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**TO:** Director, National Institute for Occupational Safety and Health

**FROM:** California Fatality Assessment and Control Evaluation (FACE) Program

**SUBJECT:** Three Oil Field Workers Died after Inhaling Carbon Monoxide Gas in an Oil **Well** cellar in California

## *SUMMARY*
### *California FACE Report #94CA0016*

Three oil field workers died after breathing carbon monoxide (CO) gas in an oil well cellar. The incident occurred during perforation, a procedure to create holes in the pipe in the well to allow the well to be used for water disposal. During the procedure, water began flowing from a valve in the well cellar. No plan had been prepared for actions by the workers in the event that this occurred. The first worker (decedent #1), a 22 year-old male, entered the well cellar to turn off the valve. Upon entering the area, he collapsed and fell into the cellar. A second worker (decedent #2), a 24 year-old male entered the cellar to assist decedent #1 but was also overcome and collapsed. A third worker (decedent #3), a 26-year-old male, was overcome while kneeling near the opening to the cellar and also fell in.

The decedents, all employed by a well maintenance contractor, were not wearing any personal protective equipment (PPE) at the time of the incident. No confined space atmospheric testing was performed prior to entry into the well space by any of the workers. Workers from another contractor, that was performing the well perforation, went into the cellar and pulled the decedents out when they saw what had happened. None of the rescuers wore any type of PPE nor was any available for their use at the incident site. Fire department paramedics arrived on the scene shortly after the incident occurred and pronounced decedent #2 dead at the scene. The other two victims were transported to the hospital where they both were later pronounced dead. Four additional workers were hospitalized, but survived the incident. The CA/FACE investigator concluded that in order to prevent similar future occurrences, employers and contractors should:

- understand the risks and how to safely avoid them, and should provide and keep available equipment for rescue operations.

- ensure that their Injury and Illness Prevention Programs (IIPP) effectively address all the present and potential hazards of their employees' worksites.
- test the atmosphere of confined spaces before any employees are allowed entry.
- if feasible, ventilate confined spaces so that employees are not exposed to hazardous air contaminants.
- insure employees are provided and wear approved respiratory equipment when entering• confined spaces where there is the presence or suspicion of harmful mists, fumes, or gases, or oxygen deficiency.
- ensure employees are provided and wear approved safety harnesses and life lines when entering confined spaces not kept safe through forced air ventilation.
- train employees in rescue operations so that in the event of an emergency, workers

## INTRODUCTION

On August 10, 1994, three oil field workers were killed when they were overcome by CO gas during an oil well perforation and collapsed in the well cellar. The CA/FACE investigator became aware of this incident through a metropolitan newspaper article. An on-site investigation and employer interview were conducted by the FACE investigator on August 11, 1994. The California Division of Occupational Safety and Health (Cal/OSHA) Report, medical examiner-coroner's autopsy report, and a report from a private engineering consultant hired by the California Division of Occupational Safety and Health were obtained by the CA/FACE investigator. Photographs of the incident site were also taken by the FACE investigator.

The victims in the incident all worked for a contractor (contractor #1) that performed general well maintenance for the company that owned the oil well. Contractor #1 had been in business for 26 years, and had worked at the incident site for one week. They employed 400 to 500 workers, five at the site of the incident. They employed four full-time safety professionals. The victims had been working for the employer for 1, 6, and 5 years, and all had been working at the incident site for five days.

A second contractor (contractor #2) had been hired by the host company to perform the perforation. There were two workers for contractor #2 at the incident site.

Contractor #1 had an extensive safety program and procedures which covered the hazards of confined space work. According to their employer, the decedents in this incident had received

confined space training. However, their training primarily dealt with tanks as an example of a confined space and did not cover well cellars. Their confined space rescue program did not contain detailed information regarding safety precautions and how they should be followed. No documentation was available which verified training the decedents may have had on unexpected well flow. Workers for Contractor #2 did not have specific training from their employer on how to proceed with a rescue operation involving a confined space.

## INVESTIGATION

The oil well where the incident occurred was being converted into a water disposal well. To convert a well for disposal, initially the ground layers through which the well passes are studied. The history of the wells in the area are reviewed, especially those of wells already converted. An analysis is performed to predict what materials/chemicals may exist in each layer, and whether or not there will be spontaneous flow of those materials from the layer to the surface if a perforation is performed. It is necessary to find a layer that will not have flow for the well to be successfully converted. A layer is identified which can safely contain the waste water. The thickness and depth of the layer is determined, and the well casing(pipe) below that depth is sealed off with a cement plug. The pipe and plug are pressure tested to insure their integrity. Perforation is then performed to create holes in the well casing. These holes allow the water to be disposed to drain from the well casing into the chosen ground layer. During perforation, a device called a gun is lowered into the well casing. At the depth equal to the ground layer into which the water will be pumped, small explosive charges in the gun are set off. These explosions create the holes in the pipe casing.

