AIHce 2017

Welcome to Seattle, Washington

Measuring atmospheric hazards at commercial cannabis grower and extractor facilities

Presented by:

Bob Henderson, BS, MBA

AIHce 2017 EXP
Seattle, Washington • June 4-7

Growth and extraction of marijuana products legal, licensed, taxed and regulated in Colorado

- 28 states and the District of Columbia currently have laws legalizing marijuana in some form
- Atmospheric hazards exist in classic PCS as well other workplace areas which may or may not be formally designated confined spaces
- Fire Service personnel perform periodic inspections at licensed commercial sites, and are exposed to potentially dangerous atmospheric conditions
- Emergency response can expose fire department personnel to additional risks

Types of enterprises

- **Non-commercial**
  – Products for personal use only
- **Commercial (licensed) enterprises**
  – Recreational marijuana
    - Independent growers and extractors
      – Smaller scale, heavily taxed, minimally funded
  – Medical marijuana
    - Larger scale, integrated growth and extraction, better funded, better managed, increasingly big business

Commercial marijuana enterprises in Denver must have license

- **Requires signoff and yearly inspection by Denver Fire Department**
- **"Grow" areas (greenhouses):**
  - Cultivation areas where atmosphere often artificially enriched by adding CO_2
  - Required to be monitored by means of fixed CO_2 detection system with alarm at 5000 ppm
- **"Extraction" rooms:**
  - Rooms where LPG (butane) used to extract "hash oil" (BHO) and other fractionated products deemed to be Class I Division 1 hazardous locations
  - Adjacent areas deemed to be Class I Division 2 areas
  - Required to be monitored for combustible gas
  - Rooms where supercritical CO_2 used for extraction must be monitored for carbon dioxide

Grower hazards

- **CO_2 necessary for plant growth (photosynthesis)**
  - Increasing light (lumens), temperature, humidity and CO_2 concentration used to accelerate growth
- **Optimal CO_2 concentration for growth between 1200 and 1500 ppm**
  - Grow area tightly sealed
- **At most licensed enterprises CO_2 introduced via:**
  - Compressed CO_2 gas: cylinders of high concentration gas controlled with solenoids and valves
  - CO_2 generators: make by burning alcohol or natural gas
- **At non-commercial sites CO_2 generation via:**
  - Open flame burners, fermentation (sugar yeast and water), dry ice, vinegar + baking soda, composting (aerobic decomposition)

Best practices for eliminating or managing hazards

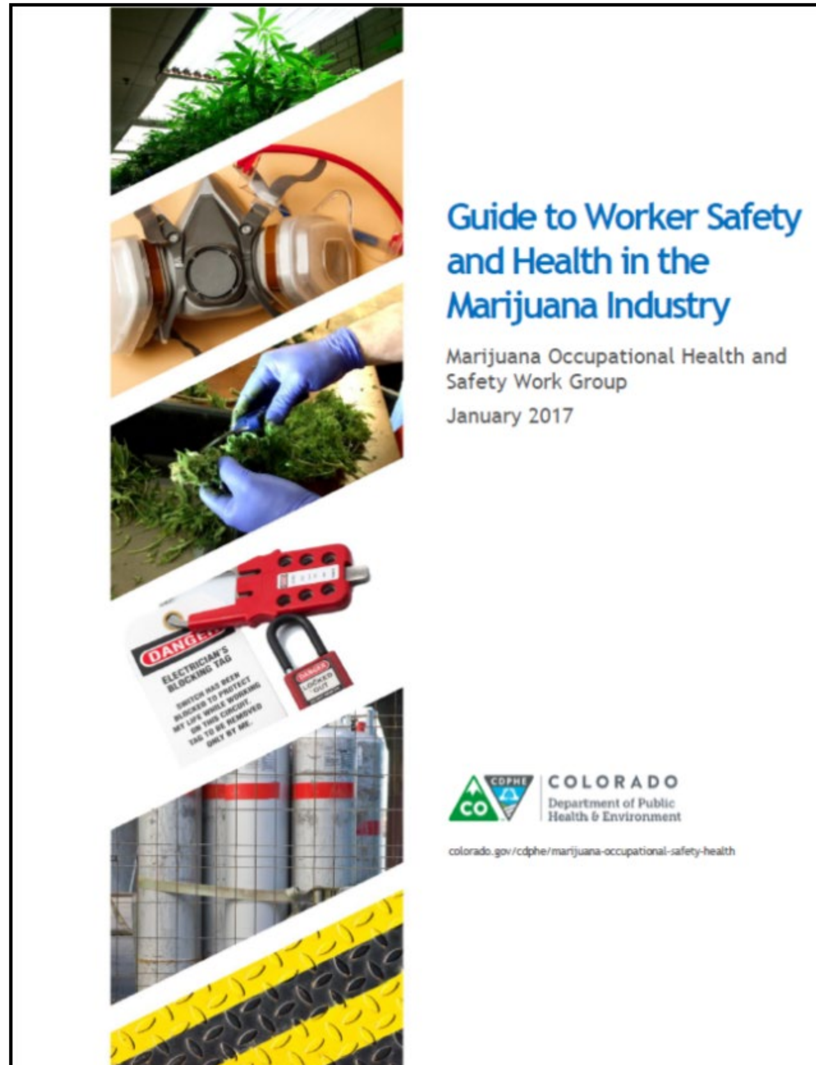
Provides guidance from Colorado Department of Public Health and Environment

"In normal concentrations, CO_2 does not pose a health hazard. However, at high concentrations, CO_2 acts as a simple asphyxiant. A simple asphyxiant is a gas or vapor that displaces oxygen."

"Install CO_2 monitoring devices in areas where concentrations of CO2 might be elevated."

"Implement engineering controls to maintain environmental concentrations below permissible exposure levels."

"Do not use or store dry ice in confined areas, walk-in refrigerators, environmental chambers or rooms without ventilation. A leak in such an area could cause an oxygen-deficient atmosphere."



Denver FD Carbon Dioxide (CO_2) Gas Enrichment System Policy

8. Signage shall be provided on the exterior door of each grow cultivation room/area utilizing CO_2 and in each room storing CO_2 stating:

NFPA 704 Simple Asphyxiant placards shall also be provided at the exterior main entrance and at rooms where CO_2 is used or stored.

CITY AND COUNTY OF DENVER	POLICY	DENVER FIRE DEPARTMENT
Subject: CARBON DIOXIDE (CO_2) GAS ENRICHMENT SYSTEMS		
Reference: IFC, Denver Amendments, NFPA		
Approved: Joseph L. Gonzales, Division Chief, Fire Prevention Division		
Number: IFC- 2009	Effective Date: March 9, 2014	Page 1 of 8

This policy is meant to provide basic information based on currently available information regarding the use of carbon dioxide gas enrichment systems for most common conditions and situations. In any given occupancy, many other Fire Code requirements may be enforced. These will be addressed by the Fire Inspector during a premises inspection. Questions can be addressed to the Fire Prevention Division office between 6:30 a.m. and 4:30 p.m. Monday thru Friday at (720) 913-3474 or at DFDFPB@DENVERGOV.ORG. Permits may ONLY be obtained Monday thru Friday, between 6:30 a.m. and 9:00 a.m. from the 1st floor at 745 West Colfax Avenue.

I. **SCOPE**

This policy covers the safety requirements as they pertain to the use and storage of carbon dioxide (CO_2) gas enrichment systems within the City and County of Denver for any system storing and using more than 100 pounds of carbon dioxide **or** any system storing or using any amount of CO_2 below grade, including a basement or crawl space **or** any natural gas CO_2 generators.

II. **PERMITS**

An annual operational permit shall be obtained from the Denver Fire Department's Fire Prevention Division for a carbon dioxide (CO_2) enrichment system as defined in the scope.

