CASE STUDY

Confined Space Entry - Worker and Would-be Rescuer Asphyxiated

No. 2006-02-I-DE

November 2, 2006

Valero Energy Corporation Refinery
Delaware City, DE
November 5, 2005

This Case Study describes the Valero Delaware City refinery asphyxiation death of two contractor employees who were preparing to reassemble a pipe on a pressure vessel while it was being purged with nitrogen. The first worker, in an attempt to retrieve a roll of tape from inside the vessel, was overcome by nitrogen, collapsed in the vessel, and died. His co-worker, the crew foreman, was asphyxiated while attempting to rescue him.

The CSB issues this Case Study to reemphasize nitrogen hazard awareness and safe work practices when working in or adjacent to confined spaces.

KEY ISSUES:

- Oxygen-deficient Atmosphere Hazards Outside Confined Space Openings
- Nitrogen Hazard Awareness
- Unplanned Confined Space Rescue

INSIDE . . .

1.0 Incident Description

This Case Study examines the November 5, 2005, nitrogen asphyxiation death of two Matrix Service Industrial Contractors, Inc. (Matrix) employees at the Valero Energy Corporation (Valero) refinery in Delaware City, Delaware. Matrix was contracted by Premcor, Inc.,[1] the previous owner of the refinery, to serve as the primary maintenance contractor during the fall 2005 maintenance turnaround (unit shutdown).

Nitrogen, which makes up 78 percent of the air we breathe, is non-toxic. The normal oxygen concentration in air is about 21 percent. Nitrogen is frequently added to process equipment to significantly reduce the oxygen concentration inside. This oxygen-depleted atmosphere inside the equipment is hazardous because there is not enough oxygen to support life (Table 1). Furthermore, an oxygen-depleted, hazardous atmosphere might be present outside the equipment near unsealed equipment openings.

A few days before the incident, Matrix installed a temporary nitrogen supply system on the hydrocracker unit[2] reactor (R1). The Valero operators opened the nitrogen valve “about one or two turns” to provide a nitrogen purge[3] inside R1 as part of the catalyst loading procedure. The nitrogen flowed slowly out of the reactor through the top manway (Figure 1), the only open discharge point on the reactor.

The nitrogen purge in the reactor continued to protect the newly loaded catalyst from reacting with oxygen in the air[4] until emergency responders closed the nitrogen supply valve the night of the incident. However, contrary to the Valero refinery safety procedures, a nitrogen purge warning sign and barricade were not in place in the work area.

Two days before the incident, workers employed by Catalyst Handling Services Corporation (CHSC), the catalyst contractor, finished loading the reactor with the new catalyst and placed a temporary plastic tarp and wooden cover over the open manway to prevent moisture and debris from falling into the reactor. They also attached a confined space warning sign to the studs surrounding the opening. About five hours before the incident, a CHSC foreman wrapped red "danger" tape around the studs.

Figure 1. Plastic sheet and plywood disk on R1 manway. Red "danger" tape on the studs alerted workers of the unsecured confined space access opening.

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[1] Premcor Refining Group Inc., the operator of the Valero Delaware City refinery, is a wholly owned subsidiary of Valero Energy Corporation.

[2] The hydrocracker unit converts heavy oil fractions to lighter molecular structure hydrocarbons using high pressure hydrogen and catalysts.

[3] Purging is the process of pumping inert gas, such as nitrogen, into pressure vessels, pipes, and other equipment to remove oxygen or other hazardous gases.

[4] The inert nitrogen atmosphere was required to protect the new catalyst from exposure to oxygen until the reactor was resealed.

Table 1. Effects of oxygen deficiency on the human body.

Percent Oxygen	Physiological Symptoms
23.5	Maximum “safe level’
21	Typical oxygen concentration in air
19.5	Minimum safe level
15 - 19	First sign of hypoxia. Decreased ability to work strenuously. May induce symptoms in persons with heart, lung, or circulatory problems
12 - 15	Respiration increases with exertion, pulse up, impaired muscular coordination, perception, and judgment
10 - 12	Respiration further increases in rate and depth, poor judgment, blue lips
8 - 10	Mental failure, fainting, unconsciousness, ashen face, blue lips, nausea, vomiting, inability to move freely
6 - 8	Six minutes–50% probability of death Eight minutes–100% probability of death
< 6	Coma in 40 seconds, followed by convulsions, respiration ceases, death

Source: *Hazards of Nitrogen and Catalyst Handling*, Institution of Chemical Engineers, 2004

To begin work on the hydrocracker unit, a Valero hydrocracker unit operator issued a safe work permit to a Matrix nightshift boilermaker crew to "install [the] top elbow," or pipe assembly, on R1.[5] The operator told the Chemical Safety Board (CSB) investigators that he and the Matrix foreman agreed that the crew would only set up the work area, and that the foreman would return to the control room after lunch to get a new permit to perform the installation work. However, the permit was not amended to limit the work to “set up only.” Furthermore, the nitrogen purge status was marked “N/A” on the permit even though the reactor continued to be purged with nitrogen.

