



# 2026 Analyzer Technology Conference

## Flammability Measurement in Inerted VOC Waste-Gas Streams: Challenges and Monitoring Strategies

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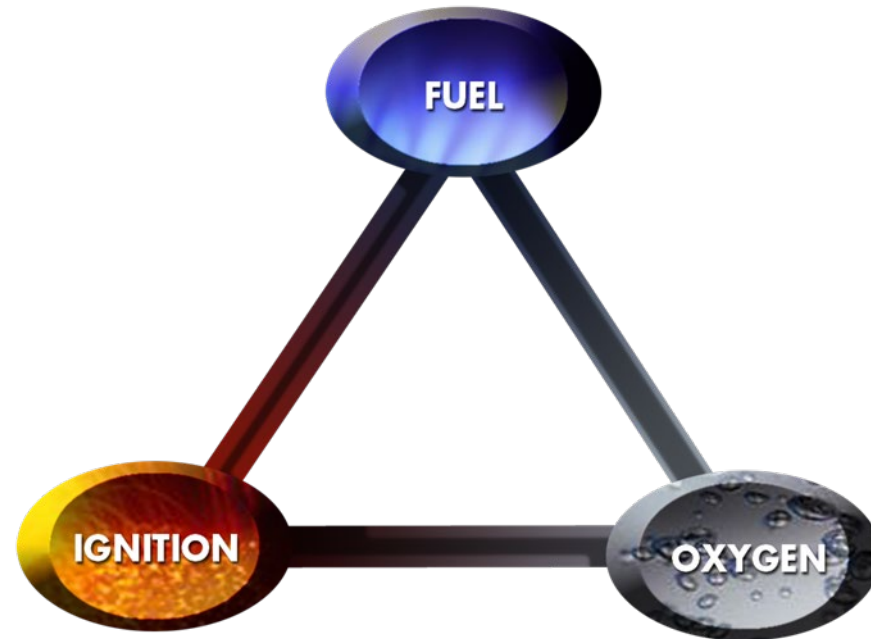
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- Enclosed Processes (i.e. ovens, dryers, oxidizers, waste gases, etc.)
- Typically operate at elevated temperatures
- Often operate near legal limits for combustible gas concentrations
- Inerted Gas Streams; reduce corrosion, improve product quality



- Industrial fires and explosions are far more common than most people think
- These fires and explosions result from a dangerous mixture of flammable vapors with air and a source of ignition
- They cause downtime, property damage, substantial fines, injury and sometimes death

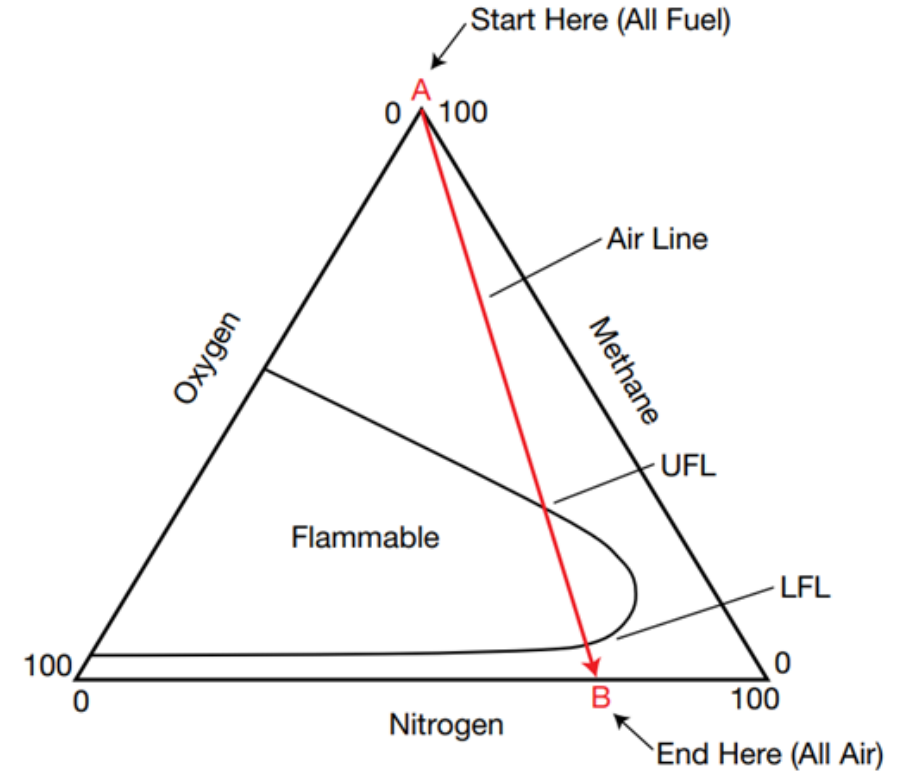
**3 Elements MUST be present for for a flammable hazard to exist**



