



The National Institute for Occupational Safety and Health (NIOSH)

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# Municipal Water System Operator Dies After Entering Oxygen-Deficient Valve Vault in Montana

FACE 9117

## SUMMARY

A 35-year old male water system operator (victim) was asphyxiated after entering a valve vault at a municipal water system plant. The victim was assigned to turn on a water line valve serving a nearby tree farm. The valve was located at the water treatment plant inside an underground valve vault that “always had normal air.” The victim entered the valve vault through a ground-level manhole without testing or ventilating the vault atmosphere. A co-worker, who had last seen the victim 1 hour earlier, checked the manhole and saw the victim lying on his back at the bottom. The victim did not respond to any calls. Other workers summoned from the plant building and local fire department personnel ventilated the valve vault and removed the victim. The vault atmosphere was subsequently found to be oxygen deficient. There were no witnesses to the incident, but evidence suggests that the victim lost consciousness and fell from the ladder railings to the bottom of the vault. NIOSH investigators determined that, in order to prevent future similar occurrences, employers should:

- recognize that confined space atmospheres are dynamic environments subject to unexpected changes, and address those dynamics in all written and practiced safe work procedures and subsequent worker training
- develop and implement a comprehensive confined space entry program to address all provisions outlined in NIOSH publications 80-106, “Working in Confined Spaces,” and 87-113, “A Guide to Safety in Confined Spaces.”

In addition, municipalities should ensure that:

- **police, as well as fire and rescue personnel, are trained in confined space entry and rescue procedures.**

## INTRODUCTION

On May 23, 1991, a 35-year old male water system operator (victim) was asphyxiated after entering a valve vault at a municipal water system plant. On May 31, 1991, officials of the Montana Department of Labor and Industry notified the Division of Safety Research (DSR) of the death, and requested technical assistance. On June 5, 1991, a research industrial hygienist and a supervisory industrial hygienist from DSR traveled to the incident site and conducted an investigation. The

DSR investigators reviewed incident with representatives from the municipality, police officers, fire department personnel, and personnel from the Department of Labor and Industry assigned to this case. Photographs of the incident site were obtained during the investigation.

The employer in this incident was a municipal public utilities department that had performed water purification and wastewater treatment operations for 26 years. The employer had 98 employees, most of whom were water and wastewater system operators and maintenance workers. The employer had a written safety policy, safety program, and established safe work procedures. There was no full-time safety manager. Employees rotated the responsibility of “safety manager” among themselves on a monthly basis. This temporary “safety manager” was responsible for conducting safety meetings to discuss a variety of safety issues pertaining to potable water and wastewater systems.

## INVESTIGATION

[NOTE: DSR investigators were unable to interview the investigating detective, policeman, and responding fire department personnel, or obtain copies of their written reports.]

Several days before the incident, the victim had told others that he was going to shut off a valve on a water line serving a nearby tree farm, and then drain it to prevent the line from freezing during a forecasted cold snap.

The shut-off and drain valves on this water line were located inside a concrete valve vault below ground at the water treatment plant. The valve vault was 7 feet deep, and 6 feet in diameter. It was accessed by a 24-inch-diameter manhole at ground level, and steel rungs mounted onto the inside wall. The waterline and valves were approximately 6 inches above the bottom of the vault. These valves could be opened or closed from ground level, using an 8-foot-long valve key or portable extension rod.

On the day of the incident, the victim was assigned to turn on the same valve to the tree farm. There were no witnesses of the incident. However, evidence suggests the following sequence of events: At about 2:00 p.m. on the day of the incident, the victim entered the valve vault without first testing or ventilating the vault atmosphere. Since the vault atmosphere was oxygen deficient (the atmosphere, tested at the bottom of the vault, had as low as 2% oxygen on the day the DSR researchers investigated the incident), the victim was overcome, and fell from the ladder railings to the bottom of the vault. A co-worker noticed a utility truck that the victim had been driving, parked next to the vault manhole. Knowing the victim had not been seen for about an hour, the co-worker walked over to the manhole. When he looked inside, he saw the victim lying on his back at the bottom. The co-worker yelled to the victim, but the victim did not respond.

The co-worker ran to the plant superintendent, about 300 feet away, and told him about the victim. The superintendent ran to the manhole, yelled to the victim, and also received no response. Help was summoned from the plant building. Workers arrived within a few minutes with a portable blower fan with an 8-inch trunk hose and a self-contained breathing apparatus (SCBA). The manhole was immediately ventilated with the blower while one of the workers donned the SCBA and entered the manhole. Approximately 15 minutes after the rescue attempt began, the alarm on the worker's SCBA sounded (possibly due to over-breathing by the rescuer who was wearing it).