At about 11 p.m., two Matrix boilermakers removed the wooden cover and plastic tarp and cleaned the manway flange surface, a prerequisite to reinstalling the pipe assembly (Figure 2).

[5] The top elbow assembly included the 12-inch diameter process pipe mating flange; 12-inch diameter pipe and elbow; and 24-inch manway mating flange (See Figure 2).

Figure 2. Pipe assembly connects 12-inch diameter process pipe to the reactor top manway (photo taken after the incident).

While the boilermakers were cleaning the manway flange surface, a Matrix pipefitter told them that a roll of duct tape was lying on the distribution tray[6] (Figure 3) about five feet below the opening. The boilermakers knew that reactor cleanliness criteria prohibited leaving the tape inside the reactor, so they discussed retrieval options with their foreman.

They considered entering the reactor to retrieve the tape, but knew entry would require a specially trained and equipped crew and confined space[7] entry permit,[8] which would delay their work, possibly beyond the end of their work shift. Instead, they decided to make a long wire hook (Figure 4) and lower it through the manway to retrieve the tape.

A few minutes before the incident, nearby workers saw the first victim standing next to the studs surrounding the open manway trying to retrieve the tape with the wire. One worker saw him kneeling next to the studs while he worked with the wire. Nobody saw him enter the nitrogen-filled reactor, but he either fell in or intentionally went into the reactor.

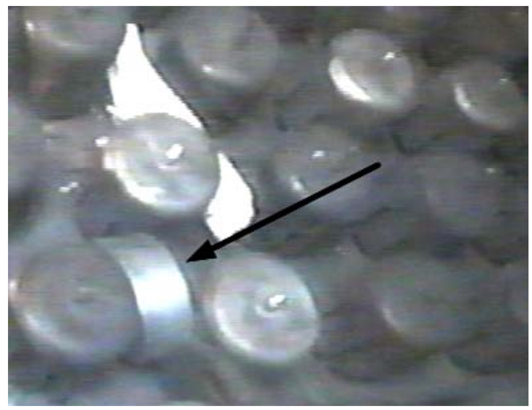

Figure 3. Roll of duct tape on the top distribution tray inside reactor R1 (photo taken after incident).

An eyewitness working on the platform of an adjacent reactor saw the boilermaker foreman (the second victim) and the nightshift contract administrator looking through the manway into R1. The eyewitness watched the foreman hurriedly grab a ladder, insert it into the reactor, and immediately climb down.

The eyewitness next saw the nightshift contract administrator approach the ladder, hesitate, and then heard him urgently call for help on his radio. The site emergency siren then activated.

Valero Emergency Response Specialists and Matrix safety personnel arrived on the platform in less than two minutes, and saw two victims lying motionless inside the reactor on the tray five feet below the manway. They inserted an oxygen meter

[6] A tray is a perforated platform installed inside a reactor used to support catalyst material and/or distribute the process fluid.

[7] A confined space is a space that is not designed for continuous occupancy and has restricted means for entry or exit, but is large enough and configured such that an individual can enter and perform assigned work (OSHA, 1994).

[8] Permit-required confined space access control prohibits breaking the plane of the confined space entry point with any part of the body without first obtaining an entry permit and applying proper safety prerequisites (OSHA, 1994).

through the manway and it immediately alarmed—the oxygen concentration was near zero.

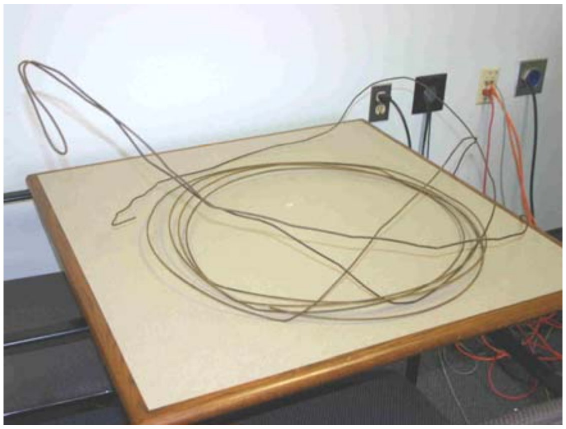

Figure 4. Fifteen foot wire with hook formed on end used by the first victim to retrieve the duct tape.

A Valero operator put on his self-contained breathing air respirator then entered the reactor to help the two victims. An Emergency Response Specialist asked a contractor loading catalyst into the adjacent reactor to put on his supplied breathing air helmet[9] and climb down the ladder into the reactor to help the operator.

Because the manway opening was only 24 inches and the victims were not wearing safety harnesses, recovering them from the reactor was very difficult. Rescue workers wrapped a confined space recovery tripod[10] hoist cable around each victim, and lifted them out one at a time. In spite of the quick arrival of the emergency responders, the two victims were deprived of adequate oxygen for nearly ten minutes.