The well in this incident had been drilled in 1942 but had not been in production since 1982. The well was obtained by the employer in 1993. The previous owner had obtained permission from the California Department of Oil and Gas for the conversion. The employer did not have information about the well's history at the time of the incident. Since the well had been approved for conversion, the personnel at the site expected that there would be no flow.

On the day of the incident a safety meeting took place before work. In this safety meeting, the supervisor from contractor #2 discussed company safety operating procedures for the perforating process. Items discussed in the safety meeting included laying out grounding straps, insuring that the volt meter was on, and that there was no stray voltage. It was also required that signs be posted stating that a perforating operation was taking place. It was not necessary for other contractors to be in the area during the perforating procedure. If there was a problem and workers were needed they would be called in by contractor #2. There was no plan of action if material began flowing from the well.

Perforation began at 7:30 am. Two of the workers from contractor #2 performed their duties on the well platform. The workers from contractor #1 were observing the operation from

nearby. The process was for the loaded gun to be lowered into the well, the charges detonated, and the gun to be raised back up and reloaded. Each cycle of this activity was called a run. After approximately twenty runs, while taking the gun out of the well, one of the workers from contractor #2 noticed water rising up inside the well casing. After the gun had again been lowered into the well, a small stream of water began to leak from an open valve on the well casing in the oil well cellar. The cellar was an enclosed space below the oil well platform where the work was being performed. It was 8 feet wide, 8 feet long, and 9 feet tall. The worker who had originally noticed the rising water brought this to the attention of a petroleum engineer who had been hired by a consultant to the host company to help supervise the operation. Water had been pumped into the well during the process to prepare the well for perforation. Such rise of water can be a temporary phenomenon caused by the work of perforation, or it can be caused by material flow if perforation occurs in an unsuitable ground layer. The worker for contractor #2 was told by the supervising engineer to continue with the perforation . A few runs later, when the workers from contractor #2 began the process of removing the gun from the wellhead for reloading, water began to stream at a greater rate from the open valve. Since the opening of the valve pointed upward, the water shot through an opening in the floor and onto the platform. Workers from contractor #1 moved onto the platform to see what was occurring. They placed a bucket over the stream to keep the water from spraying over the platform. A worker (decedent #1) climbed down rungs set into the wall of the cellar to close the valve with a wrench. Upon entering the cellar this worker collapsed. A second worker (decedent #2) climbed down the rungs into the cellar well to rescue decedent #1 and he also collapsed. A third worker (decedent #3), who had been kneeling on the platform holding the bucket over the stream of water, was overcome and fell into the cellar. Approximately five minutes elapsed from the time the valve began strongly streaming to the time all three victims were unconscious on the floor of the cellar.

Workers from contractor #2 saw the three workers in the well, entered the cellar within two minutes, and pulled them from the cellar floor. None of these rescuers wore any type of personal protective equipment (PPE), nor was any equipment available at the site. Cardiopulmonary resuscitation (CPR) was initiated by the rescuers and continued by fire department personnel who were summoned to the site. Decedent #2 was pronounced dead at the scene while the other two workers were transported to the hospital and pronounced dead one and a half hours later. Four rescue workers were also taken to the hospital and two of those workers were initially in critical condition. All four workers eventually recovered.

Hydrogen sulfide (HS) gas was initially thought to be the cause of the incident, but air sampling showed no evidence for this. Medical tests of the victims were consistent with carbon monoxide (CO) poisoning. Air samples were taken from the well casing four days and seven days after the incident. The samples showed a composition similar to natural gas, but both also contained CO. The sample taken four days after the incident measured 36,000 pm (3.6%), but the sample was analyzed using a technique that was not precise for the circumstances present. The second sample was analyzed using a more precise method and measured 30,000 pm (3.0%) of CO. Two gasoline generators were positioned approximately 50 yards from the oil well, but

neither were operating at the time of this incident. Since carbon monoxide is a product of detonation of some explosives, another oil company conducted air monitoring during perforation operations after this incident. During one such operation involving the same perforating contractor, this other oil company found concentrations of CO up to 500,000 PM in air samples from another well.

At the time of the incident, the standards for the California petroleum industry only required confined space atmospheric testing if the employer had any doubts about whether the space was gas free. According to management officials, carbon monoxide is not normally found in the type of operation being performed in this situation, and so they had no reason to ever monitor for it. They had no knowledge of other oil industry officials doing so either. Since the date of the incident, the confined space standards for the petroleum industry have undergone extensive revision and are the same as in use for general industry.

## CAUSE OF DEATH

The Medical Examiner-Coroner Report lists the cause of death to be asphyxiation by inhalation of carbon monoxide in all three deaths.