- **Official policy focus is on O_2 displacement rather than on toxic effects of CO_2 exposure**

CO_2 enrichment systems

- CO_2 from gas burner

- CO_2 from cylinder

  - CO_2 released near ceiling, flows downward as consequence of density
  - Localized pockets of CO_2 or elevated O_2 can affect growth
  - Use fans to disperse and bring gas to plants

AIHce EXP 2017
Seattle, Washington • June 4-7

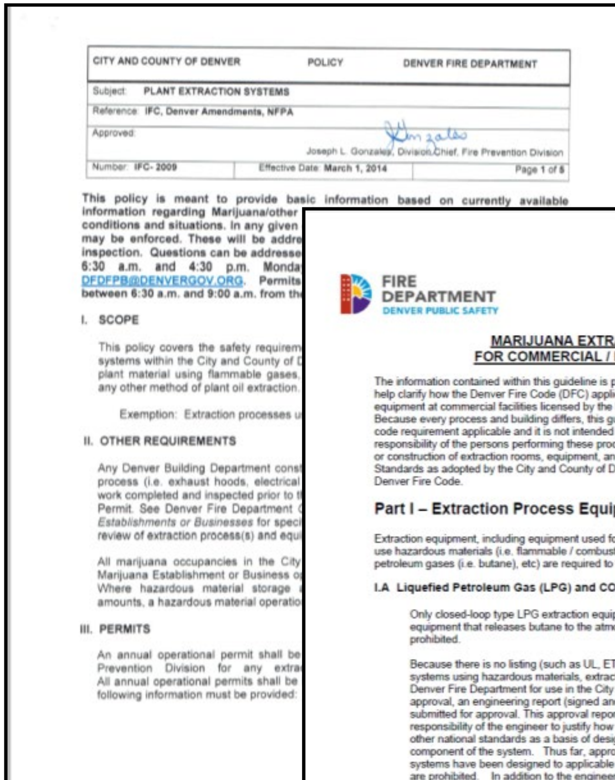
CO_2 monitoring system required

- **All CO_2 Detectors must be calibrated, and pass inspection by the Denver Fire Prevention Division, Cannabis Taskforce**

Extraction equipment

- **Performing extractions involves use of hazardous gases and solvents**
  - Using butane is the most cost effective yet most dangerous method of extraction
  - Denver Fire Department has developed extraction guidelines for commercial/ licensed facilities that clarify the code requirements of the 2016 Denver Fire Code (2015 International FIre Code with Denver Amendments) Chapter 39.
  - Supercritical CO_2 is commonly used for extractions and is covered under its own section in this document.
- **Extraction equipment that utilizes hazardous materials (i.e. flammable/ combustible liquids, carbon dioxide, liquefied petroleum gases (i.e. butane) required to be listed or approved per the Denver Fire Code**
  - Only closed-loop type liquefied petroleum gas extraction equipment is permitted
  - Equipment must be inspected by Denver Fire Department before use

Extraction rooms and equipment



CITY AND COUNTY OF DENVER	POLICY	DENVER FIRE DEPARTMENT
Subject: PLANT EXTRACTION SYSTEMS		
Reference: IFC, Denver Amendments, NFPA		
Approved:		Joseph L. Gonzales, Division Chief, Fire Prevention Division
Number: IFC- 2009	Effective Date: March 1, 2014	Page 1 of 5

This policy is meant to provide basic information based on currently available information regarding Marijuana/other conditions and situations. In any given may be enforced. These will be addre inspection. Questions can be addresse 6:30 a.m. and 4:30 p.m. Monda DFDFPB@DENVERGOV.ORG. Permits between 6:30 a.m. and 9:00 a.m. from th

I. SCOPE

This policy covers the safety requirem systems within the City and County of D plant material using flammable gases, any other method of plant oil extraction.

Exemption: Extraction processes u

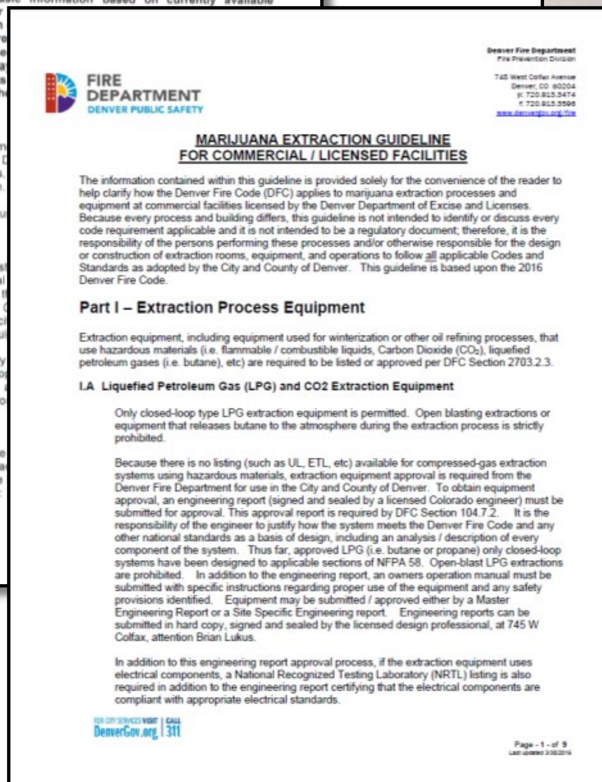
II. OTHER REQUIREMENTS

Any Denver Building Department const process (i.e. exhaust hoods, electrical work completed and inspected prior to t Permit. See Denver Fire Department *Establishments or Businesses* for speci review of extraction process(s) and equi

All marijuana occupancies in the City Marijuana Establishment or Business o Where hazardous material storage amounts, a hazardous material operatio

III. PERMITS

An annual operational permit shall be Prevention Division for any extra All annual operational permits shall be following information must be provided:



FIRE DEPARTMENT
DENVER PUBLIC SAFETY

Denver Fire Department
Fire Prevention Division

745 West Colfax Avenue
Denver, CO 80204
p: 720.913.3474
f: 720.913.3596
www.denvergov.org/fire

MARIJUANA EXTRACTION GUIDELINE
FOR COMMERCIAL / LICENSED FACILITIES

The information contained within this guideline is provided solely for the convenience of the reader to help clarify how the Denver Fire Code (DFC) applies to marijuana extraction processes and equipment at commercial facilities licensed by the Denver Department of Excise and Licenses. Because every process and building differs, this guideline is not intended to identify or discuss every code requirement applicable and it is not intended to be a regulatory document; therefore, it is the responsibility of the persons performing these processes and/or otherwise responsible for the design or construction of extraction rooms, equipment, and operations to follow all applicable Codes and Standards as adopted by the City and County of Denver. This guideline is based upon the 2016 Denver Fire Code.

Part I – Extraction Process Equipment

Extraction equipment, including equipment used for winterization or other oil refining processes, that use hazardous materials (i.e. flammable / combustible liquids, Carbon Dioxide (CO_2), liquefied petroleum gases (i.e. butane), etc) are required to be listed or approved per DFC Section 2703.2.3.

I.A Liquefied Petroleum Gas (LPG) and CO2 Extraction Equipment

Only closed-loop type LPG extraction equipment is permitted. Open blasting extractions or equipment that releases butane to the atmosphere during the extraction process is strictly prohibited.

Because there is no listing (such as UL, ETL, etc) available for compressed-gas extraction systems using hazardous materials, extraction equipment approval is required from the Denver Fire Department for use in the City and County of Denver. To obtain equipment approval, an engineering report (signed and sealed by a licensed Colorado engineer) must be submitted for approval. This approval report is required by DFC Section 104.7.2. It is the responsibility of the engineer to justify how the system meets the Denver Fire Code and any other national standards as a basis of design, including an analysis / description of every component of the system. Thus far, approved LPG (i.e. butane or propane) only closed-loop systems have been designed to applicable sections of NFPA 58. Open-blast LPG extractions are prohibited. In addition to the engineering report, an owners operation manual must be submitted with specific instructions regarding proper use of the equipment and any safety provisions identified. Equipment may be submitted / approved either by a Master Engineering Report or a Site Specific Engineering report. Engineering reports can be submitted in hard copy, signed and sealed by the licensed design professional, at 745 W Colfax, attention Brian Lukus.

In addition to this engineering report approval process, if the extraction equipment uses electrical components, a National Recognized Testing Laboratory (NRTL) listing is also required in addition to the engineering report certifying that the electrical components are compliant with appropriate electrical standards.