Once on the work platform, an emergency medical technician examined each victim; however, both were unresponsive and efforts to revive them unsuccessful. They were carried down the platform stairs to the waiting ambulance and transported to the hospital where they were pronounced dead.

[9] The contractor was fully qualified and equipped to work in an inert gas environment.

[10] A recovery tripod is a portable, hand-operated hoist used to lift victims out of a confined space.

2.0 Companies Involved

2.1 Valero Energy Corporation

Valero owns 18 refineries with a total throughput capacity of approximately 3.3 million barrels of crude oil per day (BPD). It acquired the Delaware City refinery from Premcor Refining Company, Inc. (Premcor) in September 2005, along with three other refineries, making Valero the largest North American refiner. The Delaware City refinery processes 180,000 BPD at the 5,000-acre complex and has about 570 employees.

Prior to Valero taking ownership of the refinery, Premcor contracted with Matrix and other companies to perform the fall 2005 maintenance turnaround.

During the turnaround, Valero refinery unit operators retained responsibility for unit shutdown, control and removal of hazardous chemicals from equipment, and equipment lock-out and tag-out. Valero operators prepared, reviewed, and approved all contractor work permits, including safe work, hot work, and confined space access control, in accordance with the Valero site procedures.

Valero also assigned a contract administrator[11] to each turnaround work shift. The dayshift and nightshift contract administrators were responsible for expediting the work, reporting progress to the Valero turnaround manager, monitoring safety and health issues, and coordinating the work among the turnaround contractors.

2.2 Matrix Service Industrial Contractors, Inc.

Matrix, a division of Matrix Service Company, specializes in providing maintenance and turnaround services to the petroleum refining industry nationwide. Matrix was contracted to provide pipefitters, boilermakers, and other skilled labor needed for the turnaround.

Matrix and the other contractors were responsible for providing skilled craftspeople with general industrial and refinery-specific safety training. Contractors were required to incorporate all Valero refinery safety policy requirements in their safety procedures.

Matrix was responsible for preparing written work permit requests for the assigned tasks, submitting them to the Valero unit operators, and reviewing the scope of each permit and listed safety prerequisites with the Valero permit preparer.

After the work permits were approved by a Valero unit operator, the Matrix boilermaker foremen reviewed the permit with the assigned work crew before starting the activity.

[11] The dayshift and nightshift contract administrators were employees of other outside contractors hired by Premcor to support the maintenance turnaround.

3.0 Incident Analysis

3.1 Pre-job Planning

The Matrix work crew and the Valero unit operators were required to have "mutual understanding" of the task[12] before the work could proceed. The Valero safe work permit procedure also required a Valero unit operator and a representative of the work crew, usually the foreman, to jointly visit the jobsite before approving the permit. The jobsite visit was intended to examine the work area and review the planned work tasks to clearly identify all known or suspected hazards and safe work prerequisites.

Contrary to the procedure requirement, the work permit issued to the Matrix boilermaker foreman on November 5, 2005 to install the pipe assembly was approved without first conducting this safety-critical jobsite visit.

The Matrix foreman was then required to obtain "mutual understanding" with all the crew members before starting the work. Each crew member acknowledged understanding of the work and safety prerequisites by signing the back of the permit.

Two permits were issued to Matrix for the pipe assembly work on R1. The Matrix pipefitter crew[13] was responsible for reassembling the 12-inch flange to the process pipe (Figure 5, flange A). The work description on the permit limited the pipefitters to "set up [the] job," which in this case meant taking tools and equipment up to the platform work area. Their permit correctly informed them of the continuing nitrogen purge.

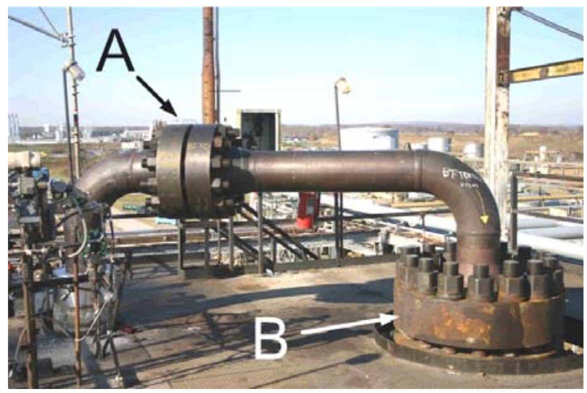

Figure 5. Top elbow pipe assembly includes 12-inch flange (A) and 24-inch manway flange (B).

But by designating an activity "set up only," operators do not typically specify "fresh air" breathing equipment and air monitoring, even if the workers might be exposed to a hazardous atmosphere. The pipefitters and boilermakers would be working near the venting nitrogen, so both safe work permits should have been designated "fresh-air" work areas, regardless of any restricted work activities.

Unlike the pipefitters' work permit, the boilermakers' safe work permit did not inform them that the reactor was on nitrogen purge. Furthermore, it did not restrict them to "set up only," even though the Valero permit preparer told the CSB investigators that he and the boilermaker foreman (the second victim) had agreed to that limitation when they discussed the permit.

