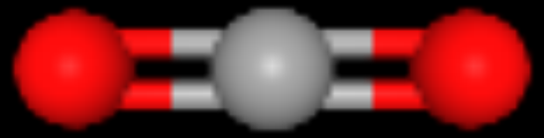
RATIONAL. OBJECTIVE. EHS SOLUTIONS.

CO_2 & YOU: WHAT YOU AND YOUR EMPLOYEES NEED TO KNOW

WHAT IS CARBON DIOXIDE?

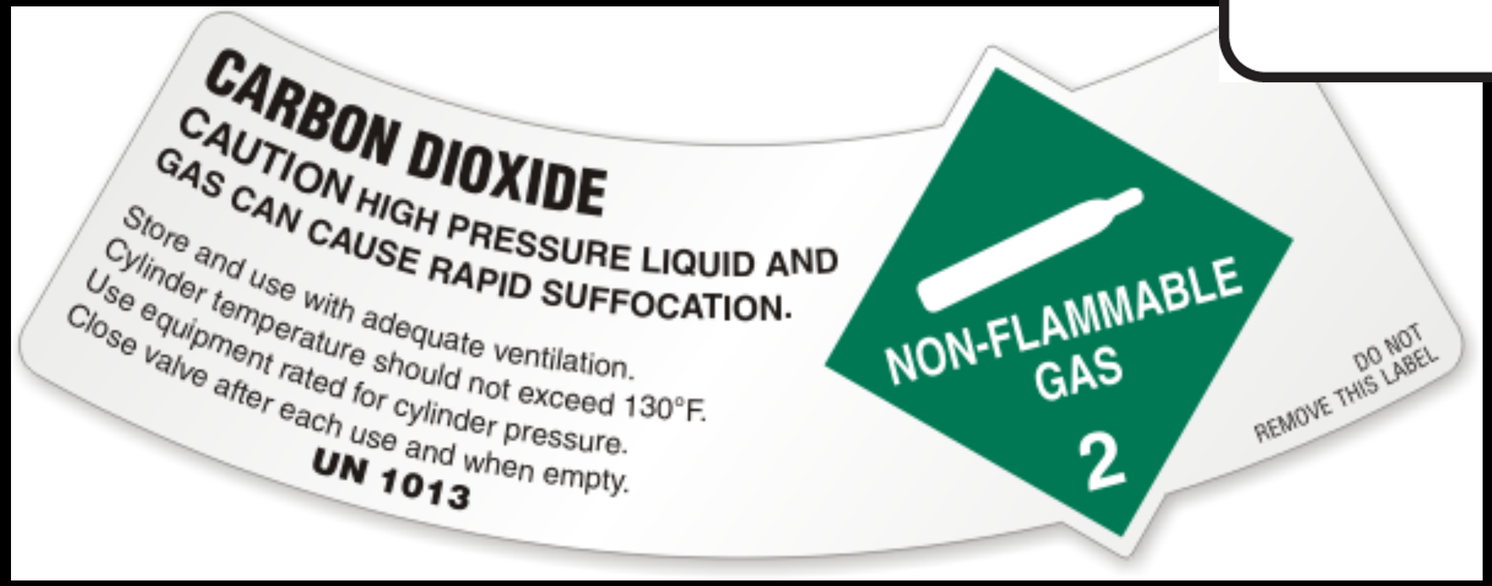
- Greenhouse gas
- Natural
- Harmless in small quantities
- Most commonly produced indoors by exhalation
- Colorless, odorless gas at atmospheric temperatures and pressures



- Relatively nontoxic and non
- 1.54x heavier than air
- Forms carbonic acid
- Under prolonged exposure fire a container may rupture violently and rocket
- Produced by respiration by all animals

WHAT IS CARBON DIOXIDE?

- US DOT Hazardous Material
  - UN1013, Carbon Dioxide, 2.2



HAZMAT CIVIL PENALTIES RAISED (AGAIN)

- Hazmat Shipping Violation Maximum: $83,439 to $84,425 per day, per violation
- Violation the results in death, serious illness, severe injury, or substantial property damage: $194,691 to $196,992 per violation, per day
- **Minimum penalty for failure to provide hazmat training for employees: $502 to $508 per employee, per day**
- For more information: https://www.govinfo.gov/content/pkg/FR-2021-05-03/pdf/2021-08224.pdf

WHAT IS CARBON DIOXIDE?