FOR CITY SERVICES VISIT DenverGov.org | CALL 311

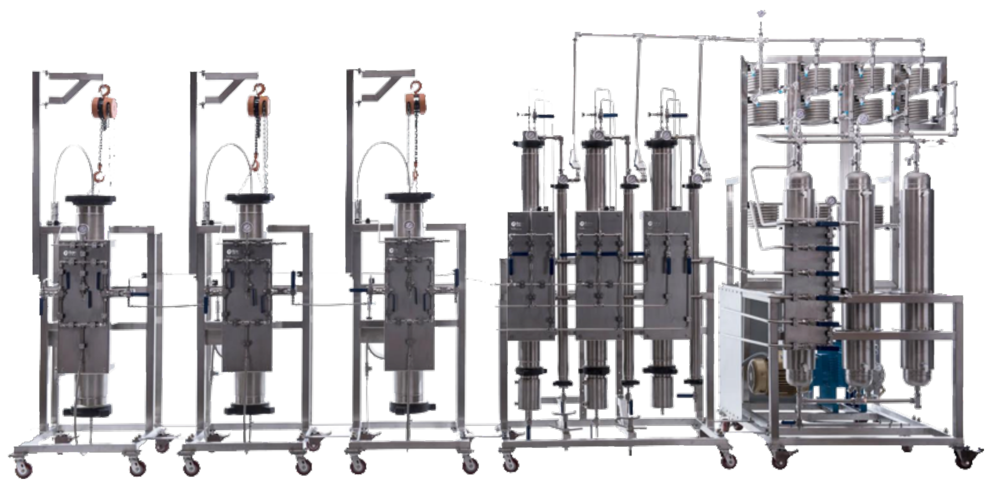
Page - 1 - of 9

- **Monitoring system required**

AIHce EXP 2017
Seattle, Washington • June 4-7

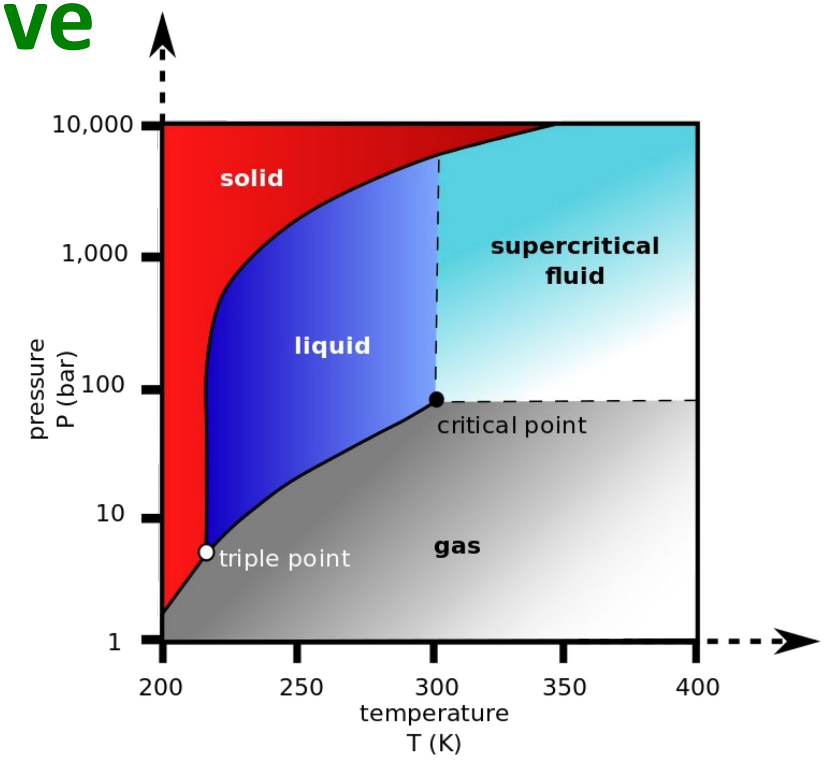
Supercritical CO_2 extraction

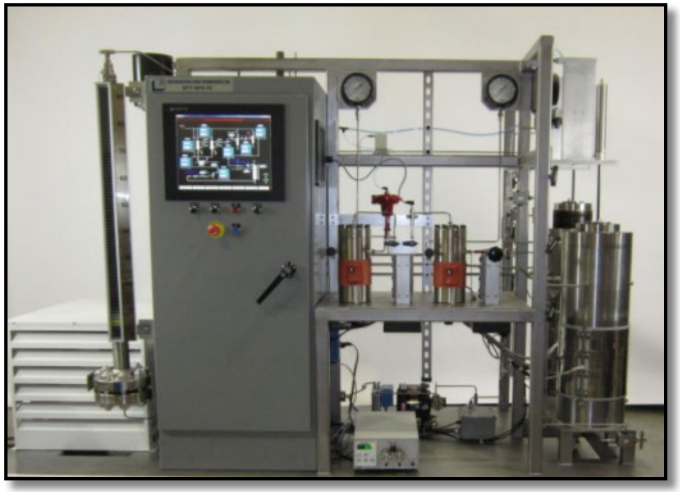
- **Requires expensive equipment, normally found in professional laboratories**
- **CO_2 compresses beyond its "critical" point at around 90 °F, a temperature well below the deactivation temperature for cannabinoids and terpenes**
  - CO_2 liquid forced through the material in the extraction vessel
  - Cannabinoids, terpenes, and waxes separate and collect in various chambers attached to the vessel
- **Second step is (winterizing), uses (usually) ethanol to separate the pure cannabinoids and terpenes from other byproducts**
  - In some cases desired constituent that is not soluble in alcohol or water is extracted via a more exotic solvent like ether, naphtha or isopropyl alcohol, benzene, butane, methanol, and olive oil



Supercritical fluids behave as both liquid and gas

- CO_2 behaves as supercritical fluid above its critical temperature (304.25 K, 31.10 °C, or 87.98 °F) and critical pressure (72.9 atmospheres, 7.39 MPa, 1,071 psi)
- Supercritical fluid expands to fill its container like a gas but with a density like that of a liquid
- Supercritical fluid diffuses through the dried plant material (like a gas), extracted material diffuses out of the matrix into the solvent (CO_2 fluid)
- Properties of supercritical fluid can be altered by varying pressure, temperature, solvent to feed ratio and flow rate
- Allows selective, "tunable" extraction of specific compounds or fractions





Butane (BHO) extraction

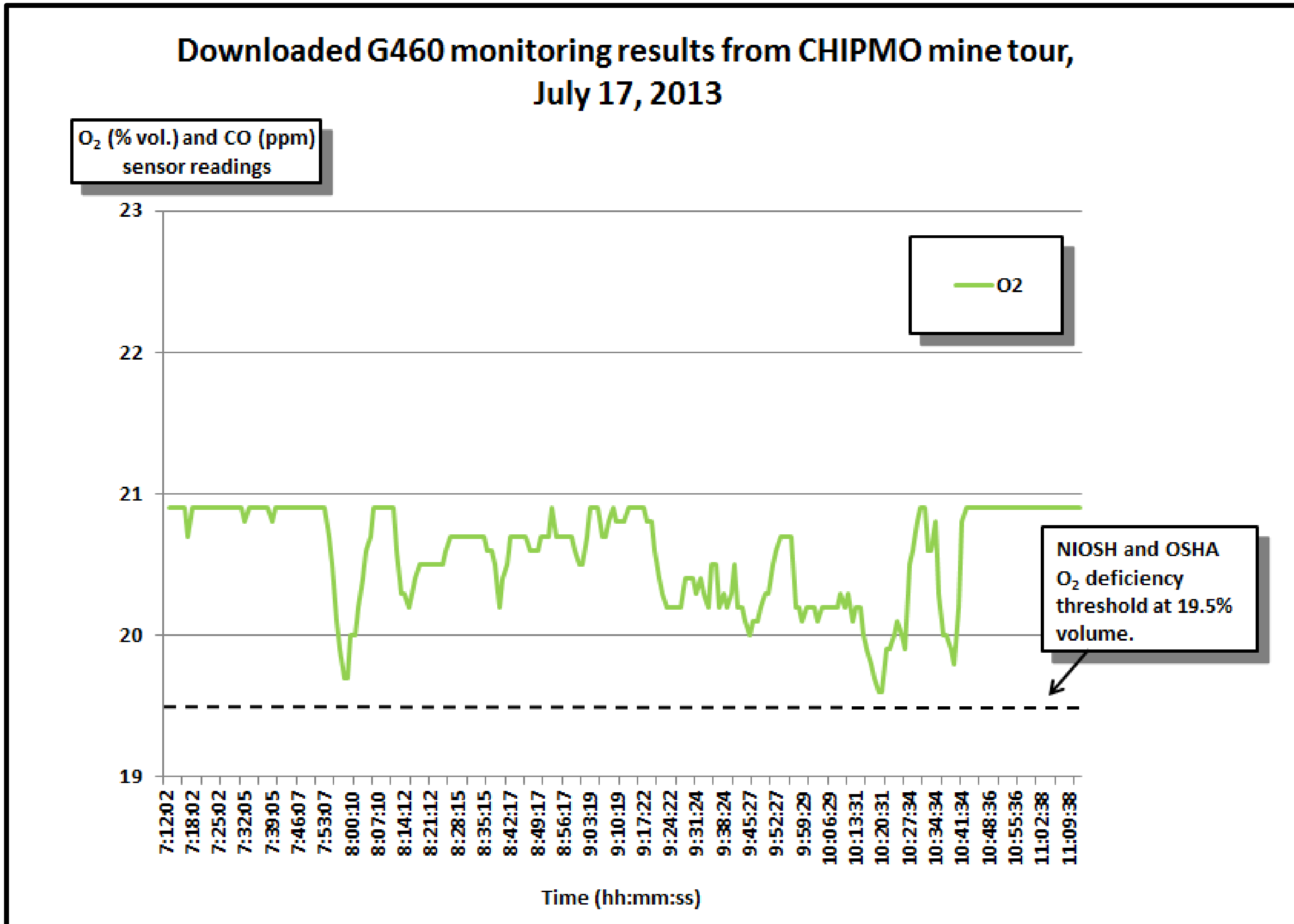
- **Less expensive, much more dangerous**
- **Butane (LPG) run through macerated plant matter, pulling out the desirable oils**
- **To remove the residual solvent, the solution is heated (butane evaporates in low temperatures) in a vacuum**
- **Only closed loop BHO systems permitted at licensed facilities**
- **90% of the cannabinoids remain in the extracts**
  - CO_2 method is easier to control, and the extract contains more terpenes (up to 10 % compared to BHO (which has 0.5–3.5 %)