[12] Mutual understanding requires the unit operator and work crew to review the permit, jointly visit the jobsite, and understand the conditions, limitations, and precautions of the permit.

[13] By Union agreement at the Valero refinery, pipefitters performed the maintenance work on piping and piping components, such as pipe-to-pipe bolted flanges. Boilermakers performed the maintenance work on the pressure vessels, including the bolted flanges that connect the pipe to the vessel.

With no specified restrictions, the permit allowed the boilermakers to perform all the assigned work, including lifting and setting the five-ton assembly onto the manway and reinstalling the stud nuts and washers (Figure 5, flange B).[14]

As the lunch break neared, the boilermaker foreman was told that the crane being used by the catalyst handling crew at the adjacent reactor had become available. The foreman and the contract administrator decided to take advantage of the crane availability since both the dayshift and nightshift contract administrators had been told that Valero management wanted the pipe installation work completed and the reactor sealed before the end of the night shift.

The boilermaker foreman then told his crew that they would have to work through the lunch break to get the pipe installed before the catalyst handling crew needed the crane back.

3.2 Initial Vessel Entry

Before the pipe installation could begin, however, the boilermaker crew needed to retrieve the roll of duct tape from inside the reactor.[15] Eyewitnesses told the CSB investigators that the first victim tried several times to retrieve the tape with the fabricated long wire hook. He tried from a standing position next to the manway and then, apparently to get closer, tried kneeling on the platform next to the manway. Each time, however, he was unable to hook the tape and remove it from the reactor.

The CSB concluded from the physical evidence, including the autopsy report, size of the reactor manway opening, and tall studs surrounding the opening, that it was extremely unlikely for the first victim to have fallen into the reactor from either the standing position directly over, or next to the manway, or while kneeling next to the manway (Figure 6). However, if he stepped over the studs, sat down, and dangled his legs inside the reactor he could pass through the manway.[16]

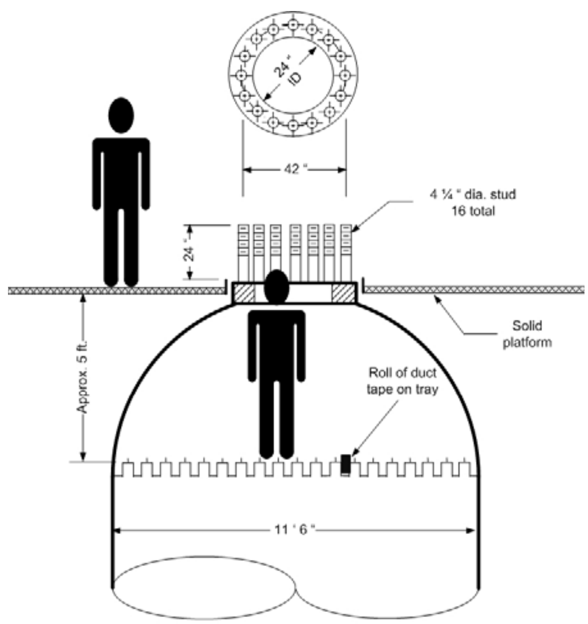

Figure 6. Reactor R1 work platform (figures approximately to scale).

Although nobody saw him go into the reactor, the CSB concluded that the first victim likely stepped over the manway studs and then sat on the narrow ledge (Figure 7). From this position, he might finally be able

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[14] The Matrix crew also needed a final closure permit. The permit required a final reactor cleanliness inspection and acceptance by a Valero representative prior to placing the pipe assembly on the reactor manway.

[15] The Valero equipment closure procedure required a Valero operator to visually verify cleanliness inside the reactor and approve a "closure permit" before the crew could install the pipe.

[16] Both victims knew that a confined space entry permit was required before breaking the plane of the manway with any part of the body.

to retrieve the roll of tape lying on the tray only five feet below him with the flexible wire hook.

With both legs through the opening,[17] two reactor entry scenarios are possible: unintentional entry after becoming disoriented or losing consciousness from oxygen deprivation or simply slipping off the narrow ledge, or intentional entry. Eyewitness accounts and physical evidence were insufficient to establish which scenario was more likely.

3.2.1 Unintentional Reactor Entry

The nitrogen purge gas was slowly venting out of the reactor through the manway. Weather data confirmed eyewitness accounts that the air was very calm, so the nitrogen purge gas may have accumulated above the manway, reducing the oxygen concentration outside the confined space access opening to an unsafe level.

From the sitting position, and possibly leaning with one arm inside the reactor to get as close to the tape as possible, the first victim could have been exposed to an oxygen-deficient atmosphere above the opening. Then, without warning, he could have become disoriented or lost consciousness from oxygen deprivation (see Table 1) and slid into the reactor. He might also have lost his grip and simply slid off the narrow ledge and into the reactor.