- Food Grade vs. Beverage Grade
- International Society of Beverage Technologies (ISBT) Carbon Dioxide Guidelines
  - 22 parameters included for purity:
    - Sensory,
    - Process, or
    - Regulatory
  - 21 CFR 184.1240
    - Ingredient must be of a purity suitable for its intended use

Parameter		Rationale [1]
Purity	99.9% v/v min.	Process
Moisture	20 ppm v/v max.	Process
Acidity	To pass test	Regulatory
Oxygen	30 ppm v/v max.	Sensory
Nitrogen compounds		
Ammonia	2.5 ppm v/v max.	Process
Nitric oxide/nitrogen dioxide	2.5 ppm v/v max. each	Regulatory
Non-volatile residue	10 ppm w/w max.	Sensory
Non-volatile organic residue	5 ppm w/w max.	Sensory
Phosphine	To pass test (0.3 ppm v/v max)	Regulatory
Total volatile	50 ppm v/v max. of which 20 ppm v/v	Sensory
Hydrocarbons (as methane)	max. of non-methane hydrocarbons	
Acetaldehyde	0.2 ppm v/v max.	Sensory
Aromatic hydrocarbon	0.020 ppm v/v max.	Regulatory
Carbon monoxide	10 ppm v/v max.	Process
Total sulfur (as S)	0.1 ppm v/v max.	Sensory
Carbonyl sulfide	0.1 ppm v/v max.	Sensory
Hydrogen sulfide	0.1 ppm v/v max.	Sensory
Sulfur dioxide	1 ppm v/v max.	Sensory
Appearance in water	No color or turbidity	Sensory
Odor	Odorless	Sensory
Taste and odor	No foreign taste or odor in water	Sensory

Table 1. ISBT Carbon Dioxide Guidelines.

[1]Rationale definitions:
Sensory: Any attribute that negatively impacts the taste, appearance, or odor of beverage.
Process: Any attribute that defines a key parameter in a controlled process and an important consideration in the beverage industry.
Regulatory: Any attribute whose limit is set by governing regulatory agencies.

WHY IS CARBON DIOXIDE IMPORTANT?

- Plants use it to produce carbohydrates during photosynthesis
- Feedstock to replace organic substances (minerals, water, wood)
- Chemical manufacturing
- Food and beverage production
- Enhanced Oil Recovery
- Dry cleaning
- Electronics cleaning
- Indoor cultivation
- Fire suppression

CARBON DIOXIDE MANUFACTURING

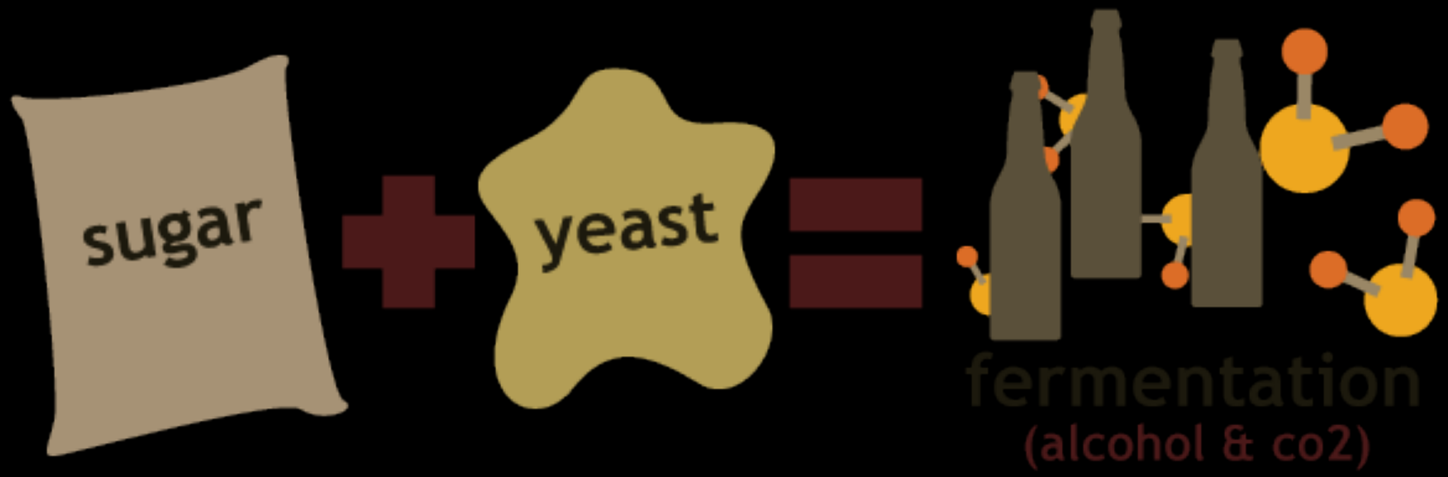
- Mostly generated as byproduct of commercial ammonia and hydrogen production
- Flue gases produced by the complete combust of carbonaceous fuels
- Fermentation processes (up to 80% may be recoverable)

HOW IS CARBON DIOXIDE USED IN BREWING?

