MIFACE Investigation Report: #08MI121

Subject: 59-Year-Old Male Worker at a Fruit Storage Facility Died After Entering a Controlled Atmosphere Storage Room

Summary

In the fall of 2008, a 59-year-old male employee at a fruit storage facility located on a farm died after entering a controlled atmosphere (CA) apple storage room. Its atmosphere contained less than 3% oxygen (O_2). The storage room had a large wooden outer door (cooler door) and an interior aluminum door, which had been seated with caulking and weather stripping and which had a Danger, Do Not Enter sign affixed (Figure 4). To maintain the atmosphere but still allow for visual observation of the produce, the door to the CA room had a 2- by 3-foot Plexiglas window attached to the door by 18 bolts/wing nuts. The event was un-witnessed. The decedent removed the wing nuts and the Plexiglas window and climbed through the door opening, and entered the CA room (Figure 1). The owner found him collapsed on the floor on his knees with his head leaning against an apple bin. A bag of apples was found next to his body. The owner leaned through the window opening into the CA room, grabbed the decedent by his coat, pulled him toward the door through the window opening, and checked for a pulse. He did not find a pulse. The owner left the area to call the farm office to have them call for emergency response. Upon returning to the decedent, he took a deep breath, leaned through the window opening, grabbed the decedent under his arms and pulled him through the window opening and out of the CA room. The owner attempted CPR after he pulled the decedent out of the CA room but was unsuccessful in resuscitating him. Emergency response arrived and he was declared dead at the scene. A bag of a different type of apple obtained from another CA room was found on the propane-powered forklift that was parked in the aisleway nearby. The Plexiglas window was found leaning against a wall with the wing nuts nearby.

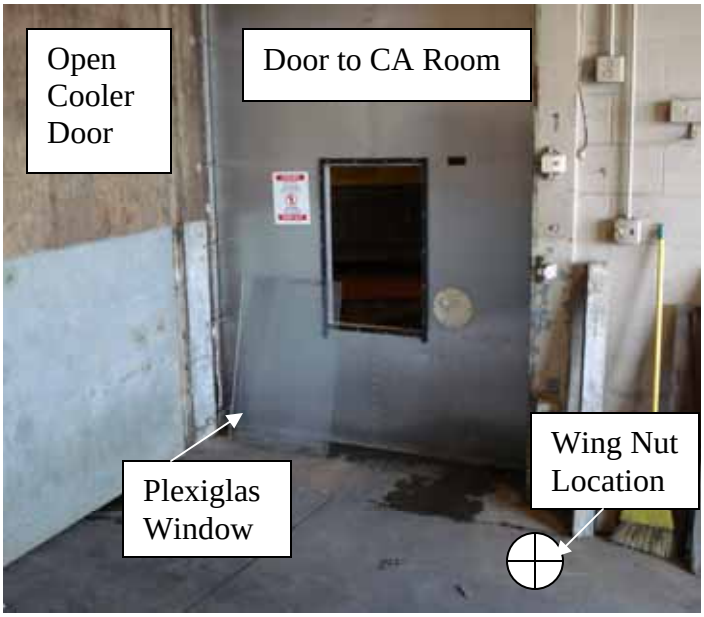

Figure 1. Outer door, inner aluminum door, Plexiglas window, opening to CA room, warning sign, wing nuts location

RECOMMENDATIONS

Recommendations that directly address the factors contributing to the fatality:

- Evaluate the workplace to determine if a confined space and/or permit-required confined space (PRCS) is present. If a PRCS is/are present, the commercial facility owner and/or farmer should develop and implement the necessary sections of MIOSHA Occupational Health Standard Part 490, Permit-Required Confined Space and MIOSHA Safety Standard, Part 90, Confined Space Entry.
- The employer should develop and implement a written safety and training program that includes the MIOSHA Right-to-Know standard (Parts 92 and 430).
- Controlled atmosphere generating equipment and door manufacturers should include a confined space warning sign(s) on the equipment/door exterior.

