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

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

**SUBJECT:** Two Oil Field Mechanics Die in a Pressure Vessel Rupture at an Oil Refinery in California


## *SUMMARY*

**California FACE Report #95CA014**

A 48-year-old male craftsman (victim #1) and a 38-year-old male pipefitter (victim #2) died when a pressure vessel (sulfur recovery unit) ruptured at an oil refinery. The upper stage of the unit had been purged with nitrogen to remove residual hydrogen sulfide ($H_2S$) and sulfur dioxide ($SO_2$). This upper unit was designed to withstand a pressure of 3 pounds per square inch (psi) although the company typically ran the process at 5-7 psi. An operator noted a rise in the upper stage pressure during the purging procedure to over 20 psi. A few hours after beginning to purge the upper stage, members of the maintenance team were sent inside the lower stage to scrape catalyst and shovel the residue into a bucket. Victim #1 and a co-worker climbed through an upper manway to the lower stage. Victim #2 was stationed outside the unit. Victim #1 was crushed to death when the dome which divided the upper and lower stages of the unit collapsed on him. The co-worker working with victim #1 was able to crawl out from the manway and survived. Victim #2 was blown off the platform through a metal guardrail and fell approximately 12 feet to his death. The CA/FACE investigator concluded that in order to prevent similar future occurrences employers should:

- not permit any confined space entry into a vessel while pressurization is taking place in any part of that vessel.
- require that harnesses and retrieval lines be available for workers who are working in confined spaces.
- install a pressure regulator in the purge (nitrogen) line set to no more than the design limits of the vessel (3 psi).
- ensure that pressure relief mechanisms are installed and maintained in all pressure vessels.
- implement a policy that states that any time a vessel is stressed beyond its design limits that an inspection must take place, and clearance given, before any work begins or resumes, or before the vessel is placed back into service.

## INTRODUCTION

On September 7, 1995, two oil field mechanics were killed when a sulfur recovery unit vessel ruptured at an oil refinery. The CA/FACE investigator was notified by the California Department of Health Services (CDHS) on September 7, 1995. The CA/FACE investigator and a Public Health Medical Officer with the CDHS conducted a site visit and employer interview on September 15, 1995. Photographs of the incident site were also taken during the site visit. Further interviews with management and witnesses from the subcontracting firm took place at a later date. The CA/FACE investigator obtained a copy of the sheriff-coroner's autopsy report, the California Division of Occupational Safety & Health (Cal/OSHA) Report, paramedic's report, and the employer's in-house report.

The employer in this incident was a subcontractor who had worked for the oil company since 1971. There were approximately 500 employees working for the subcontractor statewide, with two separate divisions located in northern and southern California. Approximately 100 workers from the subcontractor were at work at the refinery on the day of the incident. Victim #1 had worked for the subcontractor for 20 years and victim #2 had worked for the subcontractor for approximately 18 months. There were 150 mechanics working for the subcontractor statewide at the time of the incident.

Management officials for the subcontractor stated that the work the victims were doing at the time of the incident was work they had done on previous occasions. The only difference between the job they were doing on that day and other similar jobs was that the upper compartment in the vessel was being purged with nitrogen at the time. The subcontractor had written safety rules in place for the job which was being conducted at the time of the incident. There were also two safety officers on staff who worked separate shifts. They each devoted 100% of their time to safety issues. The employees received on-the-job and classroom training. They also viewed videos and studied manuals. The employees were wearing several types of personal protective equipment (PPE) at the time of the incident. This equipment included hardhats, Nomex coveralls, steel-toed shoes, goggles and dust masks. The employees were not wearing safety harnesses/belts or retrieval lines at the time of the incident.

## INVESTIGATION

The refinery where the incident occurred was originally built in 1954 and commissioned in 1955. It has a current operating capacity of 44,440 barrels of high-sulfur crude oil per day. At the time of the incident, the oil company was operating at half capacity. The refinery has dual processing trains ("A" and "B"), with two crude units, two cokers, two amine units, two sulfur units and one tail gas unit. The plant has scheduled turnarounds for general refinery maintenance about every 24 months. The last general turnaround occurred in March 1994, at which time the catalyst had been replaced in the sulfur recovery unit.

The "A" coker plant was undergoing some work on the coke drums, which required a shutdown of the "A" processing train, and reduction in refinery process flow. During a 20-day window while the coker plant was being worked on, the host employer (oil company) decided to take the opportunity of the partial shut down to change the aluminum oxide catalyst in the sulfur recovery unit. The subcontractor had been contracted to perform maintenance work under an umbrella maintenance contract, and had a specific contract for this job. Employees from the

subcontractor were part of the maintenance team. Maintenance workers were on 12 hour shifts, 6:45 a.m. to 6:45 p.m. There were four to five maintenance workers on each shift who were members of the emergency response team. These workers were trained in cardiopulmonary resuscitation (CPR) and first aid on an annual basis.