- Refrigerant
- Flavor enhancer/agent/adjuvant
- Carbonating agent
- Pre-filling bottles
- Head-spacing filling
- Blanketing Vessels

HOW IS CARBON DIOXIDE GENERATED DURING BREWING?

- Produced by yeast during fermentation and creates the “fizz” or “condition” characteristic of beer
- In anaerobic fermentation, yeast converts the sugars in the wort to, primarily, alcohol and CO_2

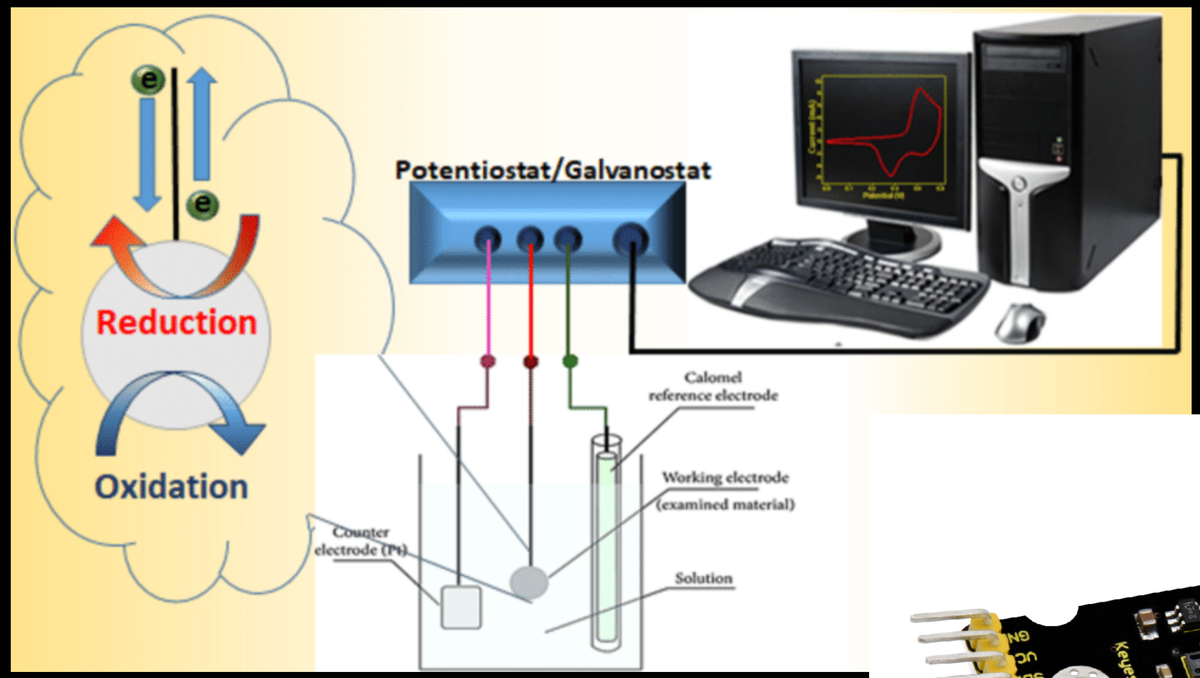


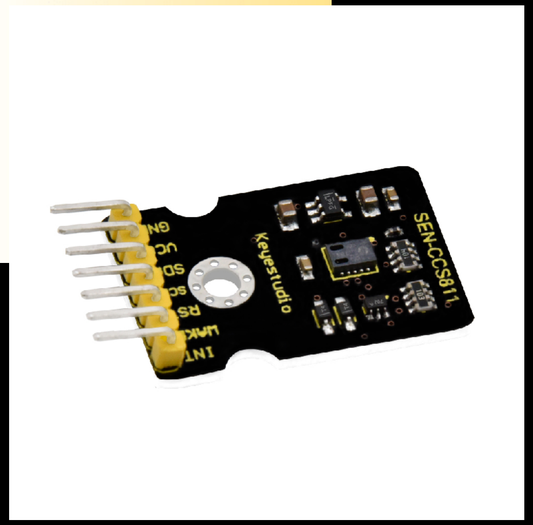
HOW TO MONITOR FOR CARBON DIOXIDE?

- Portable Monitors
  - Spot checks, walk arounds, lead source identification

HOW TO MONITOR FOR CARBON DIOXIDE?