Recommendations to commercial fruit and vegetable storage and warehousing facilities and to farmers storing fruits and vegetables in a similar way:

- Instruct employees/family members/visitors not to enter a confined space or other designated area to rescue an ill/injured individual unless trained and equipped with appropriate rescue equipment.
- Utilize electric forklifts when loading and unloading product in a controlled atmosphere (CA) room.
- Maintain and tune propane-powered forklifts for operations associated with CA rooms and any interior building use. If the forklift was manufactured prior to 2007, equip the forklift with a catalytic converter to further minimize carbon monoxide (CO) emissions, or lease/use a forklift manufactured after 2007. Since neither good maintenance nor a catalytic converter eliminate all carbon monoxide, this approach is not as effective as switching to an electric forklift.
- If propane-powered forklifts are used to load and unload product from a CA room, ensure the ventilation equipment in CA rooms is operating. Conduct air monitoring to determine the CO concentration in the room to protect the forklift operator from an overexposure. Consider using direct reading CO monitors (room or personal).
- Place oxygen and carbon monoxide air monitoring air portal lines or equipment at various locations in the CA room to better characterize the atmosphere in the room.
- Alert employees/family members/visitors to the hazard of sealed storage areas even when no oxygen drawdown has been done. These areas may have lower oxygen levels than expected.
- Establish a CA room opening procedure to minimize inhalation hazards posed by low oxygen levels.

Editor's Note: Operations involved with agricultural commodities need to determine the "industry" status of the work activities within their operations. The same work activity can be either "Agricultural" or "General Industry" and be covered by different regulations. For the purposes of this report an "agricultural operation" means the work

activity designated in major groups 01 and 02 of the Standard Industrial Classification manual, United States Bureau of the Budget, 1972 edition. Agricultural operations include any practices performed by a farmer or on a farm as an incident to or in conjunction with farming operations including preparation for market, delivery to storage or market, or to carriers for transportation to market. Individual state definitions may vary.

Recommendation to MSU Extension:

- Update the Controlled Atmosphere Storage and Warehousing Clinic manual to comply with MIOSHA health and safety standards.

INTRODUCTION

In the fall of 2008, a 59-year-old male employee at a fruit storage facility died when he entered a controlled atmosphere (CA) apple storage room. On the same day, MIFACE investigators were informed of this work-related fatality by the Michigan Occupational Safety and Health Administration (MIOSHA) personnel, who had received a report on their 24-hour hotline. The MIFACE researcher interviewed the company owner at the storage facility on October 1, 2009. During the course of writing this report, the police report and pictures, death certificate, medical examiner report, and the MIOSHA file and citations were reviewed. Pictures used in Figures 1, 3 and 4 are courtesy of the MIOSHA compliance officer. Pictures used in Figures 2, 5, 6 and 7 were taken with the permission of the firm owner during the MIFACE site visit.

The farm employer stored apples in a facility that was built approximately 50 years ago. The storage facility was used to store both the farm's produce as well as other grower's produce. The farm operation had purchased the building several years prior to the incident. The building contained equipment to sort, grade, pack, and store apples. The number of workers at the firm varied by season and activity; a higher number of employees were employed in spring and summer. During spring and summer, the employees worked 10-hour (8:00 a.m.-6:00 p.m.) days and during the fall season, employees worked 11-hour (8:00 a.m.-7:00 p.m.) days.

The decedent had worked for the firm for fifteen years. He had been the warehouse manager since 2003. He worked full time during the fall season and 20-30 hours weekly in the spring and summer. His job included general maintenance, forklift maintenance, checking refrigeration unit compressors, and documenting each storage room's temperature, atmospheric oxygen and carbon dioxide levels. The decedent did not work the day before the incident. The week before the incident, the owner stated that the size of the harvest had required workers to work extended hours and the workers had been very busy loading fruit into the storage rooms.