## RECOMMENDATIONS/DISCUSSION

**Recommendation #1: Employers should ensure that their Injury and Illness Prevention Programs (IIPP) effectively address all the present and potential hazards of their employees' worksites.**

Discussion: An effective IIPP identifies actual and potential workplace hazards and ensures that employees are informed of and prepared to deal with these hazards. In this incident, some and perhaps all of the workers had known that material might flow from the well during perforation. However, the employer had not prepared the workers to deal with this hazard as demonstrated by the lack of preventive measures taken before the incident and the responses during the incident. Preparation for well flow might have included, reviewing flow hazards with all workers prior to beginning operations, venting of the valve to a site distant from the wellhead, and immediate evacuation of the site when flow occurred. The inadequate training of the workers led to poor site preparation and emergency response, which in turn led to the injuries and deaths. Full implementation of an IIPP should include educating workers about the chances of a particular event occurring, preparing workers to respond to a given risk through classroom and onsite instruction or other methods, and ensuring worker readiness by conducting mock incident drills or using other assessment tools.

**Recommendation #2: Employers should test the atmosphere of confined spaces before any employees are allowed entry.**

Discussion: At the time of the incident, petroleum industry employers were only required to perform confined space atmospheric testing if they suspected that the space might not be gas free, and CO was not known to be a hazard of oil well perforation. Consequently, in this incident, even if the employer had been required to perform pre-entry testing, tests for CO might not have been performed. However, there would have been tests for the presence of $O_2$ and flammable gases. If the concentration of the gas leaking from the well valve was sufficient to lower the partial pressure of $O_2$, or if the presence of flammable gas was detected, the hazard would have been discovered prior to the workers' entry. Because of this incident and adoption of the general industry standard for the petroleum industry with regard to confined spaces, testing of oil well cellars for the presence of CO during perforation should become common practice.

**Recommendation #3: Employers should, if feasible, ventilate confined spaces so that employees are not exposed to hazardous air contaminants.**

Discussion: If ventilation had been used in this incident it might have dissipated the high levels of CO in the well. Under certain conditions, the use of forced air ventilation can enhance the safety and reduce the physical and administrative requirements of confined space entries.

**Recommendation #4: Employers should insure employees are provided and wear approved respiratory equipment when entering confined spaces where there is the presence or suspicion of harmful mists, fumes, or gases, or oxygen deficiency.**

Discussion: In this incident, since no atmospheric testing was performed, the workers initially had no notice of the need for respiratory equipment. Once the first worker collapsed, then all workers subsequently entering the space after atmospheric testing should have been so equipped. Under Title 8 of the CCRs section 5144(a), When and Where to Be Worn, "When it is clearly impracticable to remove harmful dusts, fumes, mists, vapors, or gases at their source, as required in Sections 5141 and 5143, or where emergency protection against occasional and/or relatively brief exposure is needed, the employer shall provide, and the employee exposed to such hazard shall use, approved respiratory equipment."

**Recommendation #5: Employers should insure employees are provided and wear**

**approved safety belts/harnesses and lifelines when entering confined spaces not kept safe through forced air ventilation.**

Discussion: At the time of the incident, petroleum industry workers were not required to wear safety belts with attached lifelines unless they were wearing respiratory equipment or the confined space was in imminent danger of becoming gassy. Since there was no atmospheric testing and there was no expectation of the space becoming gassy, there was no requirement that the first worker should be wearing such equipment. However, all subsequent entrants should have been so equipped. Under Title 8 of the California Code of Regulations, section 5157, except for those spaces kept safe through forced air ventilation, all entrants to confined spaces must be provided and wear some type of harness or wristlet with an attached retrieval line.

**Recommendation #6: Employers should train employees in rescue operations so that in the event of an emergency, workers understand the risks and how to safely avoid them. Employers should provide and keep available equipment for rescue operations.**

Discussion: In this incident, the workers from contractor #1 had not had confined space training specifically geared toward oil well cellars, and workers from contractor #2 had not had confined space rescue training. There was no respiratory protective equipment at the site. This lack of training combined with the lack of rescue equipment was at least partly responsible for the workers failure to use proper confined space rescue protocol; i.e. safety harnesses, lifelines, respiratory protection, standby personnel, etc. This failure to follow proper protocol contributed to the cause of the deaths and injuries. Under Title 8 of the California Code of Regulations, section 5157 Permit-Required Confined Spaces, subsection (g)(1), "The employer shall provide training so that all employees whose work is regulated by this section acquire the understanding, knowledge, and skills necessary for the safe performance of the duties assigned under this section." In addition, under section 5157 (d)(4)(H), "... the employer shall provide the following equipment at no cost to employees, maintain that equipment properly, and ensure that employees use that equipment properly: rescue and emergency equipment needed to comply with subsection (d)(9), except to the extent that the equipment is provided by rescue services."

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## FATALITY ASSESSMENT AND CONTROL EVALUATION PROGRAM

The California Department of Health Services, in cooperation with the California Public Health Foundation, and the National Institute for Occupational Safety and Health (NIOSH), conducts investigations on work-related fatalities. The goal of this program, known as the California Fatality Assessment and Control Evaluation (CA/FACE), is to prevent fatal work injuries in the future. CA/FACE aims to achieve this goal by studying the work environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in fatal injury, and the role of management in controlling how these factors interact.

NIOSH funded state-based FACE programs include: Alaska, California, Colorado, Georgia, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, New Jersey, Wisconsin, and Wyoming.

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**Additional information regarding the CA/FACE program is available from:**

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