AIChE 2017 EXPO Seattle, Washington • June 4-7

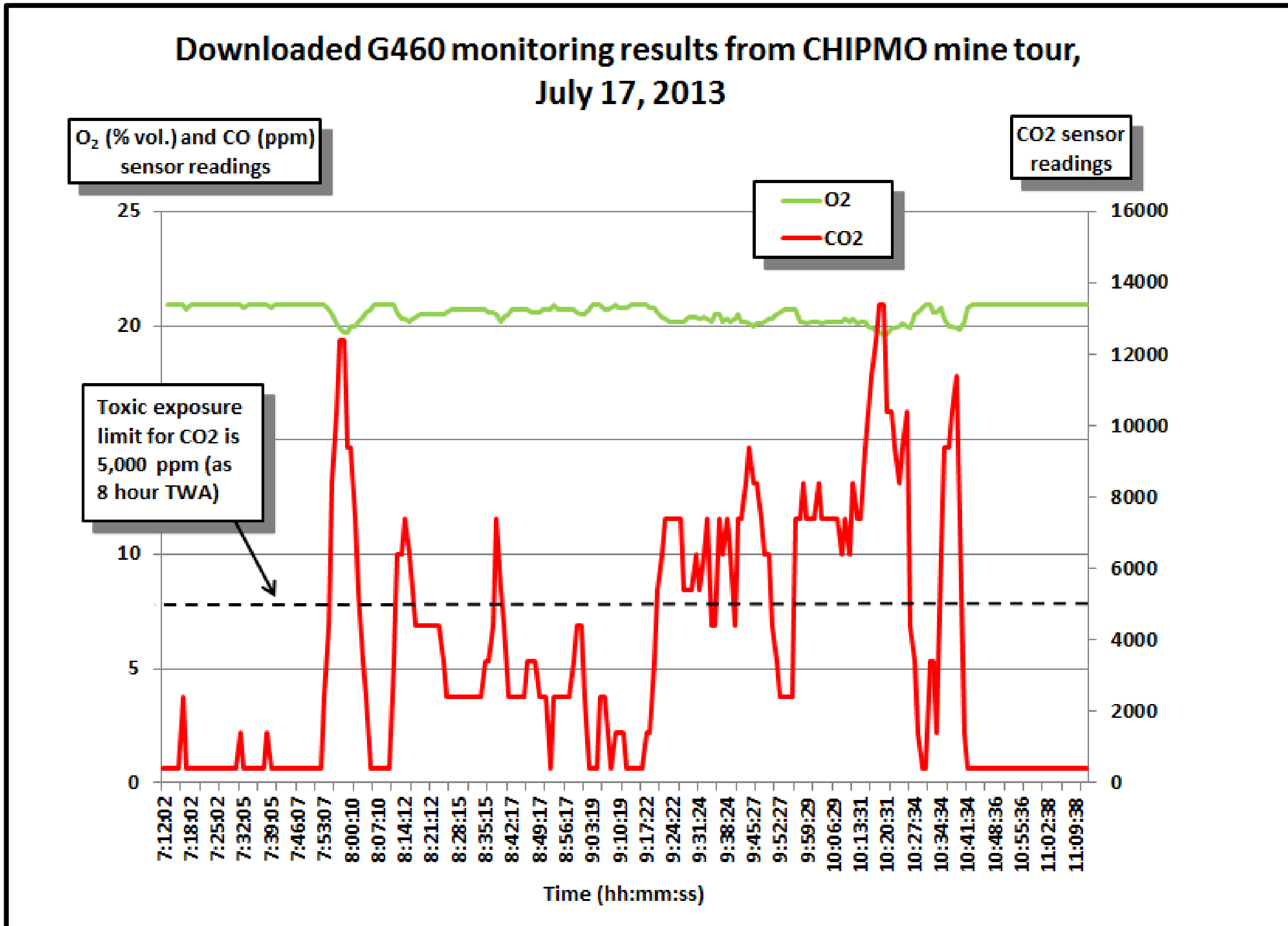
Challenge for fire department

- **Fire department personnel are regularly on site at licensed facilities for periodic inspection**
- **Fire department personnel also potentially involved in emergency response at licensed and unlicensed facilities**
- **Standard 4 gas meter with O_2 / LEL / CO / H_2S sensors does not adequately protect inspectors!**

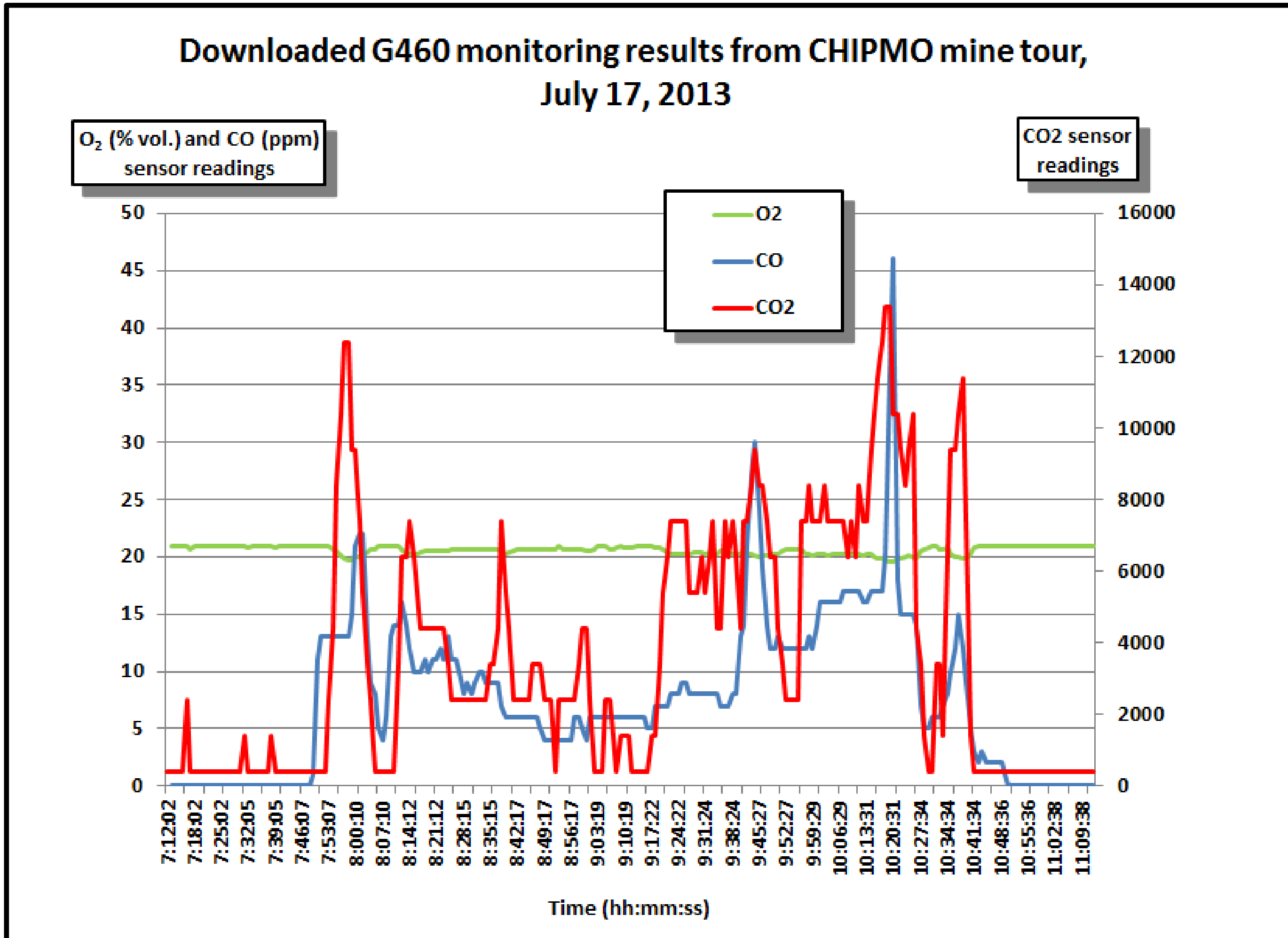
An O_2 reading lower than 20.9% indicates there is too much of some other gas present in the atmosphere