The owner indicated that at the time of the incident, the firm did not have a written health and safety program, a health and safety committee, or a written disciplinary procedure. The firm did not have written procedures for the task of checking the atmosphere of the

CA rooms or a confined space entry procedure. The employer periodically held safety meetings with his employees, but did not document the training. The employer stated that he had instructed employees regarding the danger of CA storage, including lack of oxygen and the dangers of nitrogen, and he had instructed them that under no circumstances were they to enter a room when it was under a CA condition. Employees, including the decedent, had on-the-job training.

The owner had attended a CA clinic hosted by MSU Extension that covered the techniques of CA storage, such as oxygen levels, temperatures for optimal storage, storage techniques, etc.

Company Remediation

After the incident, the firm's owner instituted the following actions:

1) Developed a written confined space entry procedure and conducted confined space training for employees;
2) Conducted forklift training;
3) Placed Confined Space Danger signs on the aluminum door of each CA storage room;
4) Identified and marked all overhead pipes,
5) Conducted emergency response training; and,
6) Placed oxygen and carbon dioxide air portal lines at the back of each CA room and ran those lines to a central location in the building. This central area was established to record results for all 12 CA rooms (Figure 2). This arrangement replaced the practice of inserting an air sampling probe through the Plexiglas window (Figure 5).

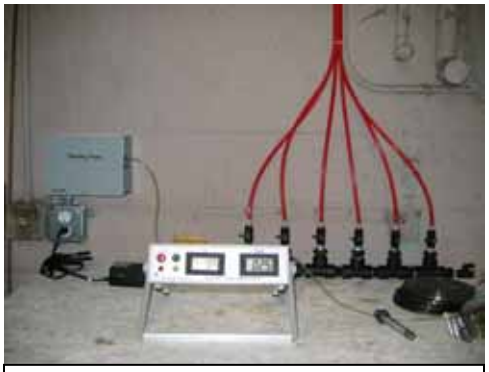

Figure 2. GCS150 and remote sampling configuration

At the conclusion of its investigation, the MIOSHA General Industry Safety and Health Division issued the following Serious citations:

SERIOUS:

PERMIT-REQUIRED CONFINED SPACES, PART 490, RULE 1910.146(c)(4): A written permit space program was not developed and implemented that complied with 1910.146 of Part 490.

PERMIT-REQUIRED CONFINED SPACES, PART 490, RULE 1910.146(c)(1): Evaluate the workplace to determine if any spaces are permit-required confined spaces.

SERIOUS:

HAZARD COMMUNICATION, PART 430, 1910.1200(e)(1):

A written hazard communication program was not developed, implemented, and/or maintained at the workplace which describes how the criteria specified in 1910.1200 (f), (g), and (h) will be met:

A hazard communication program was not developed or implemented for the facility where employees were exposed to oxygen-deficient atmospheres with elevated nitrogen and carbon dioxide levels.

SERIOUS:

MICHIGAN OCCUPATIONAL SAFETY AND HEALTH ACT, ACT 154, P.A. 1974, AS AMENDED, SECTION 14j:
Signs that advised employees of the information and rights available to them regarding hazard communication under section 14 of the act were not posted throughout the workplace.

MICHIGAN OCCUPATIONAL SAFETY AND HEALTH ACT, ACT 154, P.A. 1974, AS AMENDED, SECTION 14j:
Pipes or piping systems in a workplace that contained a hazardous chemical were not identified to an employee by a label or by a sign, placard, written operating instructions, process sheet, batch ticket, or a substance identification system:

Pipe systems used to convey and generate the controlled atmosphere environment (i.e. nitrogen, and carbon dioxide) and refrigerant lines containing ammonia and Freon as well as propane are required to be labeled.

INVESTIGATION

The east entrance to the building was via a large overhead door that opened to an aisleway (Figure 3). The building contained a total of 12 storage rooms, all of which could be converted to use as a controlled atmosphere (CA) room. Controlled atmosphere storage refers to a container, vessel, or in this case, a storage room, designed for the storage of goods, such as food, in an atmosphere where the parameters such as gas type, temperature and humidity are controlled.

Figure 3. View of incident scene from east entrance

Fruit was transported to the facility and distributed among multiple storage rooms placed under refrigeration to cool. Once cooled, the fruit was combined into one storage room that was converted to a CA room. Ten of the CA rooms were filled with product at the time of the incident.

