of this project. Once the hazard was identified, corrective action could have been taken to prevent this fatality from occurring.

Recommendation #2: In an area where asbestos removal work is being performed, electrical equipment should be de-energized whenever possible. If the equipment cannot be de-energized, workers should be isolated from potential contact with the energized lines or equipment.

Discussion: Workers performing asbestos abatement work typically wear personal protective clothing which serves to trap body moisture within the suit. In addition, it is standard practice in asbestos removal work to use "wet" removal techniques in which a surfactant-treated water mixture is used to saturate the asbestos-containing materials to control the release of asbestos fibers. The combination of a wet environment and energized electrical circuits or equipment sets the stage for potential disaster.

In this case, the victim was wet with perspiration when the contact with electrical energy occurred. The resistance of the human body to electrical energy (as high as 100,000 ohms when the skin is dry) may be reduced to 1,000 ohms when the skin is wet. This reduced resistance results in the potential for a much greater current flow through the body than would otherwise occur, a significantly increasing the potential for a fatal electrical shock.

Shutting down the major electric lines which run through this tunnel was not feasible since they control power to half of the campus; however, these armored cables posed a relatively small threat to the workers. Plastic sheeting along the side of the tunnel could have been erected to isolate these lines from the workers. The lines which actually caused the fatality served only to provide lighting for the tunnel. These lines could have been de-energized prior to the start of the project and a substitute lighting system utilizing ground fault circuit interrupters (GFCI's), battery powered lights, or similar safe systems, could have been installed to ensure worker protection.

(NOTE: Further information on electrical hazards encountered during asbestos abatement work is included in Appendix D, "General Safety Considerations," of A Guide to Respiratory Protection for the Asbestos Abatement Industry, a joint publication of NIOSH and Environmental Protection Agency (Doc. # EPA-560-OPTS-86-001).)

Recommendation #3: Property owners should periodically inspect all areas of their facilities and grounds for the purpose of identifying safety hazards. Unsafe conditions identified during such inspections should be corrected and potential hazards should be controlled in a timely manner to prevent injuries.

Discussion: The lighting circuit in the utility tunnel was an outmoded type of single insulated wire suspended upon individual insulators. The light sockets that hung down from these wires were otherwise unsupported. As a result, the insulation of the wires, as well as the unguarded light bulbs, were subject to damage.

The bare conductors which caused the fatality posed a threat to anyone using the tunnel. A comprehensive safety inspection program conducted by the property owner would have revealed these hazards. Corrective action could have been taken to protect both the employees of the property owner and contract personnel working in or moving through the area.

FACE 90-32: Electrician Electrocuted When He Contacts Energized Conductor in a Manhole in Virginia

INTRODUCTION

The employer in this incident is an electrical contractor, engaged primarily in commercial and industrial electrical construction. The company has been in operation for 22 years and employs 97 workers, including 51 electricians. The company has a written safety policy and safety rules which are administered by the loss control/personnel manager. In addition, weekly safety toolbox meetings are held. The employer also uses a safety incentive program and a stepped (graduated) disciplinary system which consists of: 1) first incident - verbal counseling, 2) second incident - a written warning, and 3) third incident - discharge. The victim worked for this employer for 3 years and 9 months prior to the incident.

INVESTIGATION

The company had been contracted to install a new lighting system for the taxiway and runway at a local airport. Work had been intermittent since September 5, 1989. At the time of the incident, the job was within 3 weeks of completion. Pre-formed concrete manholes 5-feet-square by 7-feet-deep with 24-inch-diameter openings (manways), which provided access to the underground circuitry for the three lighting systems, had been previously installed. An existing, energized 2,300-volt, 6.6-amp, runway lighting circuit was operating during twilight and night hours each day. Additionally, each manhole contained an energized, 700-volt temporary taxiway lighting circuit, and a de-energized permanent taxiway lighting circuit. Work was in progress to complete the wiring for the permanent taxiway lights. Temporary work area lighting (vapor lights) had been installed.

On the evening of the incident, a crew of six employees (i.e., one equipment operator, four apprentice electricians, and one electrician/foreman) arrived at the incident site to continue work on the lighting systems. The victim and a co-worker were assigned the task of splicing the new conductors for the permanent taxiway lighting circuit, and making the appropriate connections. All the conductors were buried underground and the manholes provided access to the conductor junctions. Standard company procedure involved testing each circuit in the manhole by using an amp probe (i.e., a device used to detect current in a conductor) prior to working on that circuit, identifying the energized runway and temporary taxiway circuits, cutting the de-energized circuit (permanent taxiway circuit), and splicing together the appropriate de-energized conductors.

Prior to the incident, the victim and co-worker had completed connections for the permanent taxiway lights in six separate manholes without incident. The victim entered the seventh manhole via a 24-inch-diameter manway, descended a metal ladder attached to the inside of the manhole, and positioned himself on the ladder facing the circuit conductors. He removed a pair of insulated side (wire) cutters from his tool belt and, without using the amp probe to test for current in the conductors, cut a hanging conductor. The conductor, which was part of the energized runway lighting circuit, came in contact with the back of the victim's right hand after being cut in half. Current passed through the victim's right hand and exited his right thigh at the point of contact with the grounded ladder.

Two co-worker's were standing near the top of the manhole, one co-worker was using a flashlight to light the interior of the manhole while the other co-worker observed the victim. After realizing what had occurred, one co-worker entered the manhole to assist the victim. The other co-worker simultaneously notified the airport tower to have the runway and taxiway lights turned off. The airport emergency rescue personnel were summoned and arrived within 3 minutes after being contacted. The rescue squad provided advanced cardiac life support and transported the victim to the local hospital where he was pronounced dead 45 minutes after the incident occurred.

CAUSE OF DEATH

The medical examiner listed the cause of death as electrocution.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should establish required procedures for the protection of employees exposed to electrical hazards and provide worker training in the recognition and avoidance of such hazards.

Discussion: Employers should comply with OSHA construction safety standard 29 CFR 1926.416(a)(1) by prohibiting employees from working in close proximity to energized electrical circuits where the employee could make contact in the course of work, unless the employee is protected against electric shock by de-energizing and grounding the circuit and/or by effective guarding. Employers should provide worker training in the recognition of electrical hazards and safe work procedures, including identifying circuits, testing circuits, de-energizing circuits, locking/tagging de-energized circuits, and verifying de-energization.

Recommendation #2: Employers should conduct initial jobsite surveys to identify all hazards associated with each specific jobsite, and develop specific methods of controlling the identified hazards.

Discussion: Employers should comply with OSHA construction safety standard 29 CFR 1926.416(a)(3) by conducting initial jobsite surveys prior to the start of any work to identify potential situations for employee contact with energized electrical circuits, and by providing subsequent employee notification about protective measures (i.e., identification, testing, de-energization, locking/tagging of energized conductors, verification, and sufficient work area lighting) to be implemented to control the hazards.

Recommendation #3: Employers should provide and enforce the use of personal protective equipment as required by 29 CFR 1926.416(a)(2).

Discussion: The victim was working inside a 5-foot-square by 7-foot-deep concrete manhole. The manhole contained at least two energized electrical conductors and one de-energized electrical conductor, all with identical characteristics. Also, about six inches of water was present on the floor of the manhole. Employers should provide personal protective equipment (e.g., insulated protective gloves) to workers who are exposed to electrical hazards, and enforce the use of that equipment.

