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.

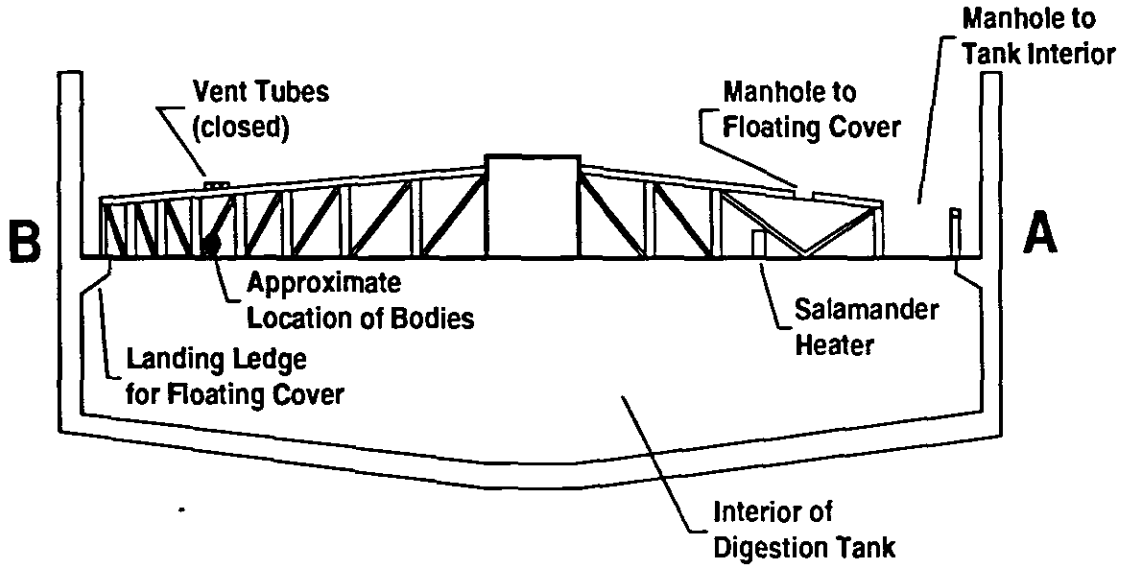

Figure 1 (84-11). Side view of digestion tank with floating cover.