To convert a storage room into a CA room, a bead of caulk was laid on the floor. A tight-fitting aluminum door fitted with weather stripping along its perimeter was placed at the

entrance of the room and against the door frame. The door was held tightly against the frame by turnbuckles. Each door to the CA room had a 6-inch circular port used for product sampling and a 2- by 3-foot 3/8-inch thick piece of Plexiglas equipped with weather stripping. The Plexiglas covered an opening in the door and acted as a window to the room. The Plexiglas had 18 drilled holes and was bolted finger-tight via bolts and wing nuts corresponding to holes in the door.

Figure 4. Close up of Danger sign on door shown in Figure 1

The Plexiglas had a small air sample port (hole) into which an air sampling probe could be placed. At the time of the incident, affixed to the door and near eye level next to the Plexiglas window was an 8.5-inch by 11-inch sign, in both English and Spanish (Figures 1 and 4) stating:

"DANGER	!PELIGRO!
DO NOT ENTER	NO ENTREN
Lack of Oxygen	Falta De Oxigeno
Will Cause Death	Causa Muerte
KEEP OUT"	

Once the CA room was sealed by seating the aluminum door and affixing the Plexiglas, the variety of apples required an oxygen drawdown. This was accomplished by initiating a nitrogen purge to lower and remove oxygen (O_2) and carbon dioxide (CO_2) from the room. The process continued until the room contained less than 3% oxygen. The room temperature was also lowered to approximately 32 degrees Fahrenheit. Once the CA room was sealed, the heavy insulated exterior 14- by 16-foot wood cooler door was closed.

Figure 5. MIFACE researcher simulating previous CA room sampling procedure using GCS150 and sampling probe (different room)

One of the decedent's duties was conducting and documenting the results of a daily atmospheric check on each sealed CA room. The firm used a direct-reading Gas Control System Inc Model GCS150 Dual Gas Analyzer (O_2/CO_2) with an attached probe to check the level of O_2 and CO_2. After opening the cooler door, a plug in the sample port of the Plexiglas window was removed and the sample probe was inserted into the hole (Figure 5). The O_2 and CO_2 levels and the room's temperature were recorded on a log sheet.

The 12,000 bushel CA incident room was filled with apples. The room was sealed seven days prior to the incident. Three days prior to the incident, the room's atmosphere was checked and the oxygen level was approximately 5%. Approximately 48 hours earlier,

the owner turned on the nitrogen in the incident room for one night for approximately 12 hours to further lower the O_2 and CO_2 levels.

On the day of the incident, the decedent arrived at work and clocked in at approximately 8:00 a.m. The owner phoned the storage facility at approximately 9:30 a.m. No one answered the phone, but the owner did not think this was unusual because the phone was mounted on the wall near the front of the building, and the decedent may not have heard it or was busy.

The owner arrived at the facility at approximately 10:20 a.m. He parked his vehicle at the building's parking area and noticed the overhead door was open on the east side of the building. The owner walked into the building through the open overhead door and began walking down the aisle. He observed the incident room's cooler door halfway open (Figure 3), and when he walked closer, he noticed the Plexiglas window on the door to the CA room had been removed and placed on the floor. Near the Plexiglas were the 18 wing nuts that had formerly held the window in place. In front of the door on the floor was a black flashlight.

The owner observed the decedent's body in the CA room a short distance from the door. The owner described the decedent as on his knees, leaning forward with his head against a wooden apple storage box. The owner took a deep breath, leaned through the window opening into the CA room, grabbed the decedent by his coat, and pulled him toward the door through the window opening. He checked for a pulse but did not find one. The owner left the area to call the farm office to have them call for emergency response.

Upon returning to the decedent, he took a deep breath, leaned through the window opening, grabbed the decedent under his arms and pulled him through the window opening and out of the CA room. The owner attempted CPR after pulling him out of the room but was unsuccessful in resuscitating him. Emergency response arrived and he was declared dead at the scene.