Recommendation #4: Employers should comply with 29 CFR 1926.56 - Illumination.

Discussion: Work was being performed at about 11:30 p.m. in a 5-foot-square by 7-foot-deep concrete manhole. Illumination of the interior of the manhole was provided by a flashlight being held by a co-worker outside the manhole. The manhole contained at least two energized electrical conductors and one de-energized conductor, all with identical characteristics. Also, about 6 inches of water was present on the floor of the manhole. Adequate illumination of the work space should be of paramount importance in instances such as these. Employers should comply with 29 CFR 1926.56 - Illumination.

Recommendation #5: Employers should tag (label) electrical circuits being worked on as required by 29 CFR 1926,417(c).

Discussion: The manhole contained at least three electrical circuits that had identical characteristics. In instances such as these, employers should label electrical circuits being worked on as required by 29 CFR 1926.417(c), to facilitate identification.

Recommendation #6: Property owners and prime contractors should ensure that areas of responsibility for safety and health issues are clearly specified as part of the contract provisions.

Discussion: Contracts between all parties (i.e., property owners and contractors) should contain language that identifies the specific site safety and health programs to be implemented before the initiation of work. Any safety program should be consistent and compatible with the agreed upon language, and any differences should be negotiated before work begins. Where property owners and contractors are involved, the contract should contain clear and concise language as to which party is responsible for each safety and health issue. The respective parties should periodically inspect worksites to ensure that the provisions of the contract regarding safety and health issues are being upheld.

Physical Hazards

Drowning

FACE 87-05: Owner/Foreman of Construction Company Dies in 15 Foot-deep Manhole in California

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), Division of safety Research (DSR) is currently conducting the Fatal Accident Circumstances and Epidemiology (FACE) Project, which is focusing primarily upon selected electrical-related and confined space-related fatalities. The purpose of the FACE program is to identify and rank factors that influence the risk of fatal injuries for selected employees.

On October 14, 1986, the owner/foreman of a construction company (the victim) was found face down at the bottom of a 15 foot-deep manhole in approximately three feet of muddy water. Four workers entered the 24-inch diameter opening and removed the victim from the manhole without any ill effects. Resuscitation efforts failed to revive the victim, who was pronounced dead by the attending physician at a local medical clinic. The incident occurred at a park.

CONTACTS/ACTIVITIES

The Water Pollution Control Federation (WPCF) notified the Division of Safety Research of this fatality and requested assistance. This case has been included in the FACE Project. On October 11, 1986, two research industrial hygienists conducted a site visit, met with the park ranger, interviewed two comparison workers and a representative of the employer, and interviewed a surrogate for the victim.

BACKGROUND/OVERVIEW OF EMPLOYER'S SAFETY PROGRAM

The construction company has 13 employees and had been subcontracted to install a sewage collection system which consisted of 20,000 feet of 6- and 8-inch pipe and 80 manholes.

The prime contractor has written safety rules. Safety meetings discussing basic safety issues relevant to the job being performed are conducted on a regular basis by the prime contractor and the subcontractor. No training had been given concerning confined space entry; however, this subject had been discussed by the prime contractor and the subcontractor as a future training need, since the workers would be required to enter the manholes previously installed.

SYNOPSIS OF EVENTS

Prior to the day of the accident the manhole involved in this incident had tilted about 10 degrees because heavy rains caused the backfill to settle unevenly. An effort to straighten the manhole resulted in extensive damage to a section of the concrete cylinder, five to seven feet below the ground surface. This damage permitted mud and water to seep into the manhole. At the time of the accident the manhole had not yet been connected to any of the sewer lines which had been laid.

On October 14, 1986, the subcontractor's construction crew was installing a section of sewer pipe, approximately 100 feet south of the manhole where the accident occurred. The owner/foreman (the victim), who was operating a backhoe, requested that one of the workers remove the manhole cover so that the victim could "check the grade". The victim then finished excavating the trench for the section of pipe that the crew was installing. Shortly after completion of the excavation, one of the workers observed the victim walking towards the manhole. About fifteen minutes later the worker looked into the manhole and saw the victim face down in the muddy water at the bottom. He immediately called to the other crew members for help.

In response, two workers climbed down into the manhole to rescue the owner. One of the workers feeling "breathless and nauseated", due to what he felt was excitement and exertion, climbed back out. Two other workers entered the manhole, placing a chain around the victim, and assisted in pulling the victim out of the manhole. None of the other workers who entered the manhole experienced any ill effects. The workers then began cardiopulmonary resuscitation (CPR) on the victim until the rescue squad arrived. The victim was rushed to a nearby medical clinic where he was pronounced dead about 90 minutes after being removed from the manhole. Although there were no witnesses to the accident, the medical examiner's report suggests that the victim slipped and fell while entering the manhole, was knocked unconscious, and subsequently drowned in the water at the bottom. If this is the case, it is not clear why the victim felt he needed to enter the manhole since the grade could have been checked from the outside and thus entrance into the confined space would not have been necessary.

An industrial hygiene consultant firm was contacted by representatives of the park. The consultants tested the atmosphere in the manhole and another manhole further east the day after the incident. Their findings indicated that the air samples contained "... normal levels of oxygen (20.5%) in both manholes ...". Tests for carbon monoxide, carbon dioxide, and other gases were "...well below levels that would be noxious".

It should be noted that the unconscious "man down" is often due to a hazardous atmosphere. A hazardous atmosphere and the impromptu rescue response that occurred during this incident could have easily resulted in multiple fatalities, which are typical of many confined space-related incidents.

CAUSE OF DEATH

The medical Examiners report indicates that the victim was knocked unconscious from falling and drowned.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: A trained standby person should remain outside of the confined space when a worker enters or works inside. The standby person should visually monitor the tasks being performed inside and should be able to communicate with the worker(s) inside the confined space.

Discussion: A person trained in emergency rescue procedures, assigned to remain on the outside of the confined space for communication and visual monitoring of the person inside is of utmost importance and might have prevented this fatality.

Recommendation #2: Employers should develop a comprehensive safety program that clearly documents procedures for safe entry into confined spaces.

Discussion: All employees who work in or around confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed prior to entering a confined space. These procedures should include, but not be limited to:

1. Air quality testing to determine adequate O_2 level.
2. Ventilation of the space to remove air contaminants.
3. Monitoring of the space to determine a safe oxygen level is maintained.
4. Employee training in confined space entry, testing, and use of personal protective equipment (respirators, clothing, etc.).
5. Standby person outside the space for communication and visual monitoring.
6. Emergency rescue procedures.

Even though normal oxygen levels were found in air samples taken from two manholes after the accident, entry into confined spaces should not be attempted until atmospheric testing of the confined space insures that the atmosphere is safe. This testing requirement applies to all confined spaces, including those under construction. Testing must be done by a qualified person prior to entry.

Recommendation #3: Property owners contract construction projects should require that a safety program be implemented. The owner should assure that all safety requirements are enforced.

Discussion: When hazardous tasks such as confined space entry are to be performed by contractors or subcontractors, the contract should require compliance with safe work procedures. These requirements should be enforced by the company letting the contract. Specific recommendations regarding safe work practices in confined spaces can be found in the NIOSH Publication No. 80-106, "Working in Confined Spaces". This publication also defines and provides recommendations on hot work, isolation, purging, ventilation, communication, entry and rescue, training, posting, safety equipment, clothing, etc.

