FACE AR-92-36

TO: **CDR Louis Smith, NIOSH, Division of Safety Research**

FROM: **Gary Bledsoe, AKFACE**

SUBJECT: **Operator Dies in Oxygen-Deficient Compartment of Ice-Making Barge - Alaska**

SUMMARY

On September 7, 1992, a 59-year-old, male barge operator (the victim) was asphyxiated as a result of entering the oxygen-deficient atmosphere in a compartment of a stationary barge used in ice-making operations. The victim was inspecting the condition of a compartment (which had been sealed for approximately one year) because he believed the barge was not properly ballasted. He entered the confined space without testing the atmosphere or obtaining a confined space entry permit. As he was descending the compartment ladder he lost consciousness and fell to the bottom of the compartment (a maximum distance of about 11 feet). A would-be rescuer heard the victim's wife call for assistance over the marine VHF radio, and came alongside the barge on a fishing tender. He observed the victim lying in the compartment and entered the compartment to attempt rescue. He too lost consciousness, but was revived by fire/rescue personnel. The barge operator was pronounced dead at a nearby clinic; the would-be rescuer recovered fully.

Based on the findings of the epidemiologic investigation, to prevent similar occurrences, employers should:

ensure that all employees potentially exposed to confined spaces receive specific training in confined space safe work procedures

ensure that all confined spaces are appropriately and clearly identified with standard warning signs (currently not required by regulation for vessels "under way")

ensure that a confined space entry permit system is developed for each confined space (currently not required by regulation for vessels “under way”) and that confined space entries are not performed if the work task can be completed from outside the confined space

ensure that appropriate atmospheric testing and proper ventilation is performed prior to entering and maintained continuously while working in confined spaces

Consideration should be given to new Coast Guard regulations which would provide minimum standards for confined space entry and work on vessels that are "substantially moored"

INTRODUCTION

On September 7, 1992, a 59-year-old male barge operator died from asphyxiation after entering the untested atmosphere of a barge compartment. The Alaska Division of Public Health, Section of Epidemiology was notified by the Deputy Director of the Alaska Department of Labor on September 8, 1992. An investigation involving an Injury Prevention Specialist from the Alaska Department of Health and Social Services, Division of Public Health, Section of Epidemiology ensued on September 8, 1992. The incident was reviewed with the U.S. Coast Guard investigator, a Marine Chemist, witnesses, company officials, and the incident survivor. The incident site was visited, measurements were made, and photographs of the fatality site were obtained. Appropriate documents (police reports, fire/rescue logs, etc.) were obtained during the investigation.

The employer was a local packing company which had been in business for 14 years. The company did not have a written safety policy which addressed rules and procedures specific to prevent the type of fatality that occurred. The local company was a branch of a larger out-of-state company. The parent company had a safety officer, and the local packing company periodically received safety literature from this parent company. Local safety meetings were occasionally held, but not regularly scheduled.

INVESTIGATION

A local packing company maintained a moored barge (approximately 150 feet offshore) with ice manufacturing machinery mounted above deck to produce ice for a fleet of fishing tenders maintained, the packing company and other vessels. Fishing vessels could pull alongside the barge and take on ice in their fish holding tanks. This produced an ice slurry used for fish preservation. The barge also had fish holding tanks to take overloads when vessels were unable to proceed to fish processing facilities (these tanks were infrequently used).

The barge was built during World War II for the Navy (1942) and displaced 336 gross tonnes. Its dimensions were as follows:

Length - 110 feet (see Diagram 1)
Width - 34.1 feet
Depth - 10.8 feet

The barge had 8 divided spaces, two of which were filled with water for ballast. The remaining six spaces were empty, and had no history of use for storage of materials or equipment. The barge was used primarily to provide easy vessel access, and as a support structure for the ice-making equipment and living quarters for the crew.