A bag of apples was found by the decedent's body in the storage room. The GCS150 gas monitor and a bag of a different type of apple retrieved from a different CA room were found on a forklift that was located a short distance away in the aisleway (Figure 3). The owner noted to the MIFACE researcher that on day of incident, the decedent had not documented the temperature, O_2 or CO_2 levels for any CA room.

RECOMMENDATIONS/DISCUSSION

Recommendations that directly address the factors contributing to the fatality:

- Evaluate the workplace to determine if a confined space and/or permit-required confined space (PRCS) is present. If a PRCS is/are present, the owner and/or farmer should develop and implement the necessary sections of MIOSHA Occupational Health Standard Part 490, Permit-Required Confined Space and MIOSHA Safety Standard, Part 90, Confined Space Entry.

Commercial fruit storage and warehousing facility owners and farmers who store farm products should evaluate the workplace to determine if a permit-required confined space (PRCS) is present. If a PRCS is/are present, the owner and/or farmer should develop and implement the necessary sections of MIOSHA Occupational Health Standard Part 490, Permit-Required Confined Space and MIOSHA Safety Standard, Part 90, Confined Space Entry.

Controlled atmosphere storage rooms, by their design, meet the MIOSHA/OSHA definition of a permit required confined space (PRCS). A confined space is considered a permit required space if it has one or more of the following characteristics:

1) *Contains or has the potential to contain a hazardous atmosphere*; (italics added)
2) Contains a material that has the potential for engulfing an entrant;
3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or
4) Contains any other recognized serious safety or health hazard.

Figure 6. All doors to the CA rooms in the facility have the required Confined Space signs (in Spanish and English) affixed

MIOSHA Safety and Health Standards Part 490 and Part 90 do not apply to farmers who store their own farm products (and no other grower's products) in CA storage rooms. Farmers who have this type of storage practice face the same hazards as commercial farm product storage and warehousing facilities, which must comply with MIOSHA PRCS requirements.

A farmer storing fruit and/or vegetables in a controlled atmosphere room should inform exposed employees by posting danger signs, or any other equally effective means, of the existence and location of and the danger posed by the controlled atmosphere room. Additionally, farmers should determine if there is a need for anyone to enter the space

when it is under a controlled atmosphere condition, e.g. to repair malfunctioning equipment. If it is necessary to enter a room under CA condition, then at a minimum, an entry procedure in conformance with MIOSHA standards should be written and persons trained prior to entry.

At commercial and farm CA storage rooms, a sign reading: "DANGER – PERMIT REQUIRED CONFINED SPACE. DO NOT ENTER" or other similar language should be located at the entrance of the room (Figure 7). These signs should be understandable to all workers. In some workplaces, signs in more than one language may be necessary. The facility owner posted the required signs following the incident (Figures 5 and 6).

Figure 7. Close-up of Confined Space sign shown in Figures 5 & 6

If contractors could be the individuals performing the work in a room under CA conditions, the facility owner/farmer should consult paragraph (c) General Requirements, section (8) of Part 490. This section details the standard requirements of a host employer (farmer) utilizing a contractor to perform work in a permit required confined space (i.e., a room under CA condition).

- Implement a written safety and training program that includes the MIOSHA Right-to-Know standard (Parts 92 and 430).

Employers should evaluate the tasks performed by workers, identify potential hazards, develop and implement a safety program addressing these hazards, and provide worker training in safe work procedures. A preliminary hazard analysis of the entire operation should identify hazardous areas (physical, chemical, environmental, etc.), conditions, and tasks that are performed. This is especially important when a new work task is initiated. Based upon the hazard analysis, safety procedures should be developed and implemented.

Agricultural employers are <u>not</u> exempt from the MIOSHA Right-to-Know law. This law requires all employers to assess the workplace to identify physical and health hazards, develop a written hazard communication program, obtain material safety data sheets for hazardous chemicals used, and provide employees with information and training on the physical or chemical hazards in their workplace.