FACE 90-14: Municipal Sewer Maintenance Worker Drowns Inside Sewer Wet Well

INTRODUCTION

The employer in this incident is a municipality with 46 public works employees, including 10 sewer workers. The victim had been employed by the municipality for 11 months (the entire time as a sewer maintenance worker). The public works department has a safety policy and confined space entry procedures, but no confined space rescue procedures. The director of the public works department is responsible for the safety program. Public works employees attend monthly safety meetings where job safety issues are discussed and training is occasionally given. The victim had previously attended a 1-hour training session on confined space safety, and a 1-hour training session on the use of supplied-air respirators since his employment began with the public works department.

INVESTIGATION

A sewer maintenance crew was assigned the task of cleaning out a sewer wet well. The crew consisted of four sewer maintenance workers (including the victim) and the foreman for the water and sewer department. The wet well is 20 feet deep, 6 feet in diameter and is located next to an underground sewage lift station. Two feet below the top of the wet well is an 18-inch-diameter sewer inlet pipe. The sewage discharge line (sewer pump intake) forms an elbow with the vertical end 1 foot above the bottom of the wet well. Eight feet below the top of the wet well is a steel grating platform. The grating has three removable sections which rest on a framework of steel "I" beams. Access into the wet well is through a 24-inch-diameter manway opening located at ground level.

The crew arrived at the site at 8:30 a.m., and turned on the lift station pumps. This lowered the sewage level to approximately 2 feet from the bottom of the wet well. With the foreman present, the victim entered the wet well through the manway (without first testing or ventilating the wet well atmosphere) and climbed down the side on steel rungs. He was wearing a pressure demand supplied-air respirator with an auxiliary, escape-only SCBA, and a full-body harness. The harness was secured to a winch cable. The other end of the cable was attached to a power winch on the front end of a maintenance truck.

After climbing down to the grating level the victim installed an inflatable rubber sewer plug into the inlet sewer pipe. The pipe was flowing about one-third full with sewage. The plug was inflated (using an air hose attached to a cylinder of compressed air) until it closed off the pipe and stopped the flow of sewage. However, the employer did not ensure that the following sewer plug manufacturer's recommendations were adhered to during the installation of the plug: (1) the pipe be cleaned out prior to insertion of the plug, (2) the plug be installed with a back-up system (i.e., gate valve), (3) the plug be anchored in place, and (4) the plug be checked to ensure proper inflation to 30 PSI.

A co-worker entered the wet well (without any respirator or harness/hoisting device) and assisted the victim in removing the 2-foot by 6-foot center section of grating. Co-workers at the street level lowered an 8-inch-diameter suction hose into the wet well from a sewer vacuum truck. The victim descended below the grating to the bottom of the wet well with the end of the suction hose and began vacuuming out the remaining sewage and solid waste material. Within a few minutes, the victim removed the respirator facepiece, complaining to the co-worker (who was standing directly above him on the grating) that the respirator was in his way.

Approximately 30 minutes later, the sewer plug gave way, causing sewage to flood the wet well. On hearing the noise, the foreman ran to the manway and yelled for the two workers to get out. Another co-worker turned on the winch and began raising the cable. Within 15 seconds the level of sewage inside the wet well was up to the grating. The co-worker who was standing on the grating reached down through the opening in the grating and made an unsuccessful attempt to grab the victim who was submerged. During this rescue effort, the winch cable became entangled in the grating support beams. As the sewage level continued to rise, the co-worker was forced to climb up further and was ultimately helped out of the wet well by other co-workers. An attempt was also made to start up the pumps inside the lift station. However, the pumps were air-locked and therefore, would not pump the sewage out.

The fire department rescue squad was notified and arrived within 10 minutes. By this time the sewage was about 2 feet above the grating. Fire department rescuers (wearing SCBA) entered the wet well, freed the entangled winch cable, removed the victim, and began administering cardiopulmonary resuscitation. The victim revived and was transported to the intensive care unit of a local hospital where he died approximately 11 hours later.

CAUSE OF DEATH

The coroner listed the cause of death as drowning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: The employer should ensure that workers follow the sewer plug manufacturer's recommendations on the installation and use of sewer plugs.

Discussion: The sewer plug manufacturer recommends the following before performing work upstream or downstream from an inflatable sewer plug:

(1) the use of a back-up system such as a gate valve;

(2) properly cleaning the pipe where the plug will be installed, since debris inside the pipe (i.e., hard objects, encrustations, grease, etc.) can cause plug damage, an improper seal, and/or plug slippage;

(3) securing the plug in place with the use of appropriate restraining rope, cable, etc., to solid anchoring points upstream from the plug; and

(4) inflating the plug to the correct air pressure (according to the plug size and using an appropriate air pressure gauge).

Even properly inflated it is questionable that the plug would have been able to withstand the amount of pressure exerted by the sewage without the restraining cable properly anchored in place. At any rate, none of the above recommendations were followed. Had they been followed, this fatality might have been prevented.

Recommendation #2: The employer should develop, implement and enforce specific confined space entry procedures.

Discussion: Although the employer had written confined space entry procedures, they were not followed or enforced. For example, the wet well in this incident was not tested prior to entry. This requirement was part of the written confined space entry procedures of the public works department, and the foreman was present during the wet well cleaning procedure. Also, the co-worker entered the wet well without wearing a supplied-air respirator/SCBA and the victim removed the supplied-air respirator/SCBA he was wearing after descending to the bottom of the wet well. The employers' confined space rescue procedures were also deficient. For example, although the victim wore a full body harness secured to a winch cable, confined space rescue was not addressed in the written procedures at all. Confined space entry procedures should be specific to each type of confined space e.g., wet wells, lift stations, utility vaults, sewer manholes, etc. 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." 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, sewer vacuum cleaning devices are currently available that will allow workers to clean out wet wells from street level.

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

3. Are confined spaces posted with warning signs (where feasible)?

4. 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 less than 10% of the lower explosive limit
   - Absence of toxic air contaminants?

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

   - respiratory protection
   - lifelines
   - emergency rescue equipment
   - protective clothing?

6. Are workers being properly trained in confined space entry?

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

8. Are employees being continuously trained in confined space rescue procedures?

9. Is ventilation equipment available and/or used?

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

Recommendation #3: The employer and other municipalities should consider installing self-priming wet well sewer pumps by retrofitting, or replacing old pumps as they are taken out of service.

Discussion: Properly installed, a self-priming sewer pump would prevent an air-lock whenever the wet well is manually pumped out below the level of the pump intake. In this incident, if the pumps in the sewage lift station had been self-priming, they could have been immediately activated, possibly preventing the fatality which resulted.

Recommendation #4: Rescue equipment should be appropriate for its intended use.

Discussion: Although the victim was wearing a full-body harness secured to a winch cable, the power winch being used was not rated for lifting humans. It is recognized that any type of rescue/lifting device might have become entangled in the grating supports. However, 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).

Recommendation #5: The employer should ensure that workers use the provided respiratory protective equipment in accordance with instructions and training received as required by CFR 1910.134(a)(3).