The barge compartments were designated as follows:

Port and Starboard Forward Rakes (empty) Number 1 Void (site of fatality) Number 2 Void (water ballast) Number 3 Void (water ballast) Number 4 Void (empty) Port and Starboard After Rakes (empty)

The ice barge operator (the victim) worked 4 days a week for as long as 16 hours per day. The victim's wife stayed with him on long shifts, and they had a small living facility above the holding tanks and ice manufacturing equipment. The living quarters were similar to the layout of a small trailer.

On the day of the fatality the victim was concerned about the ballasting of the barge. He thought that a compartment (Number 1 Void) might be leaking and affecting the stability of the vessel. He decided to inspect this compartment for bulkhead or hull leaks. The compartment had not been entered for at least one year (the would-be rescuer, a former deckhand, stated he had been in the same compartment about two years ago to scrape rust, and the barge underwent drydock repairs about one year ago). Entry was through a standard marine hatchway (approximately 24" X 18") and descent down a metal ladder. The hatch had been "dogged" (tightly shut with the hatch bolted down) for at least one year; it was not normal procedure to enter this space because it was not used for storage or any other purpose. The packing company manager reported that the victim worked most of his life in the gas storage industry (in another state) and had retired. The manager said he thought the victim would have been familiar with confined space hazards because of his previous work experience. The victim's wife reported that he had worked in the chemical industry, but she was unable to verify his participation in confined space entry and work training.

The victim opened the hatch and visually inspected the compartment from the deck by shining a flashlight into the space. He saw no evidence of leakage and decided to fully inspect the compartment. He could only see part of the compartment from the deck because of its large size (approximately 36 feet X 16 feet X 11 feet). The space was not posted as a confined space hazard, nor was an entry permit system in effect. The victim did not test the atmosphere nor did he ventilate the space prior to entry. At approximately 3:30 PM the victim's wife heard the victim fall, and observed that he had collapsed at the bottom of the ladder leading into the compartment. The time between confined space entry and the wife's discovery of the victim was approximately two minutes. She called the packing company manager on the barge's VHF radio to request assistance. A nearby vessel responded to the call and came alongside the barge; a crewman from this vessel boarded the barge and observed the victim lying at the bottom of the compartment. He believed the victim might have had a heart attack or stroke, and ran to the living facility to get a blanket (he was concerned about possible shock). He then entered the compartment and quickly lost consciousness.

At this time fire/rescue personnel were arriving at the dock (approximately seven minutes after the initial call); they boarded a skiff to get to the moored barge. They were delayed for approximately 2-5 minutes because of this process. The fire/rescue personnel donned airpacks and entered the compartment. They found the would-be rescuer lying on top of the victim. The would-be rescuer was breathing with difficulty, and was immediately started on oxygen. He was then hauled out of the compartment with a crane and transported to shore. The victim also immediately received oxygen and was then removed from the compartment. CPR was started as soon as he was placed on a backboard. He was transferred to the skiff and brought to shore. CPR was maintained during this time and was stopped only for the victim's transfer to an ambulance stretcher. No pulse was detected on the victim; electrical defibrillation was

attempted. After three attempts this procedure was discontinued, but CPR was maintained. The victim was pronounced dead at the clinic. On initial examination the would-be rescuer was gray and unresponsive, but after oxygen treatment he began to regain consciousness on the dock. He subsequently made a full recovery. He was interviewed during the investigation and exhibited no sign of physical disability.

Atmospheric measurements were made after the victim and would-be rescuer were removed from the compartment. Because of the refrigeration equipment on the barge, freon gas exposure was initially suspected. However, no leaks could be detected, and the compartment tested negative for freon. Oxygen measurements were then made, and revealed the following:

Near the hatch opening (coming) - 6.0 percent oxygen
Compartment bottom - 2.2 percent oxygen

There was an indication that the initial gas monitor used may not have been properly calibrated; however, subsequent readings by a Certified Marine Chemist with a calibrated instrument also indicated severe oxygen deficiency (see below). The compartment was then sealed pending the investigation of the Coast Guard and the State Health Department's Occupational Injury Prevention Program.