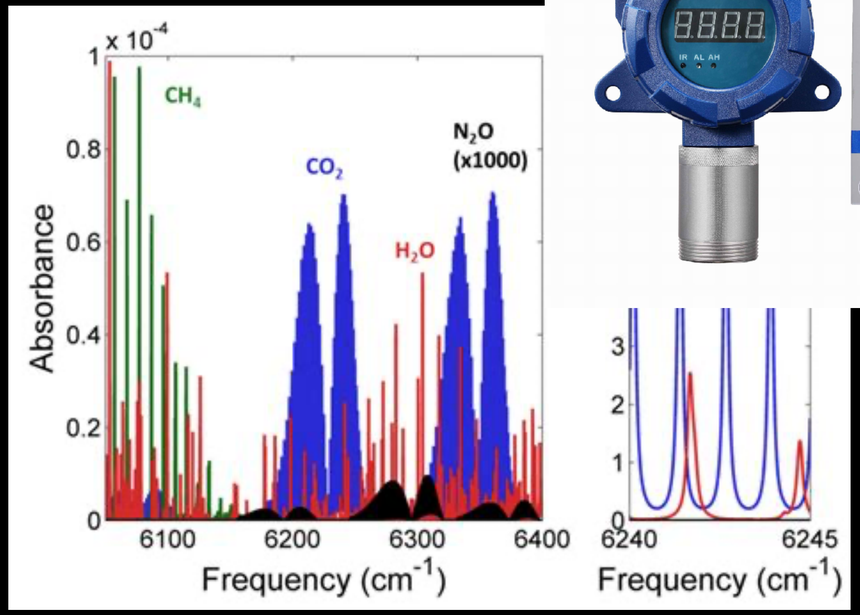
- Fixed Monitoring System
  - Electrochemical
    - Direct
    - Indirect
  - Metal Oxide/Solid State

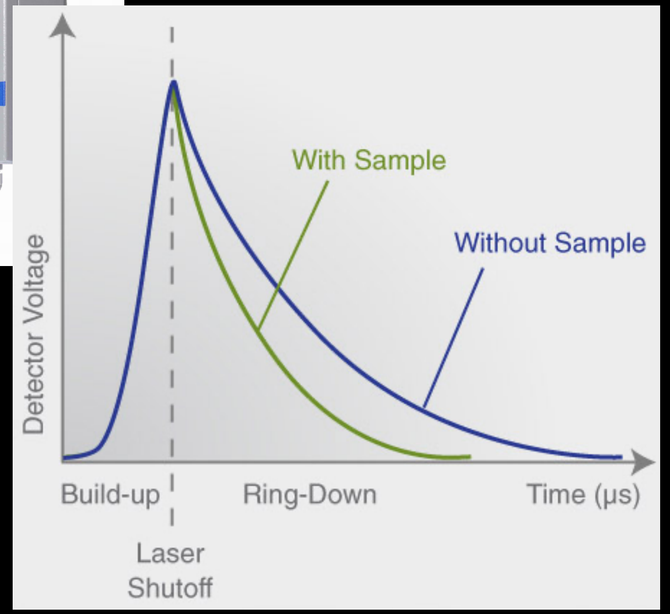




HOW TO MONITOR FOR CARBON DIOXIDE?

- Infrared
  - NDIR
  - Photo-acoustic IR
- Spectroscopy
  - Cavity Ring-Down
  - Laser Absorption