Discussion: The public works confined space entry procedures require workers to wear a supplied air respirator the entire time while work is being performed inside sewer wet wells. Additionally, the victim had received training on the use of the supplied-air respirator that he wore. In spite of this, the victim removed his respirator facepiece while working at the bottom of the wet well and was allowed to remain in the well and continue working without wearing the respirator (even though the victim's supervisor was present). Also, while the victim was working at the bottom of the wet well, the co-worker entered the wet well and climbed down to the grating level without wearing any respiratory protection. Even though supplied-air respirators are not rated for use under water, if the victim had not removed the facepiece, it may have given him enough time to climb out when the wet well flooded.

FACE 90-17: Sewer Worker Dies When Inflatable Sewer Plug Bursts

ITRODUCTION

The employer involved is a municipal utility with 1100 public works employees. Approximately 200 of the employees are sewer maintenance workers and wastewater treatment plant operators. The victim had been employed by the municipality for 23 years as a sewer maintenance worker. The public works department has a full-time safety and health manager and a full-time safety and health specialist. A safety policy exists but there are no confined space entry procedures for sewer maintenance workers. However, the victim and other sewer maintenance workers had participated in a 2-hour training session on confined space safety within the past year.

INVESTIGATION

A crew of 10 sewer maintenance workers (including the victim) was assigned the task of diverting the flow of sewage in a 6-foot-diameter sewer main branch in preparation for installing some adjustable weirs (weirs are flow diversion devices). Access into the sewer main was provided by a diversion gate chamber located below a concrete drive area in an underground parking garage for a large building. The gate chamber was 12-1/2 feet deep and approximately 10 feet wide by 16 feet long and located on top of a sewer main diversion branch which formed a "Y" configuration (Figure). The chamber had a 2-foot by 4-foot hatch with hinged steel covers and steel rungs built into the side of the chamber for access. The bottom of the chamber consisted of a removable aluminum grating over the sewer main and a concrete floor between the branches of the "Y". The top of the grating in both branches was approximately 12 inches above the surface of the sewage, which normally flows at a height of 5 feet. The chamber housed a 3/8-inch-thick, 6-foot by 9-1/2-foot aluminum slide gate in each branch of the sewer main. The purpose of the slide gates is to divert the flow of sewage for sewer maintenance purposes. Since the slide gates had not been operated for several years they had become stuck in the "open" position. Therefore, the crew used an inflatable sewer plug to block off the right branch of the sewer main, diverting all of the flow to the left branch of the sewer main (Figure).

The workers installed the sewer plug by lowering the deflated plug into the gate chamber, floating it several feet downstream into the right branch of the sewer main and anchoring it in place with a tethering line. An air line connected to an air compressor (rated at 90 PSI) on the surface was attached to an air valve on the sewer plug. The victim, who was initially above ground, began operating the compressor to inflate the plug and checking a pressure gauge on the air line at the compressor to ensure that the pressure in the sewer plug did not exceed 7 PSI (according to the sewer plug manufacturer's recommendations). The foreman sent a sewer maintenance worker (co-worker) into the chamber to check on the plug. The foreman then walked about 30 feet away to examine a manhole. The victim left the compressor running unattended (for unknown reasons), entered the gate chamber, and began inspecting the installation of the sewer plug. By this time, the plug had expanded and closed off the right branch of the sewer main. The diverted sewage was flowing at its normal height of 5 feet into the left branch of the sewer main. The bottom edge of the slide gates were level with the surface of the sewage flow. The victim was standing on the grating between the plug and the right sewer branch slide gate, while the co-worker was standing on the grating in the left sewer branch on the opposite side of the right branch slide gate (Figure). A few minutes later (after the compressor had been running for approximately 20 minutes), the plug burst, forcing sewage and air into the chamber and out the access hatch. The force of the explosion broke and lifted the grating the victim was standing on, bulged out (approximately 6 inches) the 3/8-inch-thick aluminum slide gate in the right sewer branch, and broke a fluorescent light fixture on the ceiling of the parking garage 10 feet above the chamber access hatch. Evidence gathered after the incident suggests that the force of the explosion pushed the victim up against the concrete ceiling of the chamber. The victim then fell into the right branch of the sewer main and was washed downstream with the surge of sewage. The co-worker was not injured and was able to climb up the chamber rungs where he was helped out by the foreman.

The rescue squad from the city emergency medical service (EMS) was notified and arrived at the site in 5 minutes. After a 40-minute search, EMS personnel discovered the body of the victim submerged under the sewage flow, against the bar screen of a sewage pumping station approximately 200 yards downstream from the gate chamber. EMS personnel noted that the victim was dead at the scene.

CAUSE OF DEATH

The coroner listed the causes of death as asphyxiation by aspiration of food bolus, and blunt force injuries

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Where worker entry into sewers is necessary, slide gates should be used instead of, or in conjunction with, inflatable sewer plugs.

Discussion: Slide gates provide a more positive method for diverting/controlling the flow of sewage for maintenance purposes, and should be utilized where possible. In this incident, because the slide gates had not been used for quite some time, they had become inoperative. Slide gates of this type should be properly maintained and operated regularly to ensure their proper function.

Recommendation #2: Employers should ensure that sewer workers follow all sewer plug manufacturer's safety recommendations and other safety precautions relevant to the safe installation and use of inflatable sewer plugs.

Discussion: Although some of the plug manufacturer's recommendations were followed, an important precaution for the use of this type of sewer plug was not followed. The following precaution is stated on the first page of the sewer plug installation instructions: "Under no circumstances should anyone be in the pipe or manhole when the stopper (plug) is being inflated or deflated." The victim left the air compressor running unattended. He had been trained in the manufacturer's recommendations which stipulate that this size plug was to be inflated to only 7 PSI. The air pressure inside the plug may have exceeded the recommended pressure of 7 PSI, thus causing the plug to rupture. (The burst test pressure for this plug is 21 PSI.) Another safety recommendation given by the plug manufacturer (also stated on the first page of the sewer plug instructions) was not followed: "When working under submerged conditions, as a safety precaution, the stopper should be filled with water to its appropriate pressure." According to the manufacturer, filling the plug with water instead of air when the plug is submerged will greatly reduce the force of a rupture.

Recommendation #3: Employers of sewer maintenance workers should develop and implement a comprehensive confined space entry program as outlined in NIOSH publication 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces."

Discussion: Confined space entry procedures should address each type of confined space that sewer maintenance workers are required to enter (i.e., diversion chambers, wet wells, lift stations, utility vaults, sewer manholes, sewer mains, etc.). At a minimum, the following items should be addressed:

1. Is entry necessary? Can the assigned task be completed from the outside? For example, a sewer monitoring camera could be lowered into a sewer diversion gate chamber which would allow workers to perform inspections from the outside.

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

3. Are confined spaces posted with warning signs and are 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 based on the following criteria:

- 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:

   - respiratory protection
   - lifelines
   - emergency rescue equipment
   - protective clothing

6. Have employees been trained for confined space entry? NOTE: The fire department that responded to this emergency is one of the best equipped and trained in the country. As a result of this preparedness, potential injury and fatalities to their personnel was avoided.