The Coast Guard requested the assistance of a Certified Marine Chemist who made atmospheric measurements on September 9, 1992. All compartments were tested for oxygen content. Except for the Number 1 Void (the site of the fatality), no compartment had an oxygen content lower than 14.5 percent. The following is a summary of measurements obtained from the Number 1 Void (the site of the fatality):

Oxygen - 5.5 percent by volume
Lower Explosive Limit - O percent
Carbon Dioxide - 2500 parts per million
Carbon monoxide - none detected
Hydrogen sulfide - none detected
Total hydrocarbons - none detected
Halogenated hydrocarbons - none detected (refrigerants)

The compartment was again sealed until the Coast Guard/State Health Department investigation of September 11, 1992. Prior to entry the compartment was again tested for oxygen content, explosive gases, carbon monoxide, and hydrogen sulfide. All tests were within normal ranges except for a low oxygen content (7.8 percent). The compartment was then ventilated and re-tested prior to entry; the oxygen content was approximately 19.5 percent at this time.

Upon entry the victim's rubberized lantern and other personal artifacts were discovered. The lantern was extensively damaged, and appeared to have been fallen on by the victim. This provided further evidence that the victim became unconscious while either descending or ascending the compartment ladder. The space was dry with no evidence of water leakage, or breaches into adjacent compartments. The compartment was empty, and had normal amounts of rust accumulation for the age of the vessel. No biologicals or other sources of hydrogen sulfide

were found. A small amount of dark precipitate (sludge) was found on the floor of the compartment. A creosote-like material was found on the walls of the compartment. There was evidence of red and black rust. There was a small weld mark (approximately 1.5 feet in length) on one of the inside upper walls. This was the only evidence of relatively recent repair work to the barge. This may have occurred approximately one year ago when the barge was in drydock in Washington State. The initial investigation revealed no immediately obvious cause to explain the lack of oxygen at the time of the incident.

The Certified Marine Chemist suggested two possibilities to explain the extremely low level of oxygen found in the Number 1 Void. The space may have been inerted (filled with a nonreactive gas, such as carbon dioxide, nitrogen, or argon) while undergoing shipyard work. This is sometimes done so that "hot-work" (on the outside wall of a compartment) can be more safely accomplished by eliminating highly flammable gases (e.g., oxygen), or to prevent excessive rusting. However, the Marine Chemist believed that the inerting procedure would have been expensive and labor-intensive for a barge of this age and value. Additionally, elevated levels of carbon dioxide were not observed; carbon dioxide is the most commonly used inerting gas in shipyard work. Moreover, no other compartment had levels of oxygen-depletion approaching the deficit in the Number' 1 Void.

A second possibility is that iron oxidation due to rust formation resulted in extreme oxygen-depletion. While the level of rusting observed seemed to be normal for a vessel of this age, areas of "black rust" (areas of very high oxidation levels which are rarely seen) were observed. "Black rust" has been reported to reduce oxygen content to less than 5 percent. At this time, this seems to be the most logical possibility.

CAUSE OF DEATH

The autopsy report attributed the victim's death to "asphyxiation".

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should ensure that all employees potentially exposed to confined spaces receive specific training in confined space safe work procedures.

Discussion: Assumptions were made by the company regarding the level of confined space entry training and/or knowledge of the victim. However, the lack of appropriate confined space entry precautions used by the victim indicated either an extreme disregard for the hazards of confined spaces or minimal knowledge of these dangers. The employee had no documentation of previous training, and received no formal training in this area during his time of employment. A formal system of confined space recognition, entry, and safe work procedure training should be instituted by the local company. All employees who may potentially enter confined spaces, such as tanks, vessel compartments, ship hulls, etc., should receive appropriate training and have documentation of such training in their personnel files.