CO_2 (not CO) actually the primary contaminant replacing the O_2 in the monitored atmosphere



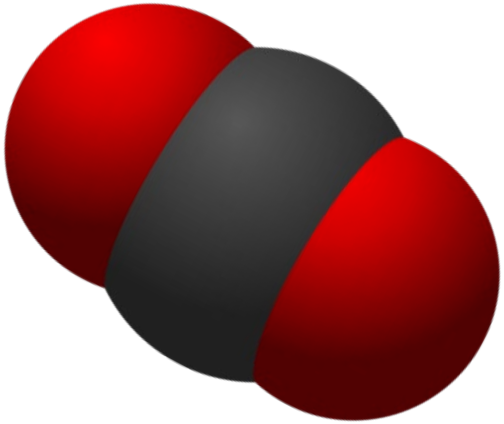
Important to directly measure all the contaminants that can materially affect the atmosphere



AIHce EXP 2017
Seattle, Washington • June 4-7

CO_2 Properties

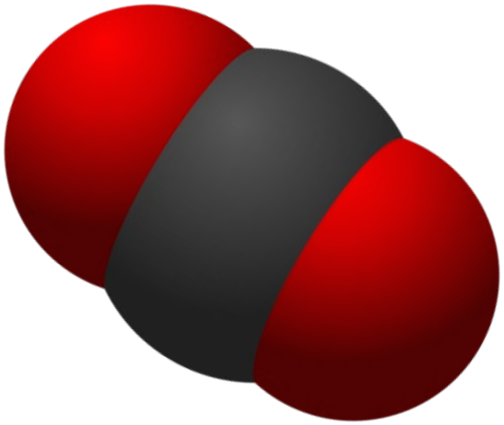
- **Present as a natural component in fresh air (approximately 350 – 400 ppm)**



  - Colorless
  - Odorless
  - Tasteless
  - Heavier than air (density of 1.5 times that of fresh air)
  - When released into enclosed space it tends settle to bottom
  - Because of tendency to settle, as CO_2 produced it can reach higher and higher concentrations

CO_2 exposure symptoms

- **Besides displacing oxygen in fresh air, high concentrations may worsen symptoms related to oxygen deficiency, and interfere with successful resuscitation**
- **Exposure Symptoms include**
  - Headaches
  - Dizziness
  - Shortness of breath
  - Nausea
  - Rapid or irregular pulse
  - Depression of central nervous system



Even moderate concentrations of CO_2 can produce symptoms

Concentration	Symptom
350 – 400 ppm	Normal background concentration in outdoor ambient air
350 – 1,000 ppm	Concentrations typical of occupied indoor spaces with good air exchange
1,000 – 2,000 ppm	Complaints of drowsiness and poor air
2,000 – 5,000 ppm	Headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present
>5,000 ppm	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma and even death

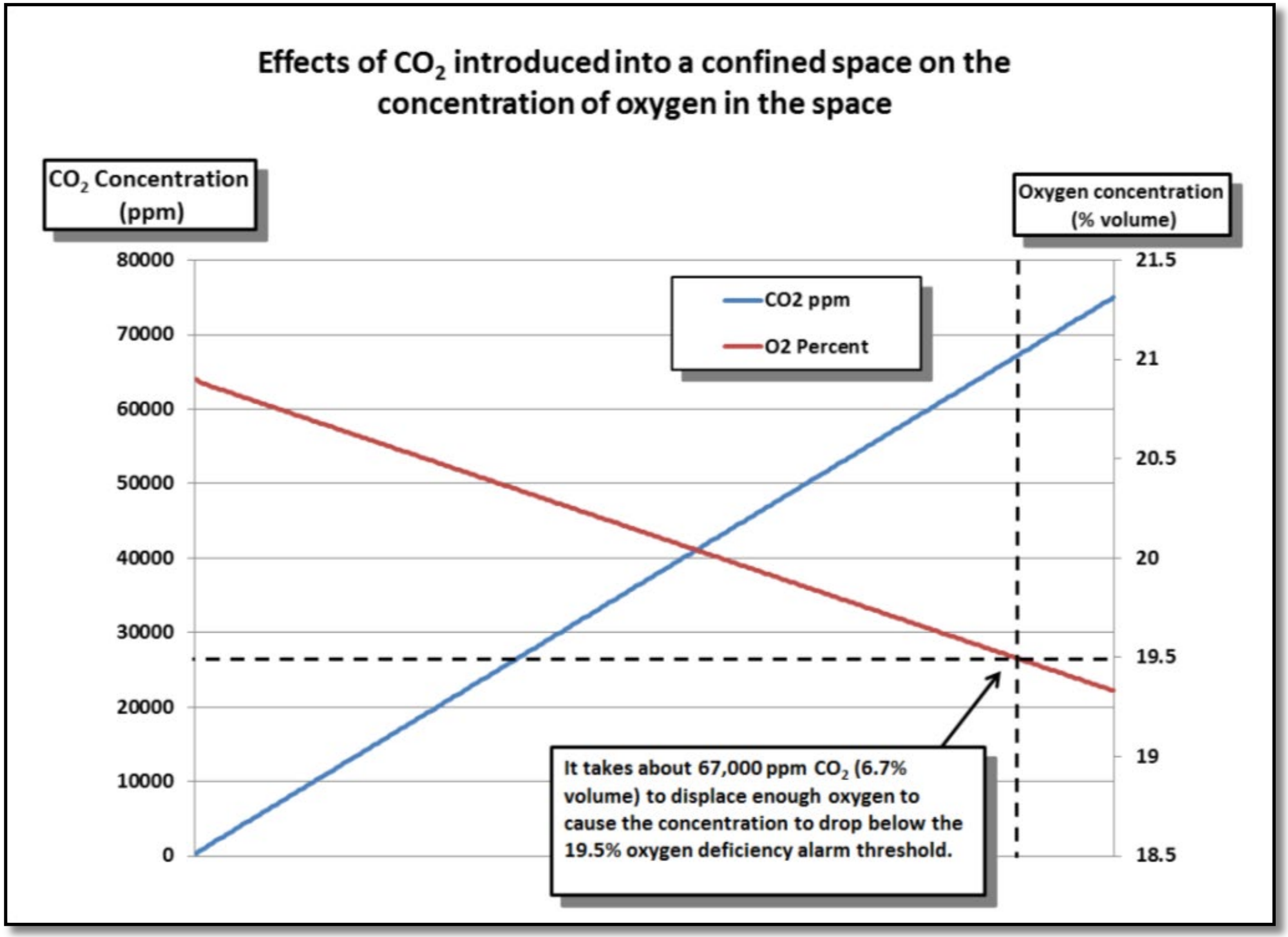
Concentrations of 40,000 ppm CO_2 or higher should be regarded as IDLH

- Exposure to very high concentrations (e.g. exposure to 6% volume CO_2 for several minutes or 30% volume CO_2 for 20-30 seconds), linked to permanent heart damage

- Concentrations greater than 10% capable of causing loss of consciousness within 15 minutes or less