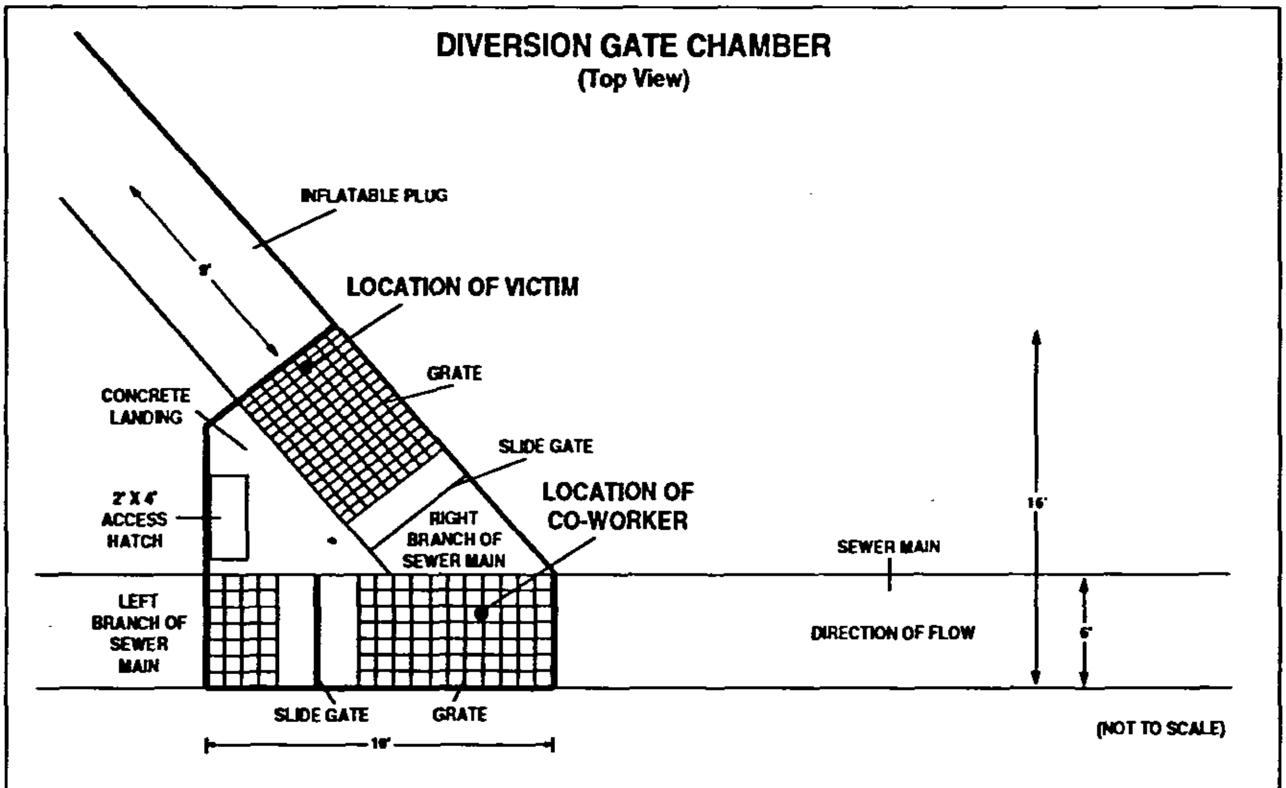


Figure (90-17)

FACE 91-23: Wastewater Treatment Plant Operator Drowns In Recirculation Pit

SUMMARY

A 21-year-old operator at an aerobic wastewater treatment plant drowned in the plant's recirculation pit after apparently falling into the pit while performing general maintenance duties. The victim had been assigned the task of hosing down foam in an adjacent transfer pit. The recirculation pit and transfer pit were located on the outside of the operations building of the wastewater treatment facility. The adjoining pits formed one large, 11-feet-deep rectangular compartment divided by a 1-foot-thick concrete wall. The outside perimeter was fenced off with aluminum railings, with one gate for entry into the pits. There were two large openings over the recirculation pit, and one opening over the transfer pit. The operator was in the process of hosing down the transfer pit, when the plant superintendent left the plant to give a contractor a ride downtown. The superintendent stopped at a lift station to take flow readings before returning to the plant. Thus while the operator was unobserved, he apparently stepped or fell into the recirculation pit. When the plant superintendent returned to the treatment plant, he heard one of the recirculation pumps hammering. After shutting off the flow into the pit and letting it drain, he discovered the victim at the bottom, against one of the pump inlets.

The NIOSH investigator concluded that, in order to prevent future similar occurrences, employers and employees should:

- *conduct job hazard analyses of worker tasks required in the operation of the wastewater treatment plant, and use the results to develop a written safety program and task-specific safe work procedures*
- *develop and implement confined space entry procedures*
- *relocate the gate used to access the recirculation/transfer pits*
- *provide fall protection equipment for employees that work over areas where fall hazards exist*
- *provide atmospheric testing equipment for testing confined spaces at the facility and ensure that atmospheric testing is conducted before workers either enter confined spaces or initiate work near open pits.*

INTRODUCTION

On May 25, 1988, a 21-year-old male operator at a wastewater treatment plant drowned after apparently falling into the plant's recirculation pit while performing general maintenance duties. On July 31, 1991, the Commissioner of Labor for the State of Iowa notified the Division of Safety Research (DSR) of this fatality and requested technical assistance. On August 12, 1991, a DSR investigator traveled to the incident site to conduct an investigation. The DSR investigator met with the city administrator, the director of public works, the assistant superintendent of public works, the superintendent of the wastewater treatment plant, the current operator of the wastewater treatment plant, the retired superintendent of the wastewater treatment plant (who was superintendent at the time of the incident), the parents of the victim, and a labor safety and health consultant with the Iowa Division of Labor. The consultant provided DSR with a copy of the OSHA reports and the files related to this case. The DSR investigation included photographing the incident site, obtaining diagrams and drawings of the plant operation, sampling and monitoring atmospheric conditions at the incident site (recirculation pit) and surrounding operations (aeration basin, clarifier basin, aerobic digester basin, transfer pit, pump room, and operations building), and sampling atmospheric conditions at several manholes and pump stations throughout the city. The city administrator provided DSR with copies of photographs taken the day of the incident, along with statements from city employees and the Emergency Medical Services (EMS) crew.

The employer involved in this fatality was a small municipality with 56 employees. The public works department had five employees, including two—the plant superintendent and the operator—who worked at the wastewater treatment plant. The municipality had no written safety program or confined space entry program. On-the-job training was provided for new employees.

INVESTIGATION

The wastewater treatment plant where the incident occurred was an aerobic-type treatment plant that served a population of approximately 1,300 people. The plant consisted of an aeration basin (where the raw sewage entered and, when recirculated, activated sludge was pumped), a clarifier basin, an aerobic digester basin (the digested sludge was removed at this location), an operations building (the recirculation pit and transfer pit was located on the outside of this building), and four lagoons. The recirculation pit was 18 feet 6 inches long by 6 feet wide by 11 feet deep. The transfer pit was 9 feet 10 inches long by 6 feet wide by 11 feet deep—both pits formed one large rectangular compartment, divided by a 1-foot-thick concrete wall, with one opening over the transfer pit, and two openings over the recirculation pit. The plant was generally automated; i.e., transfer of activated sludge to the aerobic digester was performed automatically, at a predetermined rate of flow. The plant was operated by two individuals—the plant superintendent and the plant operator. The superintendent was responsible for the overall operation of the plant, laboratory sampling and analysis, etc. The plant operator was responsible for general maintenance around the plant, i.e., taking flow readings, general clean-up, hosing down foam on the clarifier basin and the transfer pit, hosing around the grating on the aeration basin, checking the pumping system to detect problems, and other maintenance as needed.