While this rescuer was returning to the top of the manhole, personnel from the local fire department arrived. One of the firefighters donned an SCBA, entered the manhole, and tied a rope around the victim's chest. The victim was hoisted out. The firefighters and arriving emergency medical service (EMS) personnel performed cardiopulmonary resuscitation (CPR) at the scene and en route to a local hospital. The victim was pronounced dead at the hospital by the attending physician within a few minutes after arrival.

A city detective and a police officer, who were assigned to investigate the incident, arrived at the scene between 6:00 and 7:00 p.m. (about 3 hours after the victim was extricated from the vault). They were admitted onto the grounds by an unidentified plant employee, who led them to the valve vault and removed the manhole cover. Seeing blood on the wall at the bottom of the vault, the detective decided to enter to get dimension measurements but shortly afterwards “came up for air, gasping.” Thinking he was only having a claustrophobic reaction, the detective attempted to enter the valve vault again, but came back out, saying that he “just could not do it.” The unidentified plant employee retrieved a gas detector, but was not trained in its use and could not interpret the meter readings; so he stuck his head into the manhole to get a general

Reports to the Montana Department of Labor and Industries indicated that the valve vault was possibly contaminated with toxic chemicals. These concerns were reportedly due to suspicions that sodium metham, a herbicide used by the municipality for root control in underground wastewater and storm drains, had contaminated the local ground water system from sewage material placed in the dewatering pit near this incident site. NIOSH investigators experienced tearing of eyes and respiratory irritation when working around the downwind perimeter of the dewatering pit, but due to the lack of appropriate air sampling detectors or equipment at the remote field worksite were unable to identify the gases and vapors emanating from the pit. Samples of green liquids in the bottom of the dewatering pit were collected and submitted for comparative analysis with samples obtained from the bottom of the valve vault.

CAUSE OF DEATH

The medical examiner listed the cause of death as asphyxia due to oxygen displacement with carbon dioxide and methane.

RECOMMENDATIONS/DISCUSSION

**Recommendation #1: Employers should recognize that confined space atmospheres are dynamic environments (constantly subject to unexpected changes) and address those dynamics in all written safe work procedures and worker training.**

Discussion: The employer had written general safe work practices for entry into underground structures that were reportedly utilized predominately when entering manholes that were part of the municipal wastewater system. The valve that was to be turned on by the victim was located at the water treatment plant complex inside an underground valve vault that contained only freshwater circuits and “always had normal air.” Municipal water works employees attested to over 200 entries into this valve vault over the preceding several years, without any problems. Investigations at the incident site disclosed that the environmental dynamics in the valve vault may have changed as follows:

- a. the river (located about 170 feet away from the underground valve vault) had been at flood-stage levels for several days preceding the incident;
- b. the water table underneath the valve vault field had risen with the rising river to an elevation just beneath the concrete floor in the bottom of the valve vault;
- c. the rising water table forced gases and liquids normally trapped deep within the surrounding soils toward the surface;
- d. the clay soils and sands used by the municipality for the surface of the valve vault field inadvertently formed a seal, or cap, forcing the gases and liquids to flow into the only two openings into the ground, the valve vault and a sewage dewatering pit (Figure);
- e. the soil gases (carbon dioxide, methane, and hydrogen sulfide) entered the valve vault through the drain hole in the center of the concrete floor and possibly through the joints between the sections of preformed concrete pipe forming the walls of the valve vault; as gases filled the valve vault, they displaced oxygen to below the minimal level to support human life; the victim lost consciousness upon entering the oxygen-deficient environment.

Cumulative results of atmosphere testing at the bottom of the valve vault by the municipal fire department, municipal water works, Montana Department of Labor, Montana Department of Health and NIOSH-DSR investigators, over a several-day period after the incident (there were no tests made on the day of the incident) detected the following concentrations:

| Gas | Concentration Range (% by volume) |
|-----|-----------------------------------|
|-----|-----------------------------------|

|                    |                              |
|--------------------|------------------------------|
| Oxygen             | 1.8 – 8.8% (3.5% avg.)       |
| Nitrogen           | 74.1 – 78.5% (76.3% avg.)    |
| Carbon Dioxide     | 11.62%                       |
| Hydrogen Sulfide   | 0.0 – 1.9 ppm (0.5 ppm avg.) |
| Methane            | 0.1 – 3.8% (1.7% avg.)       |
| Ethanes to Hexanes | <0.06%                       |

[Note: The NIOSH investigation involved a liquids analysis for sodium metham, the herbicide used by the municipality and suspected of being a factor in this fatality. Gas chromatography-mass spectrometry (GC-MS) analysis of liquid samples from the bottom of the valve vault did not detect any sodium metham. A secondary thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS) analysis of the liquid head gases also did not detect any methyl iso-thio cyanate (MITC), a volatile gas liberated by sodium metham.]

The perceived sense of security due to numerous prior entries into a valve vault without incident, apparently lulled the victim into not testing the air prior to entry. This requirement was part of the employer's written general safe work practices for entry into underground structures, but was not rigorously enforced for all underground structures.