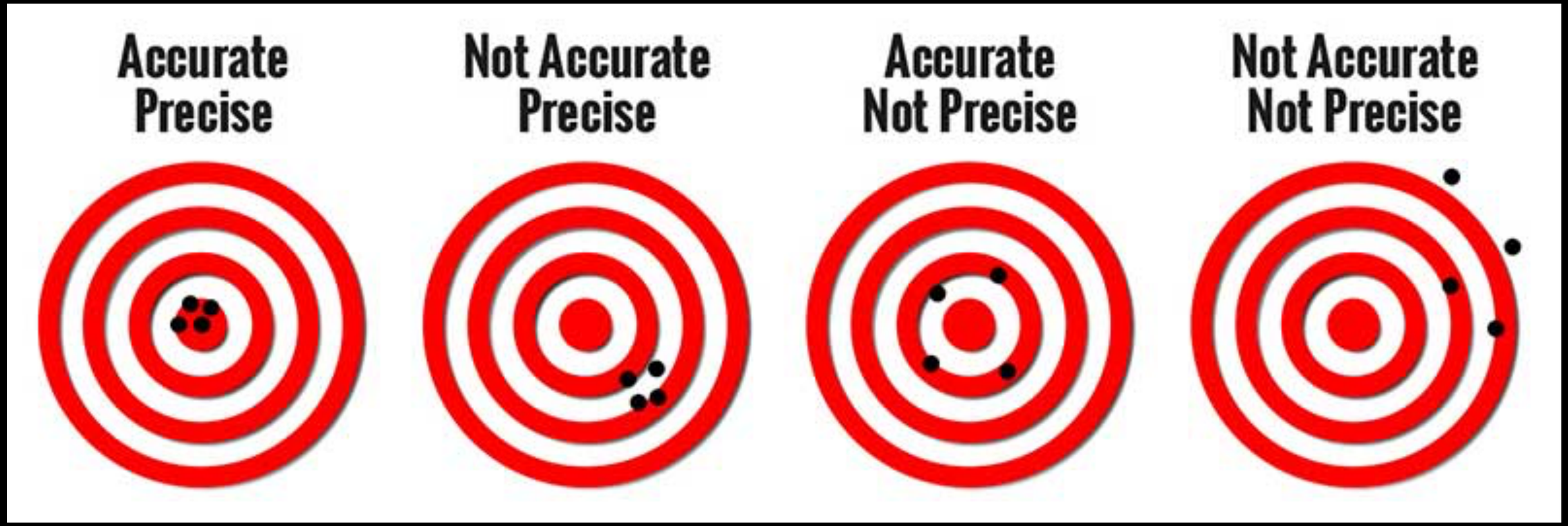
CHALLENGES TO CARBON DIOXIDE MONITORING

- Temperature
- Washdown
- Interfering Gases
- Functionality Needed
- Maintenance & Support Required
- Detection Range of Instruments

RANGE VS. ACCURACY

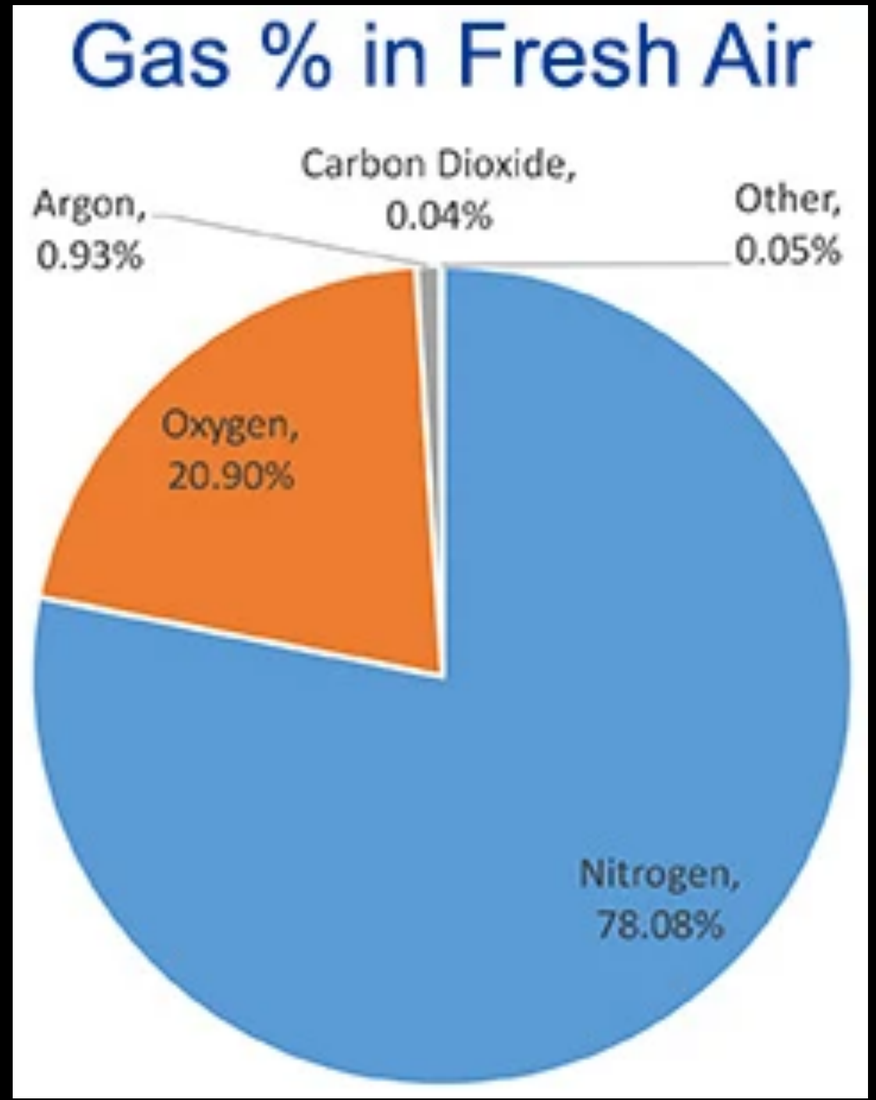
- Measure 400 ppm CO_2, using a 100% CO_2 sensor and the CO_2 level increased to 500 ppm, the change would be from 0.04% to 0.05%
  - This 0.01% (100 ppm) change is outside the 100 - 300 ppm range accuracy of a typical 100% CO_2 sensor; thus the sensor would probably not record any change
- The accuracy of a 10,000 ppm NDIR sensor is around 50 ppm (0.005%)
  - While you would likely not see an exact 100 ppm change, you would see a rising trend toward 100 ppm