On the day of the incident, the sulfur recovery unit (see Exhibit 1) was to be cleaned by the maintenance team. The sulfur recovery unit is a two-stage vessel, 25 feet tall and 10 feet wide. It serves to remove sulfur from gas vapor, using the aluminum oxide catalyst. The upper stage is separated from the lower stage by a dome-shaped steel divider, concave downward, welded to a band which is then welded around the interior of the vessel. The catalyst had already been removed from the upper stage of the vessel by a special catalyst removal team, and the upper stage had also been cleaned.

Prior to cleaning the lower stage, direct-reading instruments found residual concentrations of $H_2S$ and $SO_2$ in the upper stage of the vessel. The upper manway on the second stage was partially closed using 4 of the 24 bolts. Subsequently a "purge" of the upper stage was attempted using steam. Afterward, $H_2S$ was still present so it was decided by an operations official that they would attempt a nitrogen purge. All operation personnel worked for the host employer, the oil company. This began at 10:00 p.m. on September 6, 1995. The nitrogen supply was provided to the site by a pipe with a valve supplying 60 psi of pressure. The vessel was designed to withstand 3 psi, although operations management officials stated that it typically operates at 5-7 psi. An operator noted a rise in the upper stage pressure during the purging procedure to over 20 psi. The 60 psi feed line was used during the purge because personnel wanted to finish the purge in a reasonable amount of time. Since the line carrying nitrogen to the vessel was small, a high flow rate could only be attained by using the high pressure line.

At approximately 2:00 a.m. on September 7, 1995, operations and maintenance personnel signed a confined space entry permit for the lower stage. This permit was dated "1/06/95" and was also signed by one of the victims in the incident. The subcontractor had a separate check list which they required be completed prior to entry into a confined space. This checklist contained a series of questions including "Are the current permits on the jobsite correctly filled out?", and "Has the safety harness and lanyard been inspected?"

One maintenance worker climbed into the lower stage through the upper manway, to the screen below, followed by another maintenance worker. They were scraping catalyst and scooping it with shovels into a bucket. They would then hand the bucket up to the worker at the manhole entrance and he would in turn pass it down the line to several other workers for disposal. These other workers were working outside of the vessel on a platform approximately 12 feet off the ground. None of these workers were wearing any type of fall protection. There was, however, a 43" metal guardrail to protect workers from falling.

Another worker (hole watch) was located near the manhole entrance to alert the workers inside if an emergency situation developed. He also had the capability to sound the alarm and to notify operations that an emergency response team should be sent. Air monitors were also located around the vessel to sound an alarm if chemical concentrations were elevated. At 2 a.m. the temperature was 120°F at the manway entrance.

At about 2:41 a.m., a loud noise was heard, and workers called for help. The dome dividing the two stages had collapsed down into the lower stage. Victim #2, who had been collecting the buckets with catalyst residue, was at the entrance of the manway. He was blown off the platform and through a metal guardrail falling approximately 12 feet to his death. The dome dividing the stages fell with the leading edge toward the north end of the plant, crushing victim #1 inside the vessel. The other worker inside the vessel was able to crawl out of a lower manway.

Entry into this confined space did not require a retrieval line for non-entry rescue if it would not contribute to the rescue of the entrant or if it presented an entanglement hazard. Oil company officials stated that they had determined that retrieval lines would be in the way of workers climbing and working under the screen to remove the remaining catalyst.

First responders were from the Emergency Response Team (Fire Brigade) at the refinery. The incident commander was the shift supervisor. The body of victim #1 was not removed immediately due to concern about possible $H_2S$ contamination. After further efforts to purge the combined chamber of the two stages, the body was extricated at 4:30 p.m. on September 7, 1995. Three other maintenance workers were taken by ambulance to the hospital emergency department. One worker, who had been trapped in the vessel, was hospitalized for several days with an inner peritoneal bleed, torn spleen, and respiratory symptoms. He was released from the hospital with no further evidence of internal bleeding on Tuesday, September 12, 1995. The other two survivors were treated for eye abrasions and released from the emergency department on the morning of September 7, 1995.

## CAUSE OF DEATH

The Sheriff-Coroner's Autopsy Report stated the cause of death for victim #1 to be multiple cranial, thoracic and abdominal injuries including open cranial trauma due to crushing blunt force trauma. The cause of death for victim #2 was stated to be multiple thoracic injuries due to blunt force trauma and secondarily to extensive thermochemical burns with contusions.