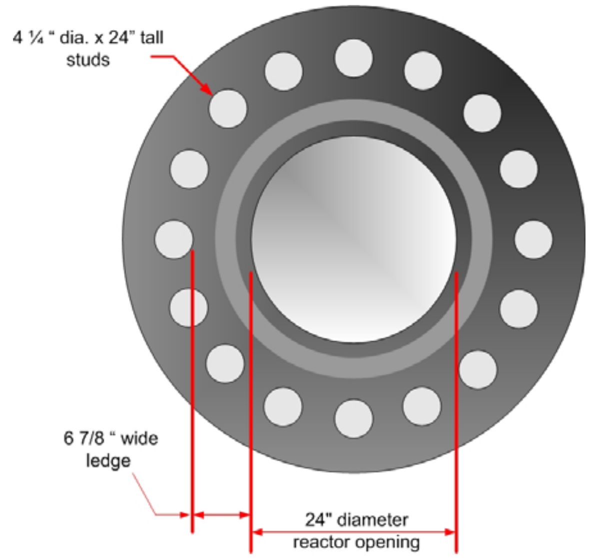

Figure 7. The first victim most likely sat on the narrow reactor manway ledge between the studs and the opening to get closer to the tape.

3.2.2 Intentional Reactor Entry

The other scenario is that the first victim may have purposely entered the reactor to retrieve the tape. After several unsuccessful attempts to retrieve the tape with the wire hook, he could have lowered himself inside the vessel, intending to quickly grab the tape then climb out.

In this scenario, he would have needed his co-worker (the second victim) to help him get out, probably by inserting the nearby ladder, as the five-foot distance down to the tray prevented him from climbing out through the 24-inch manway unaided (see Figure 6). However, unless he held his breath, he would collapse from a lack of oxygen within one or two breaths when he reached down to grab the tape.[18]

[17] Passing completely through the manway without getting caught by the studs or wedged in the opening is highly unlikely unless both legs were first dangled inside the reactor.

[18] In addition to the nitrogen purge gas flowing through the manway, his body displaced much more nitrogen out of the manway and around his head as he went in.

3.3 Failed Rescue Attempt

The crew foreman working with the first victim on the platform most likely saw him collapse on the tray immediately after he was inside the reactor. Had the foreman applied his emergency response training, he would have immediately announced the emergency on the radio and remained on the platform, safely away from the manway until qualified emergency response personnel arrived. However, eyewitness testimony confirmed that the foreman grabbed a nearby ladder, shoved it down the manway, and quickly climbed in the reactor.

Within a few breaths the foreman was the second victim to succumb to oxygen deprivation. His desire to help his co-worker overwhelmed his refinery work experience, safety training, and proper emergency response protocols.

All too often, and as this case illustrates, would-be rescuers[19] become victims. One study reports that of 88 total confined space entry fatalities, 34 workers (39 percent) died while attempting to rescue a co-worker (*Journal of Safety Research*, 1990). Another study reports that in eight incidents documented over 18 months, ten rescuers died during rescue attempts. In two of the eight, the victim survived but the rescuer died (NIOSH, 1986).

The CSB noted in the *Hazards of Nitrogen Asphyxiation* Safety Bulletin, "One of the most difficult issues concerning hazardous atmosphere emergencies is the human instinct to aid someone in distress" (USCSB, 2003).

3.4 Nitrogen Hazard Awareness Training

Training records and worker interviews confirmed that the two victims were likely aware that nitrogen can be an asphyxiation hazard. The first victim had nearly ten years experience working in refineries; the second had more than 25, and had provided hazard awareness training to many co-workers throughout his career.

In addition, Valero and Matrix employees were provided hazard awareness and confined space training that addressed the confined space nitrogen asphyxiation hazard. However, the Valero and Matrix workers interviewed by the CSB investigators stated that their training did not address the possibility that an oxygen-deficient atmosphere might be present outside the confined space near the access opening.

While industry publications[20] do address the confined space nitrogen asphyxiation hazard, the CSB found that neither the industry safety guidelines nor the Valero corporate guidelines, site procedures, or associated training material adequately address the risk of asphyxiation caused by possible nitrogen accumulation outside the confined space during a nitrogen purge.

This risk, asphyxiation outside the confined space, is not broadly recognized to be a hazard to workers. The OSHA "Permit-

[19] The term "rescuer" means a co-worker or other individual who tries to aid someone in distress without first ensuring their own safety. "Emergency responders" are trained and qualified individuals who apply proper safety precautions during rescue or recovery.

[20] *Accident Prevention in Oxygen-Rich and Oxygen-Deficient Atmospheres* (CGA, 1992) and API Standard 2217A, *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries* (API, 2005).

Required Confined Space" standard (OSHA, 1994) specifically addresses hazards associated with inerting gases "such as nitrogen" inside a confined space. The National Institute of Occupational Safety and Health (NIOSH) and the American Society of Safety Engineers (ASSE) publish safety guides for confined space work. These publications thoroughly address precautions and warnings involving nitrogen asphyxiation inside a confined space. However, they do not adequately warn of the possible asphyxiation hazard outside, near the access opening.