ACCURACY VS. PRECISION



UNDERSTANDING CONCENTRATIONS

- Imagine you have 1,000,000 molecules of air
  - Nitrogen: ~780,000 (78%)
  - Oxygen: ~209,000 (20.9%)
  - Argon: ~9,000 (0.09%)
  - CO_2, Neon, Methane, Helium: ~2,000 (0.02%)
    - CO_2: ~400 (0.04%)



HEALTH IMPACTS OF CARBON DIOXIDE EXPOSURE

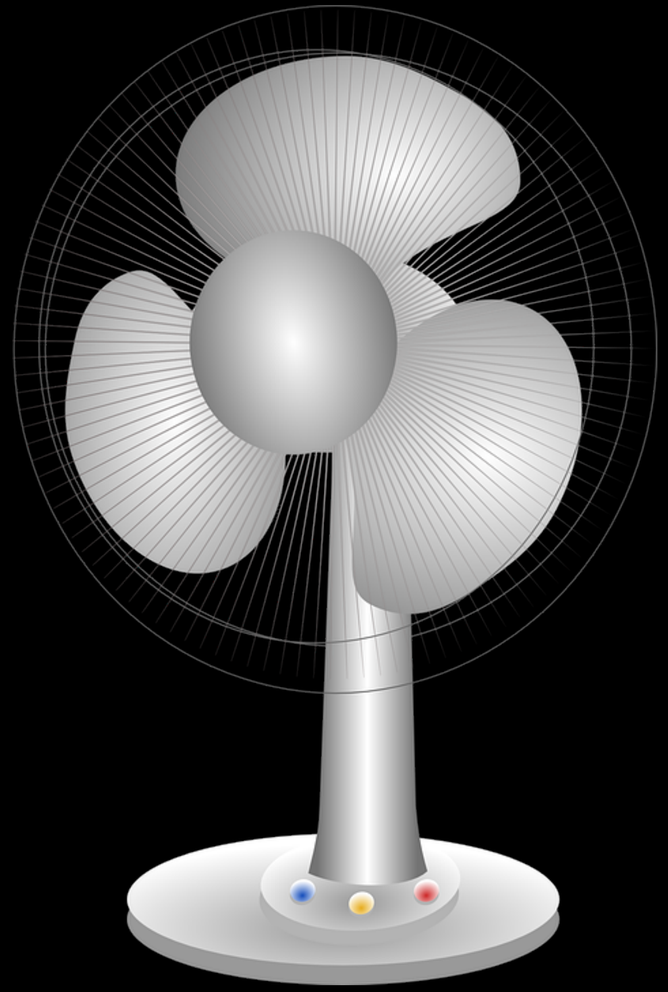
- Historically classified at an asphyxiant and thus not harmful
- Direct effects
- Indirect effects of displacing oxygen
- At 600 ppm affects brain function to assess, calculate and reason
- Increased fatigue at 1,000 ppm

ACUTE HEALTH EFFECTS OF CARBON DIOXIDE EXPOSURE

PPM	Acute Health Effects
250 - 400	Normal background concentration in outdoor ambient air
400 - 1,000	Concentrations typical of occupied indoor spaces with good air exchange
1,000 - 2,000	Complaints of drowsiness and poor air
2,000 - 5,000	Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea (OSHA PEL: 5,000 ppm)
>40,000	May lead to serious oxygen deprivation resulting in permanent brain damage, coma and even death (IDLH: 40,000 ppm)

HAZARD MITIGATION: VENTILATION

- Poor ventilation allows excessive CO_2 to build up
- Ventilation rate per person is estimated by indoor CO_2 ppm above outdoor ppm
- Higher CO_2 relates to lower occupant health, comfort and performance
  - Tap Room



HAZARD MITIGATION: VENTILATION

- ASHRAE Standard 62.1-2016 “Ventilation for Acceptable Indoor Air Quality”
  - Typical office building CO_2 concentrations 700 ppm above outdoor air levels
    - Air ventilation rate of about 7.5 L/s/person (15 cfm/person)
    - Typical outdoor CO_2 concentrations range from 300 to 500 ppm

HAZARD MITIGATION: WALK-IN COOLERS

- When CO_2 gets colder it sinks faster and moves slower
- Exhaust fans and ventilation systems become less effective at moving/mixing the air

BLANKETING VESSELS WITH CARBON DIOXIDE

- A dangerous concentration remains for hours
- Higher concentrations in the cone, below the manway
- Purge the vessel prior to work
  - Confined space entry