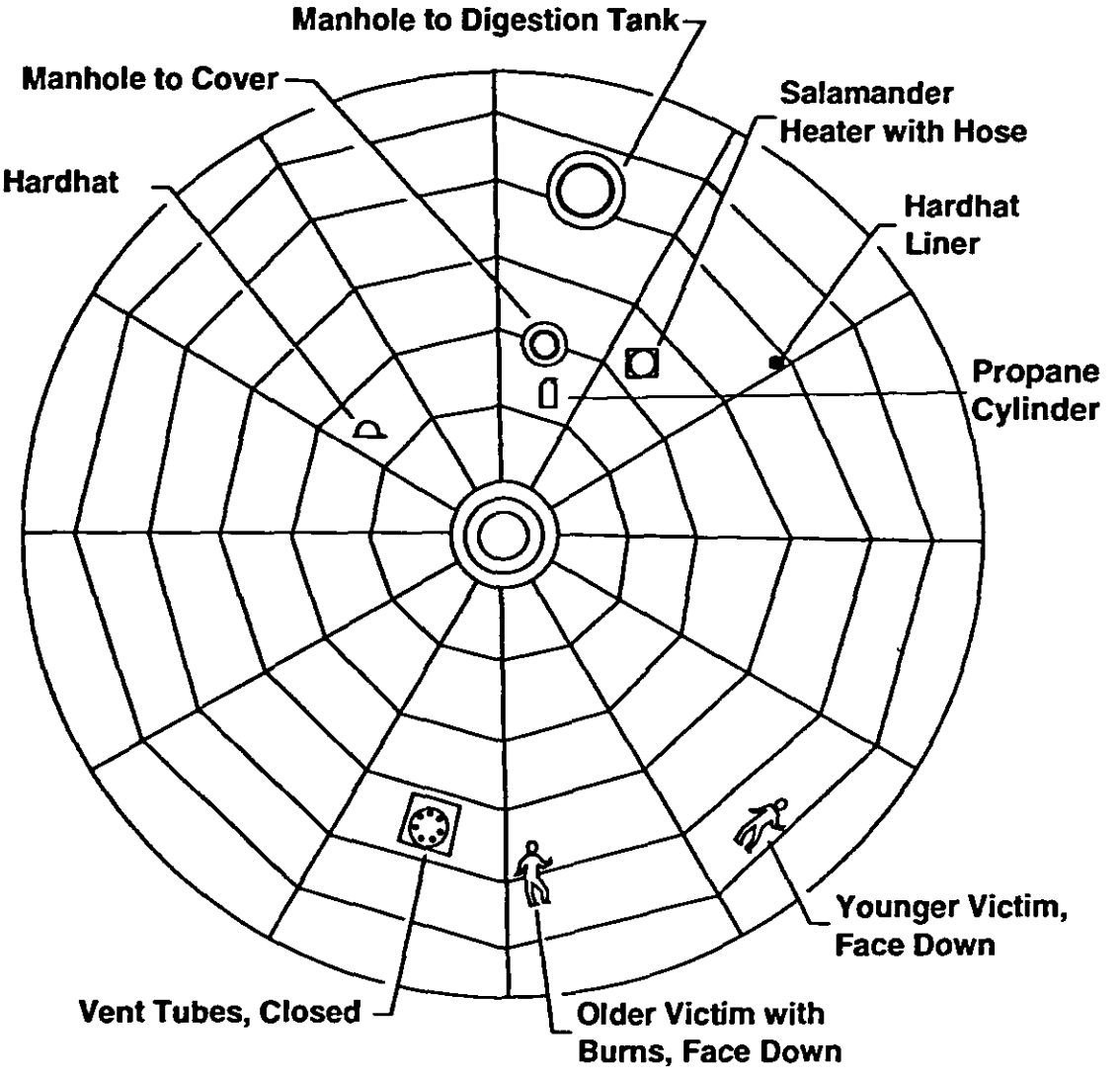

Figure 2 (84-11). Top view of digestion tank showing location of victims.

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.

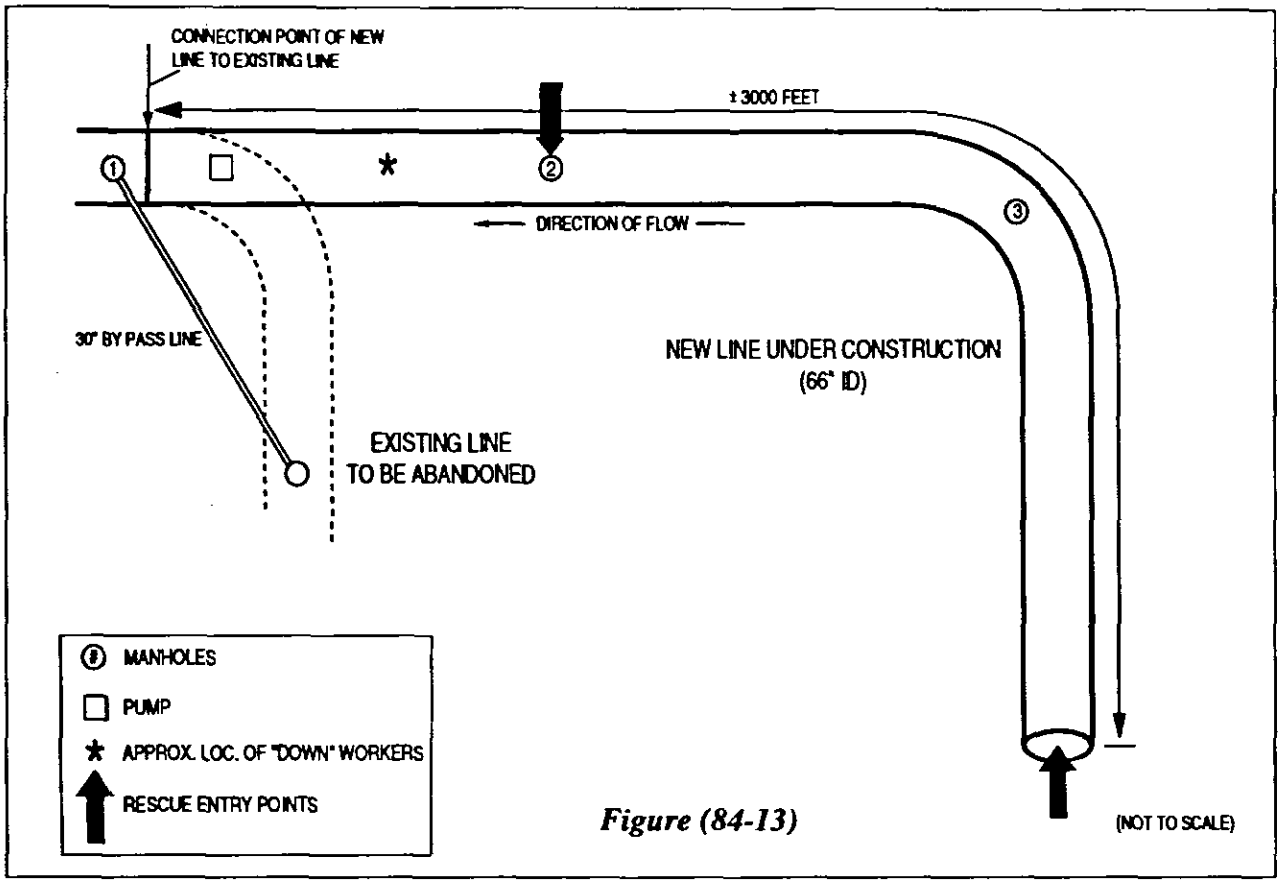
CONNECTION POINT OF NEW LINE TO EXISTING LINE
± 3000 FEET
DIRECTION OF FLOW
30" BY PASS LINE
NEW LINE UNDER CONSTRUCTION (66" ID)
EXISTING LINE TO BE ABANDONED
MANHOLES
PUMP
APPROX. LOC. OF "DOWN" WORKERS
RESCUE ENTRY POINTS
(NOT TO SCALE)

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.