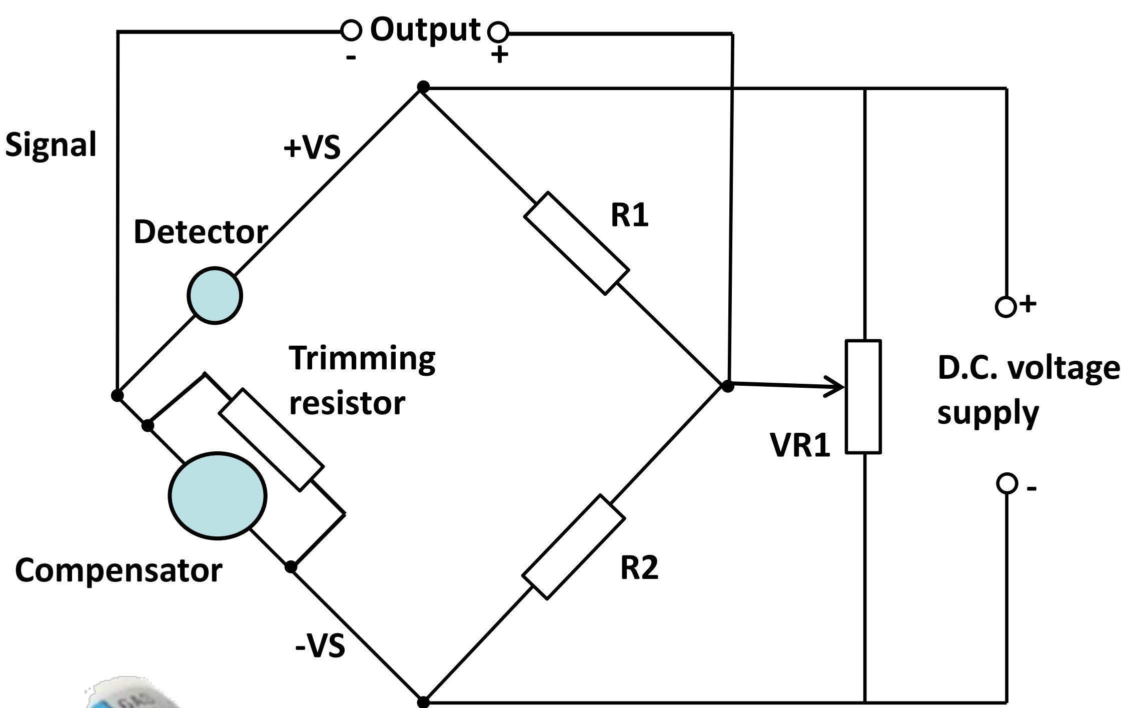
Presence of displacing gas on oxygen concentration

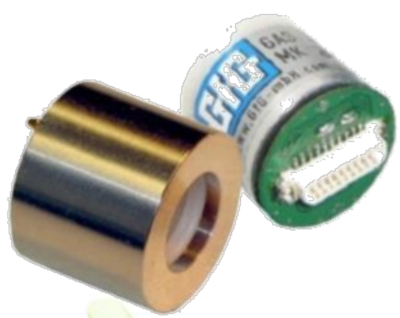
- Be <u>very</u> cautious when using O_2 concentration to estimate concentration of some other displacing gas
- Every 5% of displacing gas introduced into a confined space reduces O_2 concentration by only about 1%



Catalytic "Hot Bead" Combustible Sensor

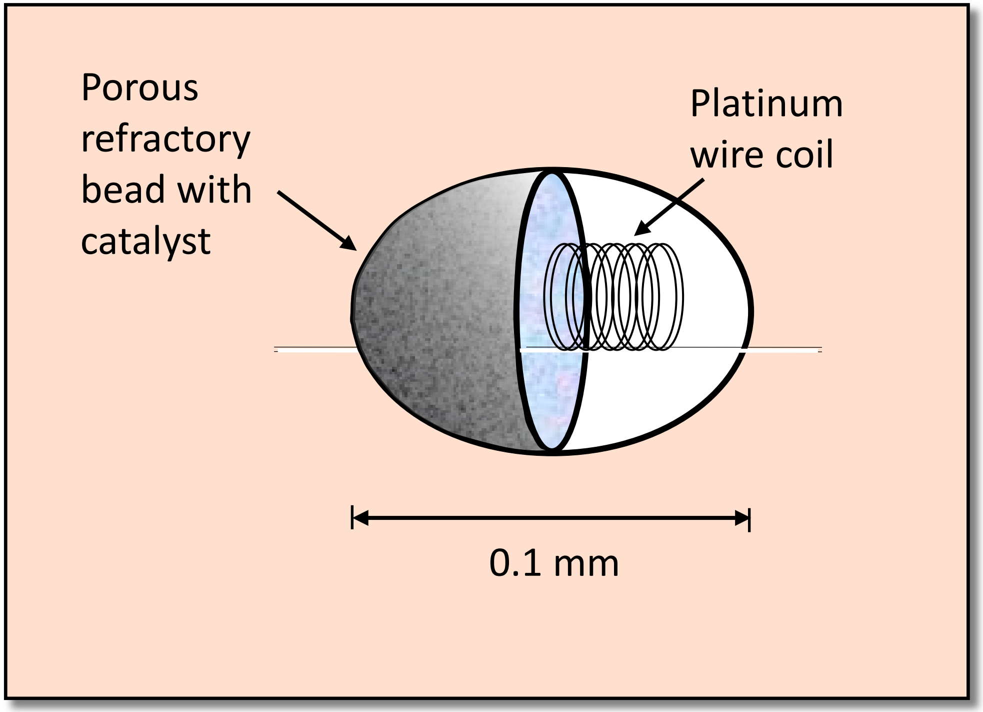
- Detects combustible gas by catalytic oxidation
- When exposed to gas oxidation reaction causes the active (detector) bead to heat
- Requires oxygen to detect gas!
- Dense, CO_2 enriched atmosphere can affect accuracy of readings





Combustible Gas Sensor

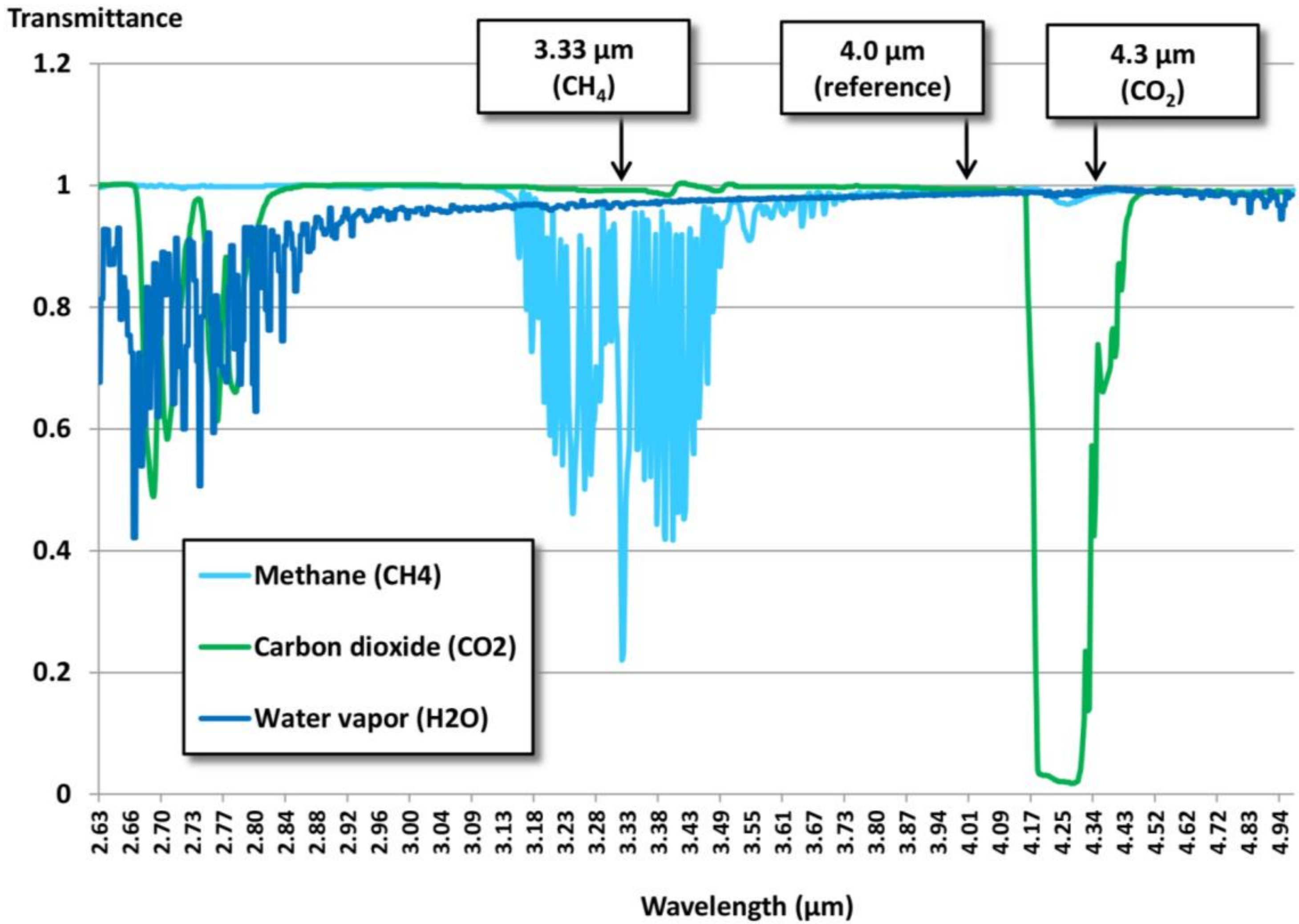
- **The catalyst in the LEL sensor bead can be harmed if it is exposed to certain substances**
- **Catalyst and proper performance can be damaged by exposure to sensor poisons and inhibitors**
  - Chronic or high concentration exposure to alcohol is very hard on standard LEL sensor!