BEST MANAGEMENT PRACTICES

- Ventilation systems should exhaust from the lowest level and allow fresh air to enter at a higher point
- Operators should be trained on proper operation, installation and maintenance of CO_2 systems and storage containers, and symptoms of exposure
- Storage containers should be stored in well-ventilated area outside
- Periodically check fittings, connections, piping/hoses/tubes, and storage container plumbing for leaks and as recommended by the manufacturer
- Install, inspect, and maintain detectors with alarm systems in appropriate areas

LEAK RESPONSE

- Evacuate the area for at least 330 feet in all directions
- Stop the leak if you can do so safely
- Ventilate the area
- Ensure emergency responders are made aware of the leaking material
- Move exposed personnel to fresh air, if it can be done safely
- ERG 120: https://cameochemicals.noaa.gov/erg_guides/en/Guide_120.pdf

POTENTIAL HAZARDS

HEALTH

- Vapors may cause dizziness or asphyxiation without warning.
- Vapors from liquefied gas are initially heavier than air and spread along ground.
- Contact with gas or liquefied gas may cause burns, severe injury and/or frostbite.

FIRE OR EXPLOSION

- **Non-flammable gases.**
- Containers may explode when heated.
- Ruptured cylinders may rocket.

PUBLIC SAFETY

- **CALL EMERGENCY RESPONSE Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- As an immediate precautionary measure, isolate spill or leak area for at least 100 meters (330 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind, uphill and/or upstream.
- Many gases are heavier than air and will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Ventilate closed spaces before entering.

PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Structural firefighters' protective clothing will only provide limited protection.
- Always wear thermal protective clothing when handling refrigerated/cryogenic liquids or solids.

EVACUATION

Large Spill

- Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire

- If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions.

EMERGENCY RESPONSE

FIRE

- Use extinguishing agent suitable for type of surrounding fire.
- Move containers from fire area if you can do it without risk.
- Damaged cylinders should be handled only by specialists.

Fire involving Tanks

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Do not direct water at source of leak or safety devices; icing may occur.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.

SPILL OR LEAK

- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material.
- Do not direct water at spill or source of leak.
- If possible, turn leaking containers so that gas escapes rather than liquid.
- Prevent entry into waterways, sewers, basements or confined areas.
- Allow substance to evaporate.
- Ventilate the area.

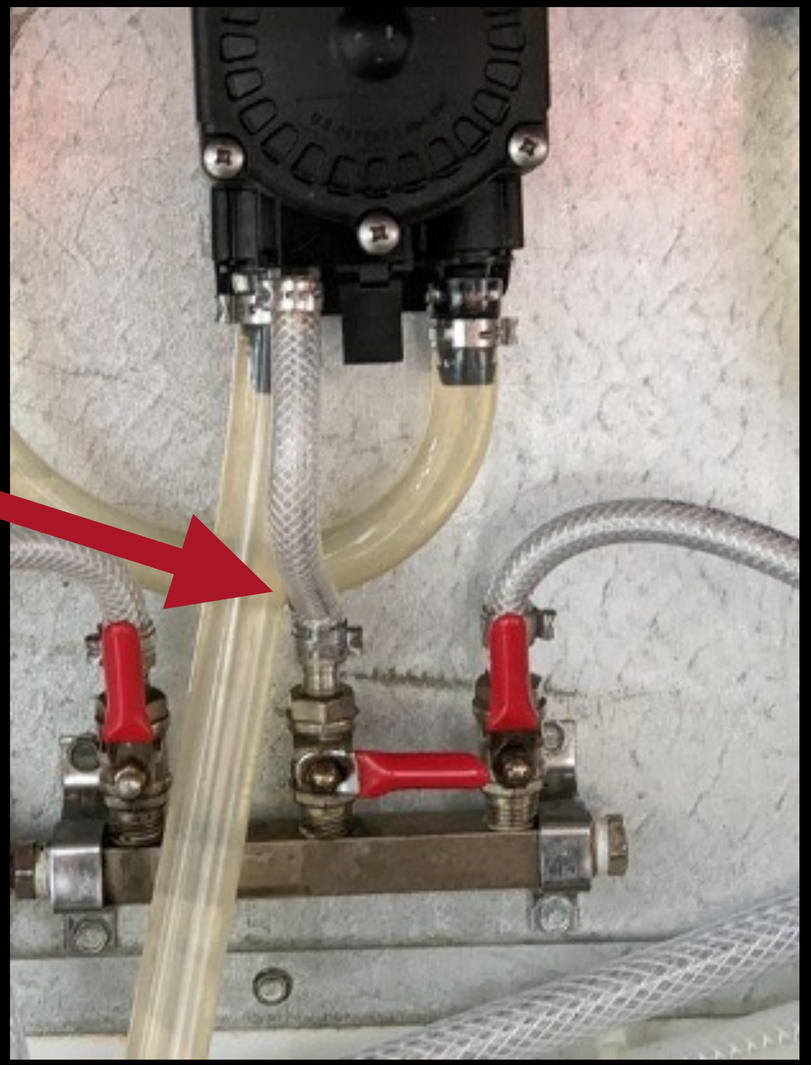
CAUTION: When in contact with refrigerated/cryogenic liquids, many materials become brittle and are likely to break without warning.