**RECOMMENDATIONS/DISCUSSION**

**Recommendation #1: Employers should not permit any confined space entry into a vessel while pressurization is taking place in any part of that vessel.**

Discussion: In this incident, the members of the maintenance team were allowed entry into the lower compartment of the sulfur recovery vessel while pressurization was taking place in the upper chamber of the vessel. Although this operation had been conducted on numerous occasions in the past, workers had never been asked on those earlier occasions to enter the vessel while the upper compartment was being purged. The pressurization of the upper vessel caused the dome divider to collapse which in turn resulted in the death of victim #1. A clause in the company's confined space operating procedures could address situations such as this. Such a clause could forbid entry into a confined space during purging operations. Under Title 8 of the California Code of Regulations (CCRs) section 5189 (f)(1)(A)(1)(2)(3), "Operating Procedures; (1) The employer shall develop and implement written procedures that provide clear instructions for safely conducting activities involved in each process consistent with the process safety information and shall address at least the following. 1. Start-up; 2. Normal operation; 3. temporary operations as the need arises."

**Recommendation #2: Employers should require that retrieval lines and harnesses be available for workers who are working in confined spaces.**

Discussion: In this incident, the victims were not wearing safety harnesses or retrieval lines. The employer stated that retrieval lines would have gotten in the way of the work the victims were doing at the time. The employees should have been wearing harnesses, however, so in the event of an entry-required rescue, a retrieval line could be quickly attached. The retrieval lines should, however, always be present at the entrance to a confined space, along with other required rescue equipment. In the event of a rescue situation, trained rescue workers would, therefore, have quick access to the equipment for use in rescue operations.

**Recommendation #3: Employers should install a pressure regulator in the purge (nitrogen) line set to no more than the design limits of the vessel (3 psi) or stop the pressure when it reaches the limits of the design of the vessel.**

Discussion: In this incident, the pressure in the vessel had been noted by an operator to be over 20 psi at one point during the purging operation. This incident may have been avoided if a company standard operating procedure (SOP) had been developed which required that all operations be halted when over pressurization occurs in any vessels.

**Recommendation #4: Employers should ensure that pressure relief mechanisms are installed and maintained in all pressure vessels.** Discussion: The sulfur recovery unit was not equipped with a safety relief device, such as a valve, when the vessel was blinded and purged with nitrogen gas. Because no pressure relief device was installed, the sulfur recovery unit was pressured by the introduction of the nitrogen to nearly seven times the unit's design limit. A pressure relief mechanism could have vented excess pressure to prevent overpressurization of the unit. Since dangerous gases, specifically hydrogen sulfide, were a by-product of this sulfur

recovery process, the unit could have been vented to an approved flare stack rather than to the atmosphere. Title 8 of the California Code of Regulations, section 6857 (j) (1) states: "all pressure vessels shall be protected by a pressure relief device. Such relief devices shall be set to prevent the pressure in the vessel from exceeding limits established by the ASME code or, where permitted, the Pressure Vessel Safety Orders, and shall prevent the pressures from rising above limits set by ASME code. Pressure vessels which are connected together in a system with piping not containing valves which can isolate any pressure vessel while connected to its source of pressure may be considered as one unit." This incident may have been prevented if, during the introduction of nitrogen gas during the purging operation, the pressure had not been able to build to levels well beyond the design limits of the sulfur recovery unit.

**Recommendation #5: Employers should implement a policy that states that any time a vessel is stressed beyond its design limits that an inspection must take place, and clearance given, before any work begins or resumes, or before the vessel is placed back into service.** Discussion: In this incident, oil company officials stated that although the sulfur recovery unit vessel had been designed to withstand only 3 psi, the average pressure in the vessel was 5-7 psi. Repeated use of the tank at a pressure above that for which it was designed may have caused weakening of the tank and led to the dome collapse. Employers should periodically review the use of all pressure tanks, to ensure that they are not being used in a fashion that exceeds their specifications.

**References**

Barclays Official Code of Regulations, Vol. 9, Title 8, Industrial Relations. South San Francisco, CA, 1990.

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**FACE Project Officer**

**September 23, 1996**

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## FATALITY ASSESSMENT AND CONTROL EVALUATION PROGRAM

The California Department of Health Services, in cooperation with the Public Health Institute and the National Institute for Occupational Safety and Health (NIOSH), conducts investigations of 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, Iowa, Kentucky, Massachusetts, Michigan, Minnesota, Nebraska, New Jersey, New York, Oklahoma, Oregon, Washington, West Virginia, and Wisconsin.

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

**California FACE Program**
**California Department of Health Services**
**Occupational Health Branch**
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