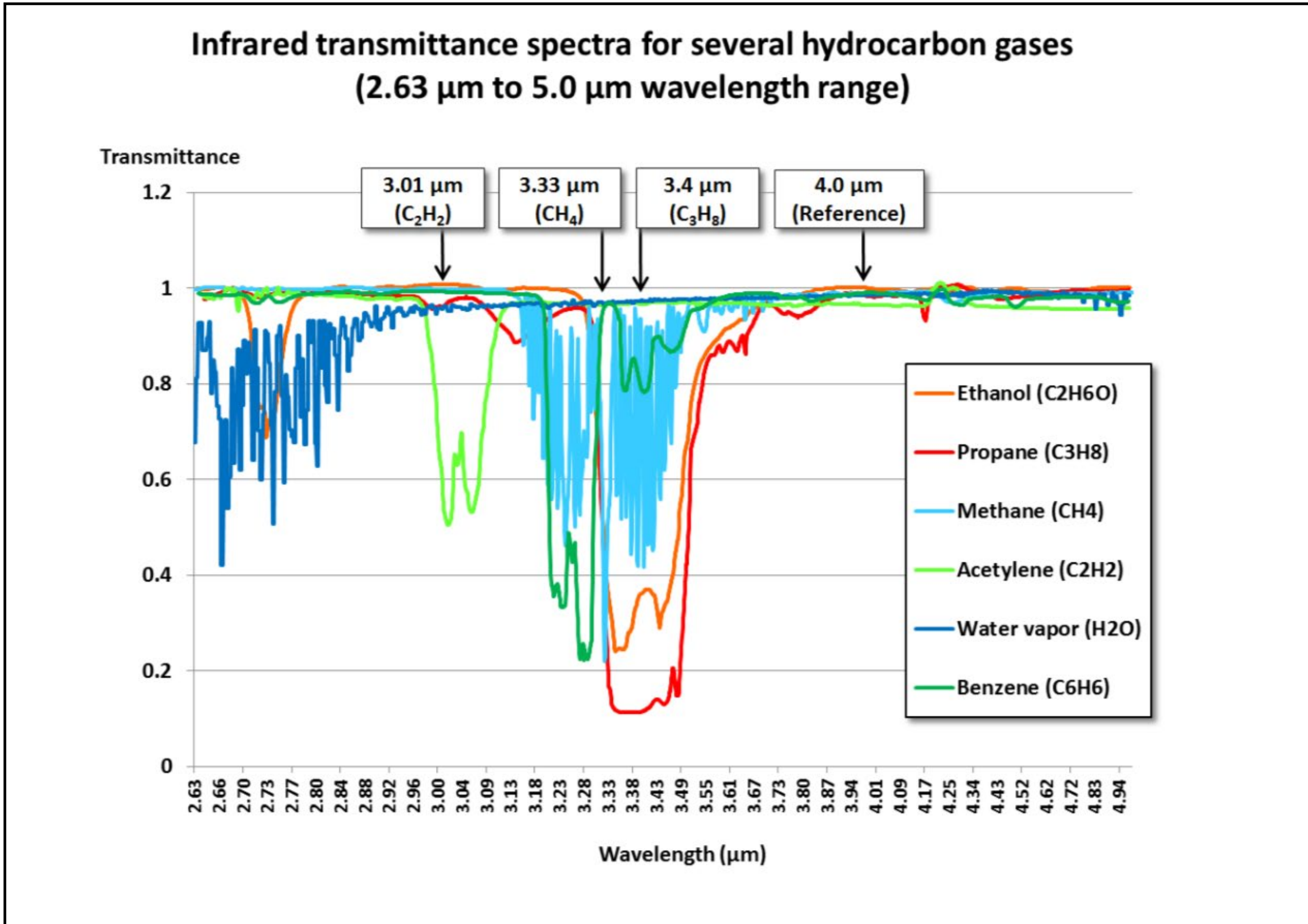
Non-dispersive infrared (NDIR) sensors

- Many gases absorb infrared light at a unique set of wavelengths
- In NDIR sensors the amount of IR light absorbed is proportional to the amount of target gas present
- IR absorption has advantages of high sensitivity, low cross-sensitivity, long life, and resistance to contamination
- IR absorption employed in both very high-performance laboratory analyzers and in very low-performance systems (e.g. inexpensive, non-intrinsically safe hand-held CO_2 detectors)

Infrared transmittance spectra for methane, water (vapor) and carbon dioxide (2.63 µm to 5.0 µm wavelength range)



Wavelengths typically used for IR LEL measurement



Volatile organic compounds (VOCs)

- **VOCs are organic chemicals or mixtures characterized by tendency to evaporate easily at room temperature**
- **Familiar VOCs include:**
  - Solvents
  - Naphtha
  - Ethanol
  - Gasoline
  - Diesel
  - Kerosene
  - Hexane
  - Jet fuel
  - Benzene
  - Butadiene
  - Hexane
  - Toluene
  - Xylene
  - Many others

Why use photoionization detector equipped instruments?

- For most VOCs, long before you reach a concentration sufficient to register on a combustible gas indicator, you will have easily exceeded the toxic exposure limits for the contaminant

- PID equipped instruments are generally the best choice for measurement of VOCs at exposure limit concentrations

- Whatever type of instrument is used to measure these hazards, it is essential that the equipment is used properly, and the results are correctly interpreted

Combustible sensor limitations

Contaminant	LEL (Vol %)	Flashpoint Temp (ºF)	OSHA PEL	NIOSH REL	TLV	5% LEL in PPM
Acetone	2.5%	-4ºF (-20 ºC)	1,000 PPM TWA	250 PPM TWA	500 PPM TWA; 750 PPM STEL	1250 PPM
Diesel (No.2) vapor	0.6%	125ºF (51.7ºC)	None Listed	None Listed	15 PPM	300 PPM
Ethanol	3.3%	55ºF (12.8 ºC)	1,000 PPM TWA	1000 PPM TWA	1000 PPM TWA	1,650 PPM
Gasoline	1.3%	-50ºF (-45.6ºC)	None Listed	None Listed	300 PPM TWA; 500 PPM STEL	650 PPM
n-Hexane	1.1%	-7ºF (-21.7 ºC)	500 PPM TWA	50 PPM TWA	50 PPM TWA	550 PPM
Isopropyl alcohol	2.0%	53ºF (11.7ºC)	400 PPM TWA	400 PPM TWA; 500 PPM STEL	200 PPM TWA; 400 PPM STEL	1000 PPM
Kerosene/ Jet Fuels	0.7%	100 – 162ºF (37.8 – 72.3ºC)	None Listed	100 mg/M3 TWA (approx. 14.4 PPM)	200 mg/M3 TWA (approx. 29 PPM)	350 PPM
MEK	1.4%	16ºF (-8.9ºC)	200 PPM TWA	200 PPM TWA; 300 PPM STEL	200 PPM TWA; 300 PPM STEL	700 PPM
Turpentine	0.8	95ºF (35ºC)	100 PPM TWA	100 PPM TWA	20 PPM TWA	400 PPM
Xylenes (o, m & p isomers)	0.9 – 1.1%	81 – 90ºF (27.3 – 32.3 ºC)	100 PPM TWA	100 PPM TWA; 150 PPM STEL	100 PPM TWA; 150 STEL	450 – 550 PPM

PID Alarms: Varying Mixtures

- **The Controlling Compound**
  - Every mixture of gases and vapors has a compound that is the most toxic and "controls" the take action threshold for the whole mixture
  - Determine that chemical and you can determine a conservative threshold for the mixture
  - If we are safe for the "worst" chemical we will be safe for all chemicals