FIRST AID

- Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves.
- Move victim to fresh air.
- Call 911 or emergency medical service.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Clothing frozen to the skin should be thawed before being removed.
- In case of contact with liquefied gas, thaw frosted parts with lukewarm water.
- Keep victim calm and warm.

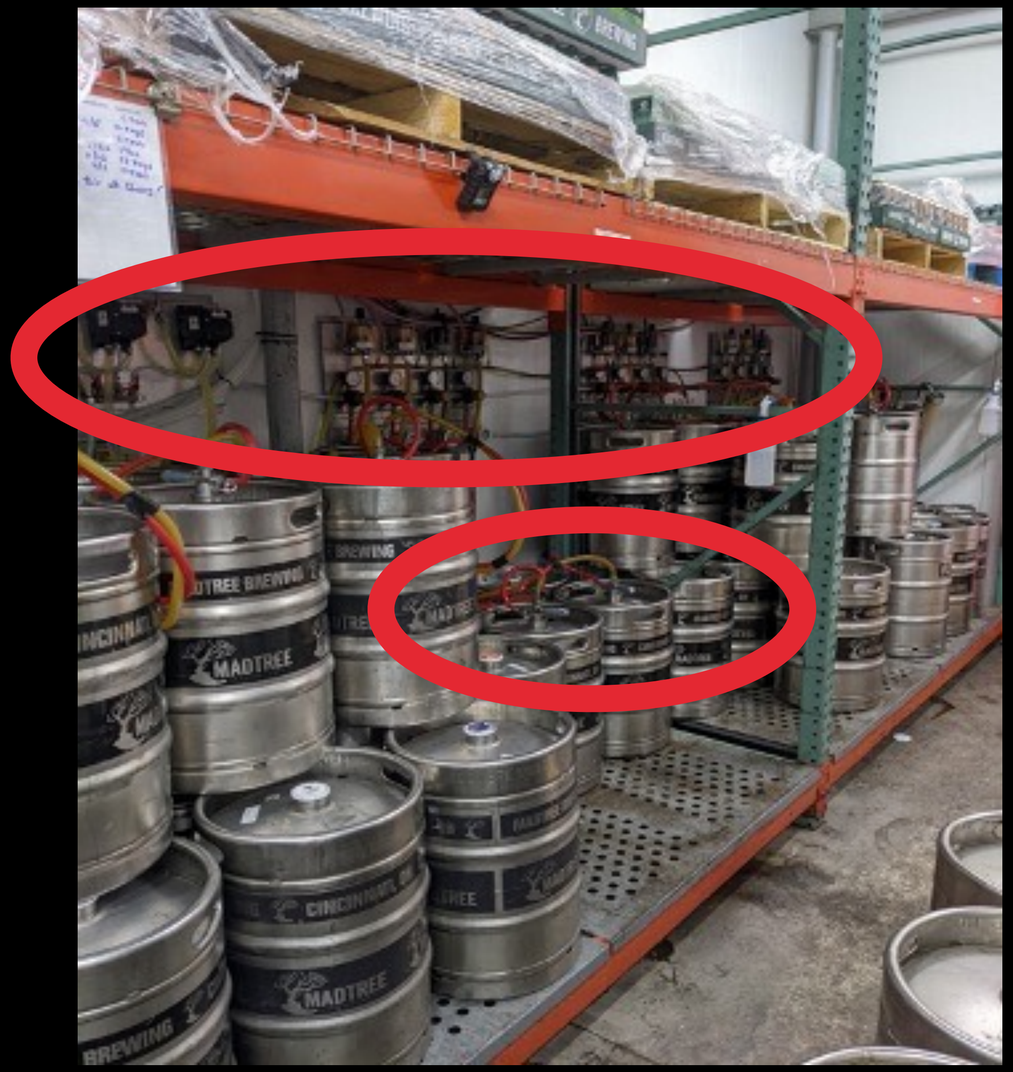
MADTREE BREWING AND CARBON DIOXIDE

- Taproom Cooler
  - Damaged Hose
- Safety Committee
  - Near Miss
- Motion of Change
  - Wide Communication Across Departments
- Opportunities
  - Training and Monitoring



MADTREE BREWING AND CARBON DIOXIDE

- Hose Clamp Failure Leading to CO2 Risk
- Previous Training and Carbon Dioxide Monitor
- Previous Efforts Helped Improve Safety



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