[Note: The day before the incident, the aerobic digester was shut down to allow the digested solids to settle to the bottom of the digester. Digested sludge was to be pumped out of the bottom of the digester into a sludge-hauling truck and the supernate (liquid from the digester) drained off into the recirculation pit, where it would be mixed with the activated sludge and returned to the aeration basin.]

On the morning of the incident, the plant operator (victim) arrived at the plant at approximately 7:00 a.m. The superintendent arrived approximately 15 minutes later. He had stopped on the way to the plant to take flow readings from a local dairy plant. When the superintendent arrived at the treatment plant, he was met by the sludge hauler (the city contracted to have digested sludge removed from the aerobic digester and hauled away) and the plant operator (victim). The sludge hauler stated that someone had removed the sludge trough from the plant, a piece of equipment which he needed for sludge removal. The superintendent agreed to drive the sludge hauler to town to recover the necessary equipment and the hauler's pickup truck. Before leaving, the superintendent told the plant operator (victim) that the foam in the transfer pit would probably need hosed down.

The superintendent drove the sludge hauler into town, dropped him off, stopped at one of the lift stations to record flow readings, and returned to the plant. When he got back to the plant (approximately 7:30 a.m.), the superintendent went inside the operations building. He noticed that one of the recirculation pumps was hammering (cavitating). Upon checking the control panel, the superintendent observed that recirculating pump number 2 was not operating properly. The superintendent went outside and looked into the recirculation pit and noticed the sewage level was elevated, although it had not reached the high water level. The superintendent checked the area for the operator (victim) and could not find him. The superintendent feared that the operator had fallen into the pit. He immediately shut off the flow of sewage to the recirculation pit, leaving the pumps running to drain the pit. (There were three return lines from the recirculation pit, each with a 30-horsepower pump with a capacity of 2,600 gallons per minute (gpm); however, only two pumps were on at any given time.) When the water level dropped, the superintendent could see the victim at the bottom of the pit against the number 2 return line, a 12-inch-diameter opening with a steel rebar grate across the inlet.

The superintendent immediately went inside and shut off the recirculation pumps, called 911 and radioed for other city workers to assist. He then went back to the recirculation pit, entered opening number 1 by stepping onto the metal grating, and jumped down to the victim. The superintendent pulled the victim away from the inlet and held him partially out of the sewage (approximately 1 foot deep). Three workers from one of the public utilities arrived within 2 to 3 minutes, and two of them entered the recirculation pit and assisted the superintendent in lifting the victim up to the metal grating.

The Emergency Medical Service (EMS) arrived and one of the technicians went down to the metal grating where the victim had been laid on his back. The victim had "no pulse and no respiration." Ventilation was started by EMS in an attempt to revive the victim. The victim was removed from the recirculation pit, and cardiopulmonary resuscitation (CPR) was started. Within a few minutes, a second emergency squad arrived and transported the victim to the hospital. CPR was continued on the way to the hospital, along with oxygen administration. Upon arrival at the hospital, the victim was started on advanced life support.

Since this incident occurred over 3 years prior to the NIOSH investigation, and there were no witnesses, it was not possible to reconstruct the immediate events leading to the victim's death. The following scenario is offered as a plausible explanation of what may have occurred.

The procedure for hosing down foam in the transfer pit was to use a gasoline-powered, 3-horsepower pump (100 gpm capacity), placing the suction end of the hose in the transfer pit or in the nearby lagoon for water. Then using a spray or fan nozzle, the foam in the transfer pit could be hosed down from the outside of the railing. However, it was noted that this procedure, hosing down the foam, was sometimes done from inside the railing. This meant the worker would be standing on the fiberglass panel (55 inches by 60 inches) over the recirculation pit, or on the fiberglass panel (58 inches by 60 inches) over the transfer pit, or on the 8-inch cement curb around the front of the pit. The victim may have been hosing down the transfer pit from inside the railing, with the suction side of the hose in the lagoon, when the hose nozzle apparently became clogged with weeds from the lagoon and would no longer spray. The victim may have exited the pit area to find the other nozzle, returned with a different nozzle and re-entered the pit area (the spare hose nozzle was found near opening number 1), then tripped, slipped, or lost his balance and fell through opening number 1. Alternatively, he may have realized that the pump was still running and had to be shut off before he could change nozzles. If so, he may have turned to exit the pit area in order to shut off the pump, when he stepped or fell into the pit through opening number 2. The victim either struck the metal grate 5 feet below opening number 1, then fell into the turbulent sludge present in the recirculation pit, or fell directly into the sludge through opening number 2. Once in the sludge, he was sucked to the bottom and trapped against number 2 return line inlet.

ATMOSPHERIC TESTING

Atmospheric testing was conducted at the wastewater treatment plant on August 13, 1991. The atmosphere in the recirculation pit and the atmosphere in the transfer pit were tested for hydrogen sulfide (H_2S), oxygen (O_2), and methane (CH_4). The H_2S and CH_4 tests were all negative; O_2 tests indicated 20.7% oxygen. The investigator tested the area around the digester, aeration basin, clarifier basin, and pump room. Neither H_2S or CH_4 was detected; all O_2 levels were between 20.4% and 20.7%. The atmosphere in the recirculation pit and the transfer pit was tested four times that day, and all readings were similar.

At approximately 3:00 p.m. on August 13, 1991, the DSR investigator requested that the digester be shut off so the conditions would be similar to the day of the incident. On August 14, when the DSR investigator arrived at the plant to start testing, the digester was still off and the supernate was flowing into the recirculation pit. This attempt to recreate conditions similar to those at the time of this incident did not effect the gas readings to any noticeable degree. There were no odors present inside or outside of the plant on any of the 3 days during the investigation. The DSR investigator concluded there was evidence suggesting only trace presence of toxic gases in the recirculation pit (H_2S 0.3 ppm), which does not represent any health hazard.

The three rescuers in the recirculation pit did not experience any ill effects. If the pit contained H_2S, or was oxygen deficient, it is possible that the rescuers would have been affected by these adverse conditions. In addition, if H_2S had been present in significant concentrations, the distinctive rotten egg odor could have been noted in the surrounding areas. It should be noted that air quality at wastewater treatment plants is always a potential area of concern. Adverse atmospheric conditions (oxygen deficiency, toxic or flammable atmospheres) have been responsible for more fatalities in confined spaces than any other hazard/condition.

On August 14, 1991, the atmospheres in the recirculation and transfer pits were continuously monitored for H_2S, CH_4, and O_2 for 20 minutes of each hour for 6 hours straight. Atmospheric conditions were also tested at the aeration basin, the clarifier basin, the aerobic digester, the operations building and along the number one lagoon. Results of the gas test were:

H_2S	0.3 ppm (highest level recorded)
CH_4	0.0 lower explosive limit (lel)
0_2	20.5%

Gas readings were taken at seven additional sites, four manholes in the municipality, at two lift stations, and at a water pump station. Neither H_2S nor CH_4 were detected, and 0_2 readings were all above 20%, with the exception of one manhole that had a reading of 19.4%.

On August 15, 1991, the atmospheres in the recirculation and transfer pits were continuously monitored for H_2S, CH_4, and 0_2, 20 minutes of each hour for 4 hours straight. Atmospheric conditions were also tested at the aeration basin, the clarifier basin, and the aerobic digester. Results of gas test were negative for H_2S and CH_4. 0xygen readings ranged from 20.4% to 20.7%.