PID Alarms: Varying Mixtures

Chemical Name	10.6eV CF	NIOSH REL Exposure Limit (8-hr. TWA)
Ethanol	10.0	1000
Turpentine	0.45	100
Acetone	1.2	250

- **Ethanol "appears" to be the safest compound**
- **Turpentine "appears" to be the most toxic**
- **This table only provides half of the decision making equation**

PID Alarms: Varying Mixtures

- **Set the PID for the compound with the lowest Exposure Limit (EL) in equivalent units and you are safe for all of the chemicals in the mixture**
- **Divide the EL in chemical units by CF to get the EL in isobutylene**

$$EL_{Isobutylene} = \frac{EL_{chemical}}{CF_{chemical}}$$

PID Alarms: Varying Mixtures

Chemical name	CF_{iso} (10.6eV)	NIOSH REL (8 hr. TWA)	$EL_{ISO\ (PEL)}$
Ethanol	10.0	1000	100.0
Turpentine	0.45	100	222.3
Acetone	1.2	250	208.4

- **IF you are following the NIOSH REL then ethanol is the "controlling compound" when the exposure limits are expressed in equivalent "Isobutylene Units"**
- **The equivalent EL_{iso} is a calculation that involves a manufacturer specific Correction Factor (CF)**
- **Similar calculations can be done for any PID brand that has a published CF list**

LEL vs. PID Sensors

- **IR LEL and photoionization detectors are complementary detection techniques**
- **IR LEL sensors excellent for measurement of methane, propane, and other common combustible gases NOT detectable by PID**
- **PIDs detect toxic VOC and hydrocarbon molecules at toxic exposure limit ranges**
- **Best approach to VOC measurement is to use multi-sensor instrument capable of measuring all atmospheric hazards that may be potentially present**

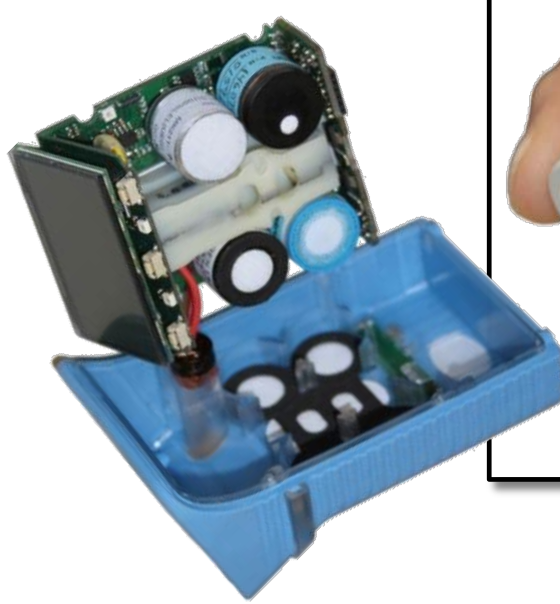
Electrochemical Detection Mechanism

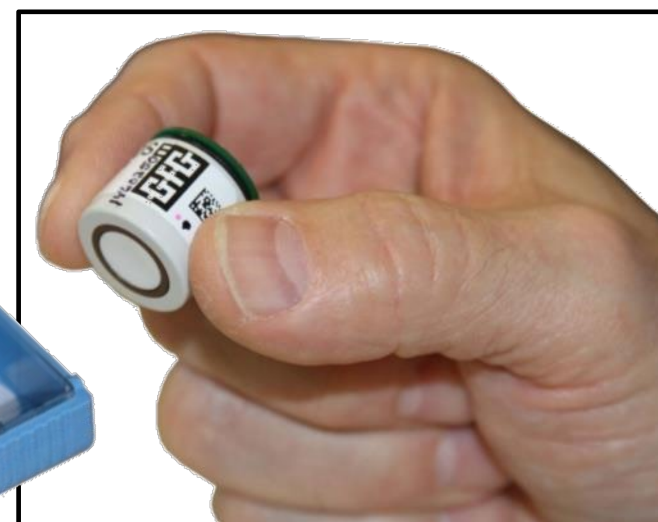
CO Gas Reaction:

CO Sensing Electrode Reaction: $CO + H_2O \longrightarrow CO_2 + 2H^+ + 2e^-$

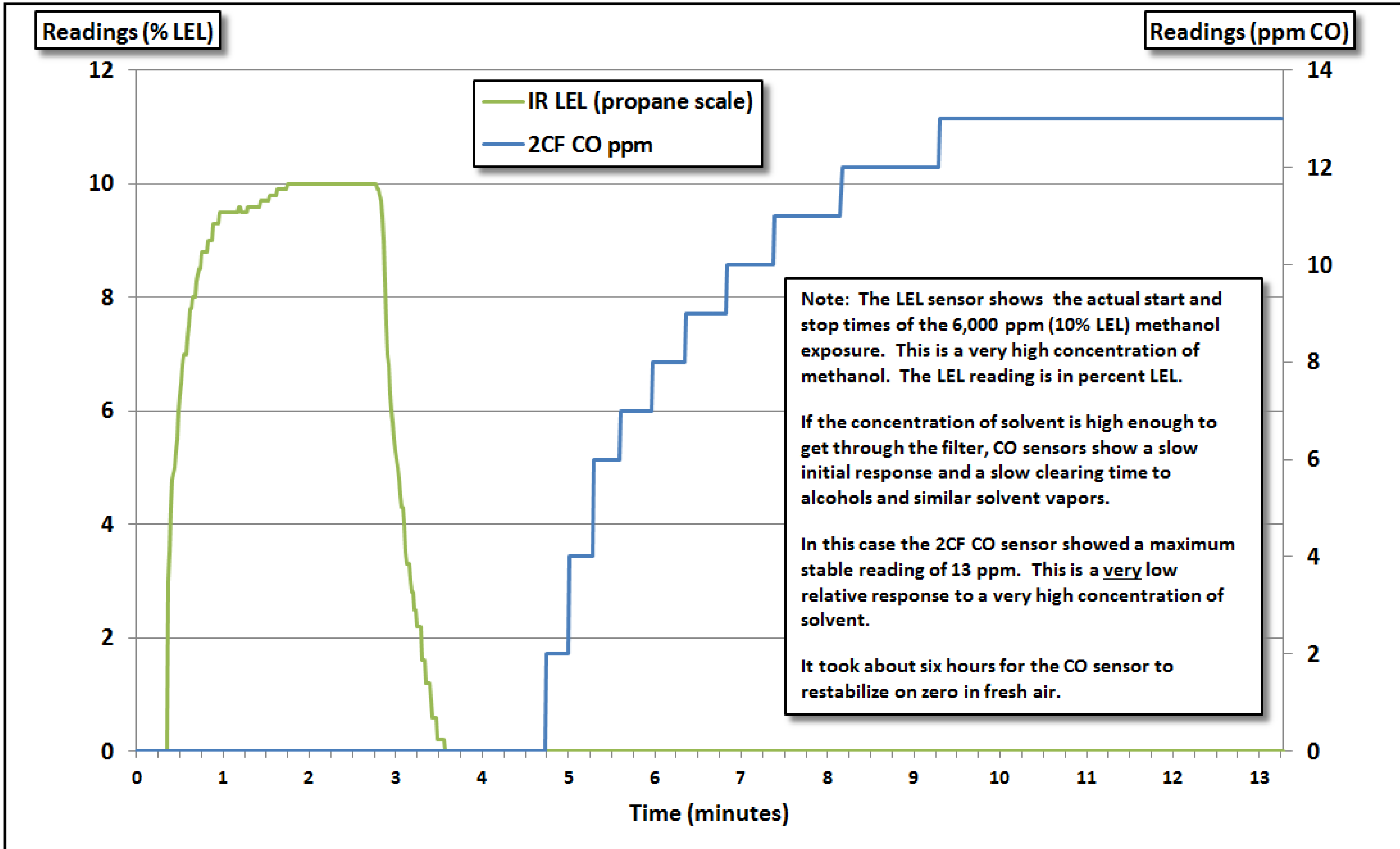
CO Counter Electrode Reaction: $\frac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

Overall reaction: $CO + \frac{1}{2}O_2 \longrightarrow CO_2$





Response of LEL and CO sensors to 10% LEL (6,000 ppm) methanol vapor



Solution:

- **Fire department inspection personnel now using multi-channel instruments with:**
    - O_2
    - IR LEL
    - IR CO_2
    - PID
    - CO
- **Much better protected!**