To maintain fruit integrity, controlled atmosphere storage rooms are designed to have oxygen-deficient atmospheres as well as altered levels of nitrogen and carbon dioxide. To alert workers and reinforce with them the health and safety issues inherent in an oxygen-deficient atmosphere, employers should develop and implement a Right-to-Know program (hazard communication) that complies with MIOSHA regulations.

- Controlled atmosphere generating equipment and door manufacturers should include a confined space warning sign(s) on the equipment/door exterior.

The facility owner indicated that the aluminum door used to seal the room was delivered with the sign shown in Figure 4. This sign did not meet the MIOSHA warning requirements. Controlled atmosphere environments for the long-term storage of fruits and vegetables require a low oxygen level in the room, thus meeting the definition of a permit-required confined space. Although equipment manufacturers routinely affix appropriate warning signs/labels indicating safety hazards on equipment prior to shipment to the end user, this door manufacturer did not. Controlled atmosphere generating equipment and door manufacturers should include appropriate confined space warning signs affixed to the products they manufacture and ship.

Recommendations to commercial fruit and vegetable storage and warehousing facilities and to farmers storing fruits and vegetables in a similar way:

- Instruct employees/family members/visitors not to enter a confined space or other designated area to rescue an ill/injured individual unless trained and equipped with appropriate rescue equipment.

"Entry" means the action by which a person passes through an opening into a permit-required confined space. Entry includes ensuing work activities in that space and is considered to have occurred as soon as any part of the entrant's body breaks the plane of an opening into the space.

When the facility owner saw the deceased in the room, his first reaction was to come to the aid of his employee. His reaction was driven by emotion; when he took a deep breath and placed his head/body into the room to pull the decedent out of the room, he put his own life at risk.

Workers/family members should never, under any circumstances, enter a hazardous environment like a CA room to attempt a rescue operation unless properly equipped and trained in the use of the equipment and methods required for rescue. Workers/family members should be instructed to immediately contact the fire department or emergency rescue squad if they observe an individual unconscious or ill inside a room under CA condition. These squads will have the training and equipment needed to accomplish a rescue without further endangerment to life.

- Utilize electric forklifts when loading and unloading product in a CA room.

The best tool to use when loading and unloading product from a CA room is an electric forklift. Electric forklifts do not emit carbon monoxide. Although electric forklifts cost more to buy, additional benefits include a lower average annual operating cost compared to a propane-powered forklift, a longer operating life, and, because CA rooms are designed to restrict air and other gas transfer with outside air, electric forklifts minimize the risk of carbon monoxide (CO) poisoning for the forklift operator.

Carbon monoxide is odorless and colorless and can quickly build up in a room if a propane-powered forklift is used. The State of Washington found, from 1994 to 1999, approximately 41% of the state's CO poisonings specific to fruit packing and storage occurred in cold rooms or open CA rooms.

MIFACE recommends that prior to purchase of an electric forklift the employer consult with their insurance company, a safety professional, and local fire department to ensure that battery storage, charging and maintenance will satisfy appropriate safety considerations.

- Maintain and tune propane-powered forklifts for operations associated with CA rooms and any interior building use. If the forklift was manufactured prior to 2007, equip the forklift with a catalytic converter to further minimize CO emission. Since neither good maintenance nor a catalytic converter eliminate all carbon monoxide, this approach is not as effective as switching to an electric forklift.

The Environmental Protection Agency adopted regulations that governed the emissions of new forklifts (those with large spark-ignition engines rated at 19kW or more). Forklifts manufactured in 2007 meet a CO emission standard of 4.4 g/kW-hr and *if properly maintained,* should generate much lower concentrations of CO than previously manufactured forklifts. If electric forklifts cannot be utilized, employers should ensure that a propane-powered forklift has regular and proper maintenance, a properly sized and tuned carburetor, and a functional and properly tuned catalytic converter to reduce CO emissions. The system should have an air to fuel (A/F) ratio of 15.2:1 to get the best fuel economy and low CO emissions at approximately 0.5%. To ensure engines are properly tuned, an exhaust gas CO analyzer designed for tailpipe exhaust sampling should be used when adjusting the fuel system.