Also, a standby person did not directly observe the victim during his entry into the compartment. Although his wife was on board the vessel, she was not actively engaged (nor did she have appropriate confined space entry/rescue training) in the work procedure being performed. She only became aware of the problem when she heard the victim fall.

In addition, another packing company employee attempted rescue without regard for appropriate confined space entry procedures. The would-be rescuer was a deckhand on one of the company's fishing tenders. His training in first aid led him to believe the victim had suffered a heart attack or stroke, and his immediate concern was to keep the victim warm to prevent shock. However, his lack of awareness of confined space hazards nearly cost him his life. All employees who potentially encounter confined spaces should receive appropriate training.

Recommendation #2: Although not required by current regulations for vessels "under way," employers should ensure that all confined spaces are appropriately and clearly identified with standard warning signs.

Discussion: The Number 1 Void was not marked with appropriate warning signs as a confined space hazard. All confined spaces should be evaluated and appropriately marked with warning signs. Signs should be easily visible and recognized, and contain a warning such as, "CONFINED SPACE - ENTRY BY PERMIT ONLY". The signs should be easily readable in English, and in the predominant languages of other workers (if applicable).

Recommendation #3: Although not required by current regulations for vessels "under way," employers should ensure that a confined space entry permit system is developed for each identified confined space and that confined space entries are not performed if the work task can be completed from outside the confined space.

Discussion: Entry into confined spaces should be by permit only. "The permit is an authorization and approval in writing that specifies the location and type of work to be done, and certifies that all existing hazards have been evaluated by the qualified person, and necessary protective measures have been taken to ensure the safety of each worker" (from NIOSH Publication 80-106: Working in Confined Spaces). Details on establishing a confined space entry permit system may be obtained from this publication.

The necessity of entering the Number 1 Void is questionable. The compartment had no indications of leaks or other critical problems. The victim entered the compartment to visually inspect it for evidence of water leakage. This could have been accomplished without entering the compartment by use of relatively straightforward and simply designed tools. A flashlight and mirror attached to a 10-foot telescoping pole could be to inspect parts of the compartment that cannot be visualized from the deck of the barge.

This arrangement would make entry for routine inspection unnecessary and still allow for safe periodic inspections. Methods of performing a work procedure without entry into a confined space should be used whenever possible.

Recommendation #4: Employers should ensure that appropriate atmospheric testing and proper ventilation is performed prior to entering and maintained continuously while working in confined spaces.

Discussion: The Number 1 Void was entered prior to any atmospheric testing for toxic or explosive gases, or oxygen-deficiency. A system of prioritization for atmospheric testing should be developed for the marine environment because of the large number of potential gases encountered. A minimum testing protocol for this situation would be percent oxygen, hydrogen sulfide, carbon monoxide, LEL, and halogenated hydrocarbons (refrigerants).

Furthermore, the space was not ventilated prior to entry. Before any confined space is entered appropriate atmospheric testing must be performed. These tests must be performed by an adequately trained specialist with properly and recently calibrated instrumentation. When dangerous atmospheric conditions are encountered, the confined space must be properly ventilated prior to re-testing and entry. Continuous ventilation must be maintained while working in confined spaces. Hazardous atmospheres can be created by work procedures (e.g., welding, painting, etc.) conducted in confined spaces through the production of toxic gases and depletion of oxygen.

Recommendation #5: Consideration should be given to new Coast Guard regulations which would provide minimum standards for confined space entry and work on vessels that are “substantially moored.”

Discussion: Currently, vessels that are semi-permanently or "substantially moored" (Coast Guard term) are considered to be "under way." Thus, these vessels are not covered by standard confined space regulations. Vessels that are "under way" are considered to be in an environment where standard confined space entry and work procedures are impractical. Even though the vessel on which this fatality occurred is infrequently moved (the last time was for shipyard repairs one year previously), it is considered to be "under way." Regulations for vessels in this status would encourage the use of appropriate confined space entry and work procedures, and would reduce the occurrence of confined space deaths and injuries.

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