The CSB Safety Bulletin, *Hazards of Nitrogen Asphyxiation,* warns:

> When fatalities and injuries occurred in 'open areas,'…the hazard of asphyxiation was not expected and personnel were typically caught off guard.

It also stresses that comprehensive training programs should include precautions when working around open equipment.

The publication, *Hazards of Nitrogen and Catalyst Handling* (IChemE, 2004), also addresses the hazard of nitrogen asphyxiation for workers around open manways. This booklet, which warns that nitrogen is "one of the most dangerous gases found in refineries and chemical plants," recommends installing warning barriers and oxygen monitors/alarms in areas around open manways that may pose an asphyxiation hazard to workers.

3.4.1 Acute Oxygen Deprivation Rapidly Overwhelms Victims

The Valero and Matrix worker training did not emphasize that equipment containing concentrated nitrogen purge gas (oxygen content less than about 10 percent) quickly overcomes the victim without warning (See Table 1). After only one or two breaths the oxygen concentration in the blood drops dangerously low, and the victim is likely to lose consciousness in less than 60 seconds (U.S. Air Force, 1995). Death occurs within a few minutes.

Both the rescuer's attempt to help his co-worker, and the possible intentional reactor entry by the first victim, suggest that some workers may believe that they can hold their breath long enough to enter an oxygen-deficient atmosphere and return to safety before being overcome. Workers might mistakenly conclude that they can hold their breath while inside the reactor, similarly to their ability to hold their breath when they swim underwater.

Swimmers are acutely aware that inhaling water causes sudden, uncontrollable coughing. This is a powerful stimulus that helps a swimmer resist the body's breathing reflex even after being submerged for a long time. But nitrogen, which is odorless, tasteless, and colorless, provides no stimulus to voluntarily resist the breathing reflex. In a highly emotional and physically demanding emergency, it is extremely unlikely that a person would hold their breath.

Furthermore, workers may be unaware of another dangerous complication: inhaling nitrogen or other inert gas suppresses the brain's breathing reflex response. The breathing reflex is controlled primarily by the amount of carbon dioxide in the blood rather than the shortage of oxygen. Normally, the ability to voluntarily hold one's breath is eventually overwhelmed by the brain's respiratory control center, which is triggered by the increased carbon dioxide concentration in the blood, combined with a drop in the blood's pH. If high-purity nitrogen or other inert gas is inhaled, the body may simply stop breathing, as carbon dioxide accumulation in the blood is insufficient to stimulate the breathing reflex (Lumb, 2005).

3.5 Nitrogen Safe Work Procedures

The Valero refinery has safe work procedures for using nitrogen, but they were inadequately implemented the night of the incident. The procedures required operators to install a barricade and post warning signs at all equipment access points (Figure 8) before the nitrogen purge was started, and to list all personnel working inside the barricaded area using a controlled area entry log. The barricade and control log were not used at the R1 manway the night of the incident, even though the reactor was on a nitrogen purge that vented directly onto the work platform area.

Figure 8. Nitrogen-purge controlled area barricade and warning installed on the R1 platform after the incident.

The Valero site fresh-air work procedure[21] applies to "known or suspected areas containing atmospheres that are immediately dangerous to life or health (IDLH)…."[22] However, the Valero permit-preparer did not specify this precaution on either the boilermaker crew's or the pipefitter crew's safe work permit, even though the workers might be exposed to an oxygen-deficient IDLH atmosphere caused by the nitrogen flowing out of the open manway.

The CSB also noted that the Valero permit-preparer was inconsistent in preparing the work permits for the two crews. The work permit issued to the pipefitter crew correctly checked the "nitrogen purge or inerted" box "yes" for the flange reassembly setup. The boilermakers, on the other hand, would need to work very close to the open manway (Figure 9) where the nitrogen was venting from the reactor, possibly exposing them to unsafe oxygen levels.

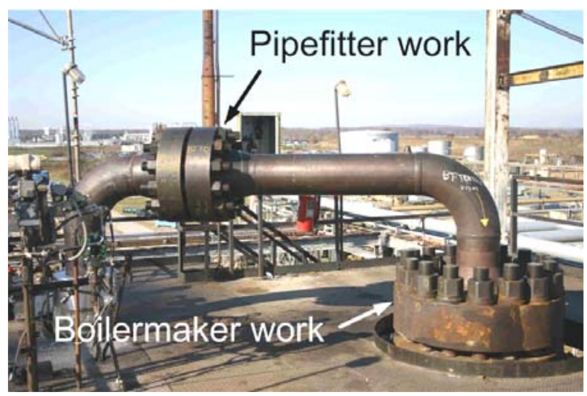

Figure 9. Pipefitters assembled 12-inch pipe flange, boilermakers assembled 24-inch manway flange.