NOTE: Catalytic converters require well maintained engines tuned to the right A/F ratio. Catalytic converters may substantially reduce the risk of CO poisoning, but do not eliminate the risk, because catalytic converters do not eliminate all CO in exhaust gas; reductions are usually in the range of 70% to 90%. Since neither good maintenance nor a catalytic converter eliminate all carbon monoxide, this approach is not as effective as switching to an electric forklift.

- If propane-powered forklifts are used to load and unload product from a CA room, ensure the ventilation equipment in CA rooms is operating. Conduct air monitoring to determine the CO concentration in the room to protect the forklift operator from an overexposure. Consider using direct reading CO monitors (room or personal).

Because CO is less dense than air, CO tends to stay where it is generated unless it is removed via ventilation. Although CA rooms have limited ventilation, it should be

operational when loading/unloading the room to provide for further air movement in the room.

Employers should conduct air sampling to determine if the propane-powered forklift operator is exposed to CO exceeding the permissible exposure levels mandated by MIOSHA Occupational Health Standard Part 310, Air Contaminants. The standard requires that the airborne concentration of carbon monoxide should not exceed 35 ppm for an average 8-hour day during a 40-hour work week or 200 ppm during any part of the workday.

To determine room concentrations of CO, stationary CO monitors may be placed in the CA room (ideally integrated with the room's environmental monitoring system). A direct reading personal monitor for CO can be used to determine real-time exposure. MIFACE conducted an internet search for a CO personal monitor and found multiple brands priced under $200.00.

- Place oxygen and carbon monoxide air monitoring air portal lines or stationary air monitoring equipment at various locations in the CA room to better characterize the atmosphere in the room.

The employer affixed air portal lines to test for oxygen and carbon dioxide to the back wall of each CA room to replace probe sampling through the Plexiglas opening. This change of work practice has the added benefit of never requiring an operator to breach the CA condition by opening the area for the probe. If the system is used to determine when an opened CA room has an oxygen level safe for entry, the one stationary monitor may not fully characterize the environment. The employer should place several air monitors in the room to better describe the room environment, not only during CA storage conditions, but also for worker safety when entering a room just opened.

- Alert employees/family members to the hazard of sealed storage areas even when no oxygen drawdown has been done. These areas may have lower oxygen levels than expected.

When asked by the MIFACE researcher what information he would like other fruit storage and warehousing facilities to know, the owner quickly identified the discovery he had made after the fatality- the potential of a low oxygen level of a sealed room that had had no oxygen drawdown. A CA storage room had been filled three days prior. The door to the CA room was in place, but the Plexiglas window had not been placed over the door opening. The cooler door had been left open during these three days. On the third night, the cooler door was shut. On the morning of the fourth day, the owner tested the atmosphere, and found that the oxygen level had decreased to 18% from the ambient oxygen level of 21%.

He conducted another experiment to further characterize the hazard of decreased oxygen levels of a sealed room that has not been placed under CA storage conditions. The owner filled the room with apples, placed and sealed the CA aluminum door, placed the

Plexiglas window over the door opening and tightened the bolts and wing nuts, and then closed the cooler door. When testing the room atmosphere five days later under normal low temperature conditions the fruit continued to respire and the oxygen level in the room was reduced to 16.3-16.4%.

Health effects for exposure to low oxygen are most noticeable at 17% oxygen in air. At 17%, an individual would note an accelerated heartbeat and an increased breathing volume. At 16%, an individual could experience dizziness and an increased reaction time. When oxygen is at 15%, an individual may have impaired thinking and attention, an increased pulse and breathing rate, reduced coordination (loss of muscle control), rapid fatigue, and a decreased ability to work strenuously. If an individual has a lung disorder or other health problems, they could experience the health effects sooner than healthy individuals.

- Establish a CA room opening procedure to minimize inhalation hazards posed by low oxygen levels.