**Recommendation #2: Employers should develop and implement a comprehensive confined space entry program to address all provisions outlined in NIOSH publications 80-106, "Working in Confined Spaces," and 87-113, "A Guide to Safety in Confined Spaces."**

Discussion: Although the employer had written general safe work practices for entry into underground structures, they were not followed or enforced at this valve vault. As previously mentioned, municipal water works employees cited over 200 uneventful entries into this valve vault spanning several preceding years without any previous problems. Although testing equipment was reportedly available 200 feet away at a waterworks facility, the valve vault in this incident was not tested prior to entry. This requirement was part of the written general safe work practices of the municipal waterworks department.

Confined space entry procedures should be specific to each type of confined space; e.g., valve vaults, wet wells, lift stations, utility vaults, sewer manholes, etc. Employers should, therefore, develop, implement and enforce a confined space entry program as outlined in the recommended NIOSH publications. At a minimum, the following items should be addressed for each type of confined space:

1. Is entry necessary? Can the assigned task be completed from the outside?

For example, in this case, the victim entered the valve vault to open and close the valves by hand. These valves were subsequently turned by another municipal water works employee standing on the surface outside the manhole used a homemade valve key or valve extension tool. Many manual and power-assisted extensions are currently available that will allow workers to turn valves at the bottom of manholes from aboveground or street levels.

2. Has a confined space safe entry permit been issued by the employer before each confined space is entered?

No confined space entry permit was issued for the victim's entry into the valve vault. Police detectives entered the property, and later the valve vault, without obtaining a safe entry permit or notifying on-duty waterworks personnel of their presence or plans.

3. Are confined spaces posted with warning signs, and are confined space entry procedures posted where they will be noticed by employees and others (e.g., police)?

4. If entry is to be made, has the air quality in the confined space been tested for safety based on the following criteria:

- Oxygen supply at least 19.5%
- Flammable range less than 10% of the lower explosive limit (LEL)
- Absence of toxic air contaminants?

[Note: Methane gas has a LEL of 5%. The LEL is the lowest atmospheric concentration of a gas or vapor which will result in an explosion if sufficient oxygen and an ignition source are present. Average methane readings during the investigation period were 1.75% (over three times the 10% LEL criteria level), and the upper range reading of 3.75% indicated a flash fire potential.]

5. Are workers and supervisors being continuously trained in the selection and use of:

- respiratory protection
- test equipment, including calibration and maintenance
- lifelines
- emergency rescue equipment
- protective clothing?

6. Have workers been properly trained in working in and around confined spaces?

7. Are confined space entry, safe work practices, and rescue procedures discussed in safety meetings?

8. Is appropriate ventilation equipment available and/or used before and during entry and work?

9. Is the air quality monitored when the ventilation system is operating?

10. Is an outside observer posted and appropriate rescue equipment (safety belt/harness and lifeline) used during every confined space entry?

For example, in this incident, the victim entered the confined space without an observer or safety equipment. An observer, outside of the confined space and equipped with appropriate rescue equipment, could have assisted the victim when he first lost consciousness. The victim was not provided, or required to wear, a safety belt or full-body harness secured via lifeline to a power winch or other lifting device rated for humans. A hoisting device designed for lifting humans will not subject the individual being lifted to crushing hazards. This is especially important if any part of the body becomes caught during an emergency lift (even though in this incident crushing injuries were not apparent).

11. Are employees continuously trained in confined space rescue procedures?

**Recommendation #3: Municipalities should ensure that police, as well as fire and rescue personnel, are trained in confined space entry and rescue procedures.**

Discussion: Police department detectives in this incident were not adequately trained in recognizing the hazards posed by confined spaces and in confined space entry and rescue procedures. They failed to get a safe entry permit for entry into the valve vault. Upon arrival at the valve vault site, warning barriers erected by the waterworks employees were removed, the manhole cover was opened, and entry into the valve vault was attempted without first testing the atmosphere. When the detective experienced breathing difficulty, he failed to associate the symptoms with oxygen deficiency or toxic vapors but instead returned to the surface and later attempted a second entry. The police officer attempted entry into the valve vault, but upon experiencing similar breathing problems also returned to the surface. Fortunately, at this point the detective and police officer decided to abandon their investigation of the valve vault for the evening. Neither the detective nor the police officer wore a safety belt, harness or lifeline for potential rescue.

## REFERENCES

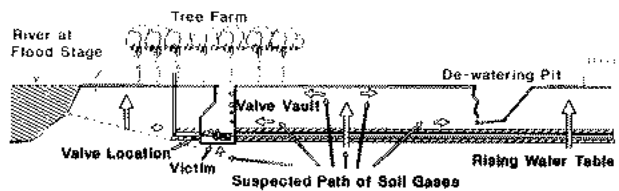
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FACE 91-17  
**FIGURE 1.**



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