- Continuous monitoring of complex gas and vapor levels provides early warning needed to correct dangerous situations
- In Inert Environments % LFL definition is no longer measured in “air”,
- The BEST way to control flammable hazards is to keep the level of fuel below the flammable level



- In Inert Environments % LFL definition is no longer measured in “air”
- Gas limits change with inerting compound; e.g. N<sub>2</sub> vs CO<sub>2</sub>
- Complex fuel mixtures add additional complexity to %LFL



# What is LFL?

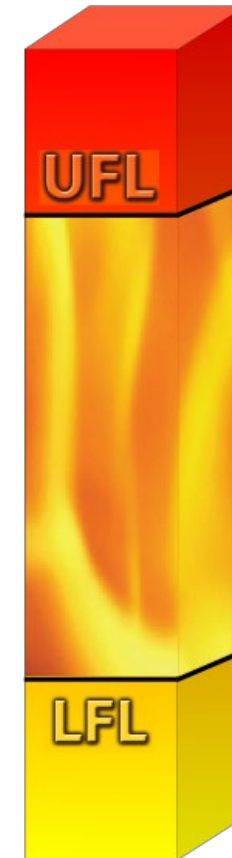
LFL is the lowest flammable concentration of a gas **in air** within which a flame can be propagated.

*Note:* NFPA use LFL and LEL interchangeable

Too Rich to Burn

The Flammable Range

Too Lean to Burn



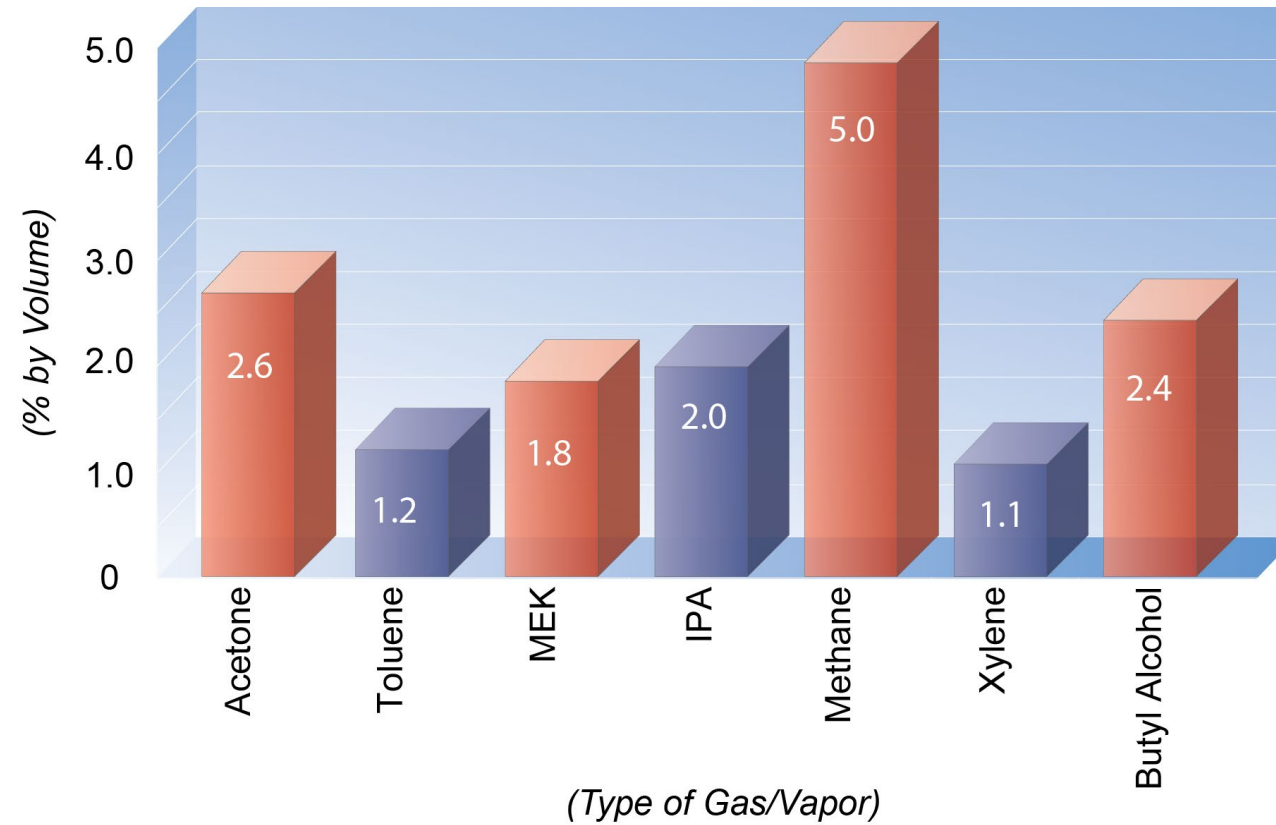
- At 100% LFL and through the flammable range, a source of ignition can start a “combustion wave” or “flame front” that travels through the mixture.
- The source of ignition can be a spark, static, hot air or a hot surface.
- The flame front can travel back to the source and start a fire.
- It can also explode.