During the opening of CA rooms, the potential of workers to be exposed to low oxygen levels exists. MIFACE recommends owners/operators of CA facilities/rooms develop a CA room opening procedure. A sample procedure could include:

- turn off the artificial atmosphere generating equipment to the room,
- open outside door (in a double door system),
- place fan in front of door to provide cross ventilation in the event of a pressure difference (between low O2 room and service area),
- open sampling port (typically 5-8 inch round port) and allow ventilation for 12 hours,
- test oxygen with internal room sensors,
- place fan in front of internal panel view window,
- remove internal panel view window from the internal panel door and ventilate with fan for 24 hours,
- check oxygen level at both test ports with extended probe to determine if the level has returned to approximately 21 percent.

If the oxygen level has returned to normal atmosphere than the internal panel door may be removed, if not, continue ventilation and retest until both ports and internal sensors return to normal oxygen levels.

While many storage facilities were designed to provide external ventilation during the room opening process, construction, renovation, stacks of bins/totes and ambient weather conditions may impede the designed air flow and allow for low O_2 level air to be vented within the facilities' service areas. Storage operators should consult with their refrigeration specialist to determine if any adjustments to opening procedures or the installation of additional equipment is appropriate for the given room(s). The installation of an additional O_2 sensor in the service area can provide a warning system during the opening process. Generally, these service areas are designed to maintain positive pressure or to have significant ambient ventilation due to temperature gradients. Storage operators

should understand which methods are employed in their facilities and assure the designed ventilation is not impeded.

Recommendation to MSU Extension:

- Update the Controlled Atmosphere Storage and Warehousing Clinic manual to comply with MIOSHA health and safety standards.

The MSU Extension Controlled Atmosphere Storage and Warehousing Clinic is essentially a primer on strategies for storage of fruit in controlled atmospheres to control internal breakdown associated with fruit aging. The Clinic education program reaches two audiences; commercial fruit and vegetable storage facilities that are required to comply with MIOSHA requirements and farmers who may store their own product in a storage/warehouse facility and are not required to comply with all of the MIOSHA requirements, but who could benefit from knowing about and adopting the safety practices required by MIOSHA for commercial facilities.

At each Clinic, a manual is given to participants to take home for reference. Within the manual there is a seven page section on Controlled Atmosphere Storage Safety Considerations. This section includes a CA Storage Safety Section. The safety section contains some useful information, but the information in the "Preparation and Procedure for Entering a Closed CA Room" and "Occupational Exposure Limits" do not comply with the MIOSHA requirements detailed in the Permit-Required Confined Space Standard, Part 490, and MIOSHA Occupational Health Standard, Air Contaminants, Part 301.

MIFACE recommends that MSU Extension update the safety section of the manual to ensure the information contained therein complies with MIOSHA safety and health standards.

REFERENCES

MIOSHA standards cited in this report may be found at and downloaded from the MIOSHA, Michigan Department of Energy, Labor & Economic Growth (DELEG) website at: www.michigan.gov/mioshastandards. MIOSHA standards are available for a fee by writing to: Michigan Department of Energy, Labor & Economic Growth, MIOSHA Standards Section, P.O. Box 30643, Lansing, Michigan 48909-8143 or calling (517) 322-1845.

- MIOSHA General Industry Safety Standard, Part 90, Confined Space Entry
- MIOSHA Occupational Health Standard, Part 490, Permit-Required Confined Spaces
- MIOSHA Occupational Health Standard, Part 430, 1910.1200, Hazard Communication
- MIOSHA Occupational Health Standard, Part 301, Air Contaminants

- MSU CA Clinic: 2006 – Controlled Atmosphere Storage and Warehousing Clinic, Volume 5, Part 2
- *Carbon Monoxide Hazards from Internal Combustion Engines.* MIOSHA Consultation, Education and Training Division. http://www.michigan.gov/documents/cis_wsh_cet5011_115680_7.doc
- Oxygen Deficiency Hazard Safety Book. Jefferson Lab. Revised July 2008. http://www.jlab.org/accel/safetylb/ODH-book.pdf
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Key Words: Confined Space, Oxygen Deficiency, Controlled Atmosphere Storage, Agriculture

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MIFACE

Investigation Report #08 MI 121
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