CAUSE OF DEATH

The medical examiner listed the cause of death as drowning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should conduct job hazard analyses to identify potential hazards.

Discussion: A job hazard analysis should be conducted for all operations at the plant. Each job/task should be broken down into component parts and analyzed for potential hazards. Once the job hazard analyses are completed, this information can be used in the development of a written safety program and operating procedures for the facility.

Recommendation #2: Employers should develop a written safety program with procedures specific to the wastewater treatment plant.

Discussion: A written safety program should be developed for the wastewater treatment plant that covers all areas of operation. The program should include, but not be limited to, control of hazardous energy (i.e., lockout/tagout of energy sources that have the potential to inflict injury to the exposed employee), electrical safety, personal protective equipment and clothing, use of respiratory protection (i.e., self-contained breathing apparatus), and address all areas cited in the job hazard analyses.

Recommendation #3: The employer should develop, implement and enforce confined space entry procedures.

Discussion: The employer should 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." Although the employee was working above the confined space and not in the space itself, confined space procedures should be followed to anticipate problems should entry, including inadvertent entry, occur. 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?

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

3. Are confined spaces posted with warning signs?

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

   - oxygen level at least 19.5%
   - flammable range less than 10% of the lel
   - absence of toxic air contaminants

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

   - respiratory protection
   - use of test equipment
   - lifelines
   - emergency rescue equipment
   - protective clothing

6. Are workers being properly trained in working in and around confined spaces?

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

8. Is ventilation equipment available and/or used?

9. Are employees trained in rescue procedures?

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

Recommendation #4: The employer should redesign the surrounding opening into the recirculation pit area so that access is onto a solid surface and not directly into an opening.

Discussion: Entry through the gate at the recirculation pit exposes the employee to an opening measuring 27 inches by 46 inches. The pit opening is the first step inside the railing/gate. The gate should be moved to a location that allows the employee to step onto a solid, safe surface, not a direct opening into the recirculation pit.

Recommendation #5: Employers should provide safeguards and/or fall protection for employees that work over areas where the potential for injury exists.

Discussion: When an employee is required to work around or over areas where the potential for falling exists, appropriate safeguards and/or fall restraints should be used particularly when the potential exists for a fall into an area containing hazardous energy or a hazardous process. Such hazards should be recognized when the job hazard analyses are conducted and the results analyzed. There are various types of safeguards and fall restraints on the market today. Each situation or task may require specific types of protection; therefore, it is essential that all hazards be identified and addressed.

Recommendation #6: Employers should provide atmospheric testing equipment for testing confined spaces prior to entry.

Discussion: All confined spaces should be tested before entry. Also, when employees are required to work over an open pit, it should be tested for possible oxygen deficiency, toxic gases, and flammability. These tests are precautionary and essential.

REFERENCES

National Institute for Occupational Safety and Health, Criteria for a Recommended Standard ... Working in Confined Spaces. DHHS (NIOSH) Publication No. 80-106, December 1979.

National Institute for Occupational Safety and Health, A Guide to Safety in Confined Spaces. DHHS (NIOSH) Publication No. 87-113, 1987.

FACE 93-17: Two Men Die In Well Cleaning Operation

INTRODUCTION

On May 1, 1993, two self-employed well cleaners (the victims) drowned while conducting well cleaning operations at a residential well site. On June 23, 1993, the Maryland Occupational Safety and Health Administration (MOSH), notified the Division of Safety Research (DSR) of these deaths and requested technical assistance. On July 12, 1993, an environmental health and safety specialist and an engineering intern from DSR conducted a field investigation of this incident. Interviews were con- ducted with the MOSH investigator, the county confined space rescue team, the county volunteer fire department, and the son of victim #2. Photographs were obtained of the incident site. Medical examiner's reports for both victims were also obtained. No atmospheric testing was conducted as the well site had been filled in and sealed.

The investigation was complicated in part by certain factors: the time lapse between the incident and the investigation, the number of emergency responders, the particular sequence of events, and the time frames of these events, and differing perceptions of the series of events occurring in a crisis situation. Therefore, a scenario of this incident was developed after carefully evaluating a diverse mixture of information. The victims in this incident worked part-time as self-employed well cleaners and grave diggers. This was the only source of employment for victim #1. Victim #2 was employed full-time as a truck driver for the county in which the incident occurred. Neither victim had any safety or confined space training. However, both victims were aware that well cleaning was a dangerous job, according to the son of victim #2.

INVESTIGATION

On May 1, 1993 three self-employed well cleaners - a 43-year-old male (victim #1), a 40-year-old male (victim #2), and his 17-year-old son - arrived at the residential well site to clean a shallow (36-inch-diameter by 40-foot-deep) well. They arrived at the work site at 9 a.m. and used a portable gasoline pump to remove water from the well, which was filled to approximately the 20 foot level. The gasoline pump was not adequate to remove all of the water, so the workmen went to a local equipment rental store and rented an electric sump pump to complete the job. They placed the pump at the bottom of the well and pumped out the remaining water to a depth of 6 to 8 inches. The victims did not use any type of respiratory protection, atmospheric test equipment, or ventilation equipment during the well cleaning operation. Victim #1 was lowered into the well at approximately 10:30 a.m. to begin cleaning. A steel bucket, steel cable, and a homemade windlass were used to raise and lower workers, supplies, and muck from the well. The windlass was made of 2-inch by 6-inch wooden boards, crudely designed in an "X" configuration, with a steel bar across the top intersection of the "X" which included a handle at each end. Victim #1 began shoveling muck out of the well and brushing down the sides. Water was the only solvent used to clean the sides of the well. Approximately 1 hour and 15 minutes later, victim #2, at the top of the well, asked victim #1 how much longer before the cleaning job would be completed. Not hearing a response, victim #2 inquired as to the condition of victim #1. There was still no response. The second victim's son asked the homeowner to call 911 (at approximately 11:50 a.m.), stating there was trouble in the well, then requested the homeowner's assistance in lowering his father (victim #2) into the well to rescue victim #1. In a rescue attempt, the son and the homeowner lowered victim #2 into the well on a small wooden (2 inch by 12 inch by 16 inch) board which served as a seat.

Using his arms, victim #2 was able to secure his co-worker and was being hoisted up by his son and the homeowner when at approximately the halfway point (20 feet), the board that was supporting the victims started to crack. Victim #2 yelled to his son to lower them back to the bottom of the well. Victim #1 was still semiconscious but unable to assist victim #2 in attempting to exit the well. The two workers made no other attempt to leave the well until rescue units arrived. The first rescue squad to arrive on the scene was the county emergency medical squad (EMS) at approximately 12 noon. The paramedics from the EMS positioned their truck 5 to 7 feet from the well opening in order to use a light to see into the well. A rope was thrown down to the victims but victim #2 was unable to secure the rope around victim #1.

By this time, the well was starting to fill with water (approximately 10 feet deep), and the victims were treading water.

