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.

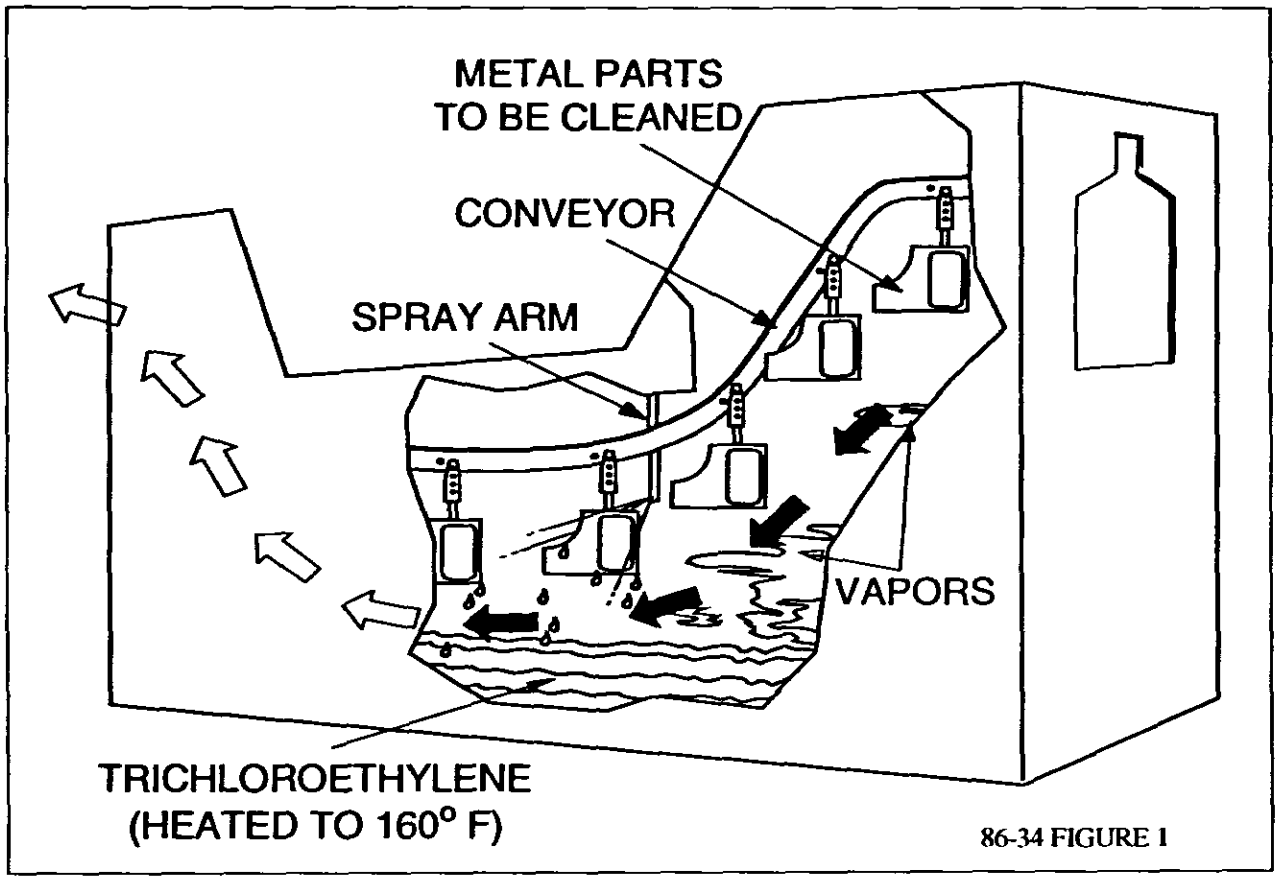
Discussion: All employees who work in confined spaces should be aware of potential hazards, possible emergencies, and specific procedures to be followed, prior to entering a confined space. These procedures should minimally include:

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. Never Work Alone. 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)

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

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.

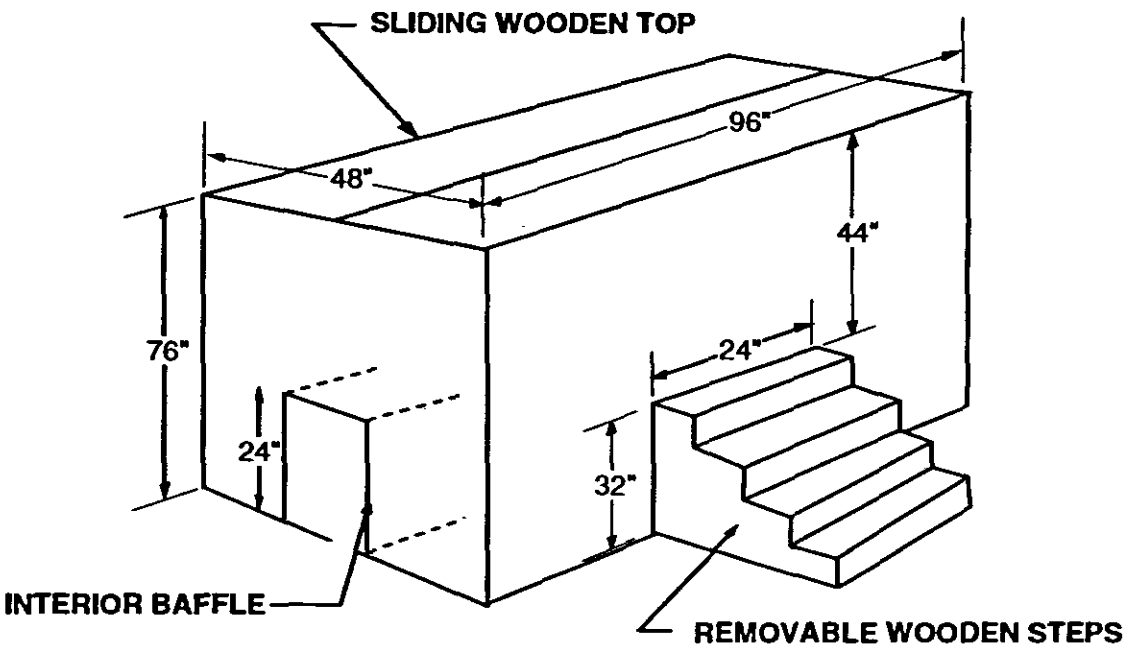
The recommendations in NIOSH Publication No. 80-106, "Working in Confined Spaces" should be used for confined space entry.

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.