[21] Valero procedures required workers to use self-contained breathing equipment or continuous fresh-air supplied breathing equipment and continuous air monitoring in all fresh-air designated work areas.

[22] Immediately dangerous to life or health (IDLH) means any condition that poses an immediate or delayed threat to life, or that would cause irreversible adverse health effects, or that would interfere with an individual's ability to escape unaided from a permit space (OSHA, 1994).

However, the permit preparer marked the nitrogen purge box "N/A." Furthermore, he did not specify "fresh-air required" on their permit, even though the purge would continue throughout the pipe assembly work.

3.6 Permit-Required Confined Space Procedures

The Valero site procedure for permit-required confined space entry required all open, permit-required confined space access points to be clearly identified with a warning sign (Figure 10).[23]

The boilermaker assigned to reinstall the pipe on R1 stated that shortly before the incident, he and his co-workers, the two victims, discussed the safe work procedure requirements and restrictions[24] when they discussed options for removing the roll of tape from the reactor. The CSB concluded that he and the victims knew a confined space entry safe work permit would be required if they could not retrieve the tape with the wire hook.

Figure 10. Typical sign used to identify unsecured confined space access opening.

[23] The wooden cover qualified only as "a temporary barrier that will prevent an accidental fall through the opening…" (OSHA, 1994).

[24] The pipe spool reinstallation work did not involve entry into the reactor, so neither crew required confined space entry permits.

Although he stated that he believed the two victims knew that the reactor was on a nitrogen purge, there was insufficient evidence for CSB to determine if the two victims had direct knowledge of the nitrogen purge.

3.7 Industry Guidelines

The American Society of Safety Engineers (ASSE) and the American Petroleum Institute (API) publish guidelines addressing inert gas safe work practices. Confined space entry safe work practices are also widely published (see References). However, the CSB concluded that these publications inadequately address three critical elements associated with inert gas purging:

- Hazardous (oxygen-depleted) atmospheres may be present outside the confined space, near openings.
- Acute oxygen deprivation rapidly overwhelms the victim, without warning.
- Unprotected entry into an oxygen-depleted atmosphere for any length of time, no matter how brief, can be deadly.

3.8 Regulatory Analysis

OSHA standard 1910.146, *Permit-Required Confined Spaces,* includes requirements for planned, safe entry into a confined space. According to the standard, if the workplace contains permit-required confined spaces (temporary or permanent), the employer must inform exposed employees and contractors of the existence, location, and the danger posed inside the confined spaces. Hazards that might exist outside the confined spaces are beyond the scope of this standard.

The employer is also required to post danger signs (Figure 11) or other equally effective means to identify the hazard [§146(c)(2)]. In this incident, the red tape was the only warning on the manway—no warning sign was in place at the time of the incident.

Figure 11. Confined space warning sign on the unsecured reactor manway after the incident.

The OSHA standard contains additional requirements for an unsecured manway: "When entrance covers are removed, the opening shall be promptly guarded by a railing, temporary cover, or other temporary barrier that will prevent an accidental fall through the opening…." [§146(c)(5)(ii)(B)]. In this incident, fall protection was provided by the wooden cover.

However, the wooden cover was not intended to, and did not prevent the nitrogen from venting out of the manway. Furthermore, the OSHA confined space standard does not specifically address situations where atmospheric hazards may be present directly outside a confined space access opening.

4.0 Other Nitrogen Hazard Reports

In 1998, the CSB published a summary report of the nitrogen asphyxiation death of a worker and serious injury to a second worker at a chemical manufacturing plant near New Orleans, Louisiana (USCSB, 1998). In that incident, workers draped a black plastic sheet over the end of a 48-inch diameter pipe to perform a black-light inspection of the pipe. Nitrogen was being pumped into the system upstream of their work location to prevent oxygen contamination inside the piping and process equipment. Nitrogen was venting out of the open pipe where they were working.


U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

SUMMARY REPORT

NITROGEN ASPHYXIATION
(1 DEATH, 1 INJURY)

UNION CARBIDE CORPORATION
Hahnville, Louisiana
March 27, 1998

KEY ISSUES:

- USE OF NITROGEN IN CONFINED SPACES
- SAFETY OF TEMPORARY ENCLOSURES

REPORT No. 98-05-I-LA

The plastic tarp they installed over the pipe opening created an enclosed space where the accumulating nitrogen displaced the oxygen in the air they were breathing. Unaware that oxygen was being displaced by the flowing nitrogen, they were overcome and collapsed.

Concerned with continuing fatalities and serious injuries involving nitrogen use, the CSB conducted a study of asphyxiation incidents involving nitrogen. The Safety Bulletin, *Hazards of Nitrogen Asphyxiation* (USCSB, 2003), summarizes the results of the CSB study and emphasizes the hazards associated with using nitrogen and other inerting gases. It includes a list of "good practices" that should be implemented whenever using inert gases or supplied breathing air systems, and when working in or near confined spaces.