Within 2 to 4 minutes after the first EMS unit arrived, the local volunteer fire unit arrived on the scene. The first rescue unit was promptly ordered by the deputy chief of the local volunteer fire unit to move their vehicle away from the well. At this point, victim #2 was coherent enough to communicate with the rescuers, but was not able to use a rope to exit the well. Victim #1 was not coherent, and was believed to be unconscious. The second rescue unit was equipped for fire rescue. Therefore, they only had 60 minute air tanks on the self-contained breathing apparatus (SCBA); they did not feel there was room in the well for a rescuer with full turn-out gear and an SCBA. The deputy chief of the volunteer fire unit requested a 15-minute (smaller in size) unit be brought to the scene from the fire house, which was approximately 5 miles from the incident scene.

Because victim #2 was going under the water, the volunteer fireman (rescuer #1) preparing to make the descent into the well in a rescue attempt told the deputy chief they did not have time to wait for the 15-minute unit. A decision was made to lower the fireman into the well without any respiratory protection, wearing the bottom half of the turn-out gear, a harness, and a lifeline. The fireman was lowered into the well, which now had approximately 20 feet of water, and was able to reach victim #2 within a few minutes and place a rescue line around him. (The temperature of the water was between 35 and 40 degrees F, as reported by the volunteer fireman.) The rescuing fireman was then hoisted from the well without any ill effects from the atmosphere or the cold water. (Note: the atmosphere was being tested before and after the fireman's entry - the oxygen level was measured at 17% by volume). Victim #2 was then pulled from the well, in an unresponsive condition. Paramedics administered CPR and transported him to the local hospital where he was pronounced dead, after further life-saving efforts were unsuccessful.

The elapsed time for the rescue of victim #2 was approximately 20 minutes after the first EMS arrived on the scene. By the time Victim #2 was removed from the well, victim #1 had been underwater for approximately 30 minutes. The volunteer fire unit was not prepared for an underwater recovery; the decision was made to avoid the risk of losing a firefighter in what was believed to be at this point, a body recovery. They chose instead to wait for the arrival of better equipped units, whose assistance had been requested to retrieve victim #1.

Divers from an adjacent county arrived approximately 40 minutes after the second 911 call. Two divers made separate dives (each equipped with self contained underwater breathing apparatus [SCUBA], full rubberized diving suits, underwater lights, and life lines). The first diver (rescuer #2) found victim #1 at the bottom of the well and managed to get a rope around him; however, when they attempted to raise him from the well, the victim slipped out of the rope and sank back to the bottom. The second diver (rescuer #3) was unsuccessful in his attempt to secure a line to the victim. A volunteer fireman from the local fire department (rescuer #4) entered the well wearing SCUBA; however, he was also unsuccessful in his recovery attempt, and complained of the cold water inhibiting his ability to recover the victim. A specialized confined space rescue team had now arrived from a different county and requested the area be cleared of all those working on the rescue effort. The specialized rescue team sent one of their divers (rescuer #5) wearing SCUBA, a full rubberized suit, life line, underwater lights, and communication equipment into the well. It took approximately 20 minutes for this diver to secure a line to victim #1. Victim #1 was then recovered from the well, approximately 4 hours after the initial 911 call. Victim #1 was pronounced dead at the scene by a forensic examiner.

In summarizing this confined space investigation, there were three major hazards identified: (1) oxygen deficient atmosphere (NIOSH, 1979), (2) toxic (carbon monoxide) atmosphere (NIOSH, 1972), and (3) cold water exposure (Golden, 1976). The medical examiner listed the blood carboxyhemoglobin saturation levels as 37% in victim #1 and 13% in victim #2.

The bacterial action and biomass in the well could have been a source for a small percentage of the carbon monoxide. However, an external source was probably responsible for the largest percentage of carbon monoxide. Testing conducted by the volunteer fire unit indicated that the oxygen level (only gas tested) at the 20-foot level was 17% by volume. When the well was pumped to the bottom, the oxygen level would have likely decreased to 12 to 15% by volume. Under conditions of reduced ambient oxygen concentration, such as the reduced oxygen level in the well, the exposure to carbon monoxide was even more critical.

The water temperature in the well was reported to be between 35 and 40 degrees F. Survival time in water at 32 degrees F is predicted to be less than 15 minutes (Golden, 1976).

CAUSE OF DEATH

The medical examiner listed the cause of death for victim #1 as "drowning complicating carbon monoxide poisoning," and the cause of death for victim #2 as drowning.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers involved in well cleaning operations, including the self-employed, should develop and implement a comprehensive confined space entry program.

Discussion: There was no confined space entry program in effect at the residential well site at the time of the incident. The atmosphere was not tested before entry, no mechanical ventilation or respiratory protection was provided, and no rescue plans were developed. Employers, even self-employed well cleaning operations, should develop and implement a written confined space entry program to address all provisions outlined in the following NIOSH Publications: Working in Confined Spaces: Criteria for a Recommended Standard (Pub. No. 80-106); NIOSH Alert, Request for Assistance in Preventing Occupational Fatalities in Confined Spaces (Pub. No. 86-110); A Guide to Safety in Confined Spaces (Pub. No. 87-113); and NIOSH Guide to Industrial Respiratory Protection (Pub. No. 87-116).

A confined space entry program should include the following:

1. written confined space entry procedures
2. evaluation to determine whether entry is necessary
3. issuance of a confined space entry permit
4. evaluation of the confined space by a qualified person
5. testing and monitoring the air quality in the confined space to ensure:
   - oxygen level is at least 19.5%
   - flammable range is less than 10% of the LFL (lower flammable limit)
   - absence of toxic air contaminants
6. training of workers and supervisors in the selection and use of:
   - safe entry procedures
   - respiratory protection
   - lifelines and retrieval systems
   - protective clothing
7. training of employees in safe work procedures in and around confined spaces
8. training of employees in confined space rescue procedures
9. conducting safety meetings to discuss confined space safety
10. availability and use of proper ventilation equipment
11. monitoring the air quality while workers are in the confined space.

Recommendation #2: Volunteer fire departments should identify the types of confined spaces within their jurisdiction and develop and implement confined space entry and rescue programs.

Discussion: Volunteer firefighters may be required to enter confined spaces to perform either non-emergency tasks or emergency rescue. Therefore, volunteer fire departments should identify the types of confined spaces within their jurisdiction and develop and implement confined space entry and rescue programs that include written emergency rescue guidelines and procedures for entering confined spaces. A confined space program, as outlined in NIOSH Publications 80-106 and 87-113, should be implemented. At a minimum, the following should be addressed:

1. Is entry necessary? Can the task be accomplished from the outside? For example, many fire departments use an under- water search and rescue device which consists of several sections of metal tubing connected together with a hook or retrieval device on the end. Such a device can be used to retrieve 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 that 15 feet. This type of pump can be lowered into a well to pump out the water 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. 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 flammable limit
   - absence of toxic air contaminants?

3. Is ventilation equipment available and/or used?

4. Is appropriate rescue equipment available?

5. 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
   - protective clothing
   - ventilation systems

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

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

8. Are firefighters trained in confined space rescue procedures?

9. 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 gasoline engine powered equipment in or around the confined space."

Recommendation #3: Volunteer fire departments should develop and implement a respiratory protection program to protect firefighters from respiratory hazards.

Discussion: The 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 protection equipment according to NIOSH Guide to Industrial Respiratory Protection (Publication No. 87-116).

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

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." As part of a safety program, fire departments should carefully evaluate each task to identify all potential hazards, (e.g., falls, electrocutions, burns, unsafe atmospheres, etc.) and implement appropriate control measures.