Safety Bulletin

U.S. Chemical Safety and Hazard Investigation Board

HAZARDS OF NITROGEN ASPHYXIATION No. 2003-10-B | June 2003

Introduction

Every year people are killed by breathing "air" that contains too little oxygen. Because 78 percent of the air we breathe is nitrogen gas, many people assume that nitrogen is not harmful. However, *nitrogen is safe to breathe only when mixed with the appropriate amount of oxygen.*

These two gases cannot be detected by the sense of smell. A nitrogen-enriched environment, which depletes oxygen, can be detected only with special instruments. If the concentration of nitrogen is too high (and oxygen too low), the body becomes oxygen deprived and asphyxiation occurs.

inadvertent use of nitrogen rather than breathing-air delivery systems.

This bulletin focuses only on the hazard of asphyxiation, though nitrogen also presents cryogenic and high-pressure hazards.

Commercial Uses of Nitrogen

This Valero Case Study reemphasizes the importance of understanding the hazards involved with using nitrogen or other inert gases in confined spaces. Furthermore, it reiterates that co-workers must strictly follow prescribed safe entry procedures, or they may become victims.

The CSB encourages industry to review policies, procedures, and training programs using the lessons learned and the recommendations from this incident and promptly implement any needed improvements.

5.0 Lessons Learned

This incident, as in many previous incidents involving confined space asphyxiation fatalities, provides important lessons in hazard awareness and emergency response training.

5.1 Hazard Identification

Worker training programs should emphasize inert gas asphyxiation hazard awareness:

1. Oxygen-deficient atmospheres in confined spaces can be deadly in only a few breaths.

2. Entering oxygen-deficient atmospheres should never be attempted under any circumstances without training and proper air-supplied breathing equipment.

3. Pre-job planning and walkdowns with the entire work team should emphasize confined space entry restrictions, especially when unsecured confined space access points are in the work area.

4. Confined space hazard warnings must be maintained at all times while the access opening is not secured.

5. Pre-job walkdowns should accurately identify all equipment where inert gas purging may be venting into the work area.

6. Barriers and warnings should be maintained around open purge vents at all times during purging activities.

5.2 Safe Rescue Operations

Worker training should emphasize:

1. The powerful human instinct to help someone in distress, especially a friend or co-worker, all too frequently results in multiple confined space incident victims.

2. Workers suddenly involved in emergency activities must not allow emotions to override safe work procedures and training. Only qualified and trained personnel equipped with the necessary safety equipment should attempt a rescue.

6.0 Recommendations

6.1 Valero Delaware City Refinery

2006-02-I-DE-R1:

Conduct safe work permit refresher training for all permit-preparers and approvers and affected refinery personnel and contractors.

Emphasize:

- All proposed work requires a jobsite visit by the requestor and a unit operator to identify special precautions, equipment status, and personal safety equipment requirements.
- The conditions for marking the "nitrogen purge or inerted" (Yes/No/NA) status box.
- The permit must clearly identify all hazards and special personal protective equipment requirements.
- "Fresh Air" work restrictions apply to "Set up only" permits whenever an IDLH atmosphere is suspected or known to be present in the work area.

2006-02-I-DE-R2:

Conduct confined space control and inert gas purge procedure refresher training for all affected refinery personnel and contractors.

Emphasize:

- The requirements to maintain posted warnings at all access points to confined space temporary openings.
- The requirements to maintain posted warnings, barricades, and access control log at equipment during purging.
- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

6.2 Valero Energy Corporation

2006-02-I-DE-R3:

Audit work permit procedures and nitrogen purge safety procedures at each Valero U.S. refinery. Determine if issues identified in this Case Study are occurring elsewhere. Implement corrective action, including training, where necessary.

2006-02-I-DE-R4:

Require Valero U.S. refineries to revise and conduct nitrogen hazards awareness training.

Emphasize:

- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

6.3 Matrix Service Industrial Contractors, Inc.

2006-02-I-DE-R5:

Conduct confined space control and inert gas purge procedure refresher training for all affected personnel.

Emphasize:

- The requirements to maintain posted warnings at all access points to confined space temporary openings.
- The need to maintain posted warnings, barricades, and access controls as required by the client.
- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

6.4 American Petroleum Institute

2006-02-I-DE-R6:

Revise *Guidelines for Safe Work in Inert Confined Spaces in the Petroleum and Petrochemical Industries* (API, 2005) to clearly address the following:

- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

6.5 American Society of Safety Engineers

2006-02-I-DE-R7:

Revise *Safety Requirements for Confined Spaces*, ANSI/ASSE Z117.1 to emphasize that:

- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

6.6 Compressed Gas Association

2006-02-I-DE-R8:

Issue a safety alert to address nitrogen/inert gas hazards in confined spaces. Emphasize that:

- An oxygen-deficient atmosphere rapidly overcomes the victim.
- There is no warning before being overcome.
- An oxygen-deficient atmosphere might exist outside a confined space opening.
- Rescuers must strictly follow safe rescue procedures.

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