# Published LFL Values

- Because LFL values are determined empirically, there are variations in the data published by different authorities at different times.
  - Standard deviation of values can be as high as 10% (based on six different authorities)
- Inaccuracies due to test procedures, air flow, temperatures, sample preparations, measurement rounding
  - Therefore, LFL of substances are NOT absolute

# Examples of LFL Values

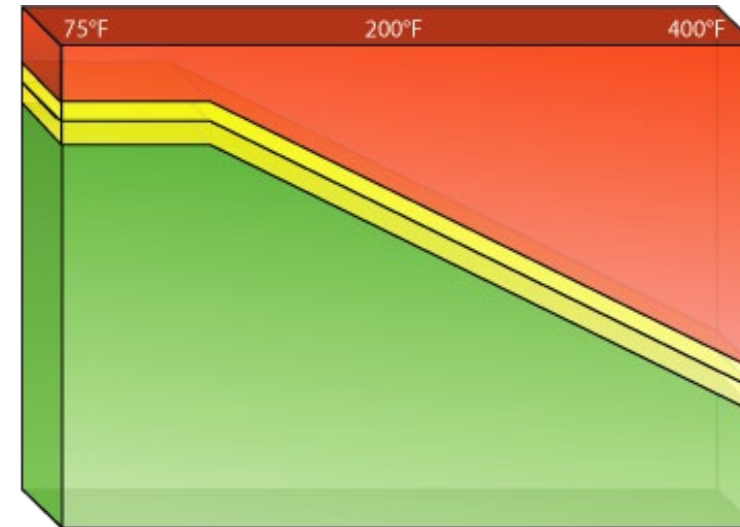


## Effect of temperature on flammability

- What happens when the mixture is heated?
  - It's flammability increases
  - The concentration required to achieve 100% of it's LFL is LESS
  - More likely to have a fire or explosion

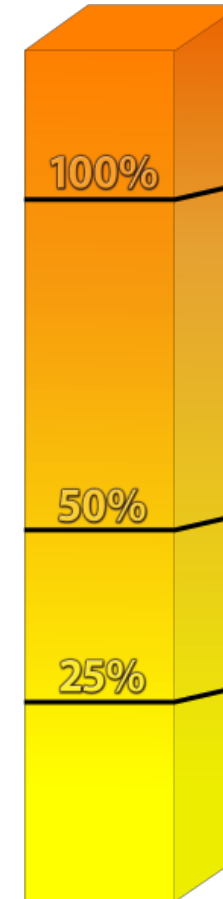
# When Temperatures Increase

- Yellow - 100% of the LFL (given the degree of uncertainty in published values).
- Red - the danger zone, becomes greater as the temperature increases.
- Green – the “safe” area.
- What was safe at 75° becomes dangerous at 200° or 400°



# Safety Margins: Exceptions – NFPA-86

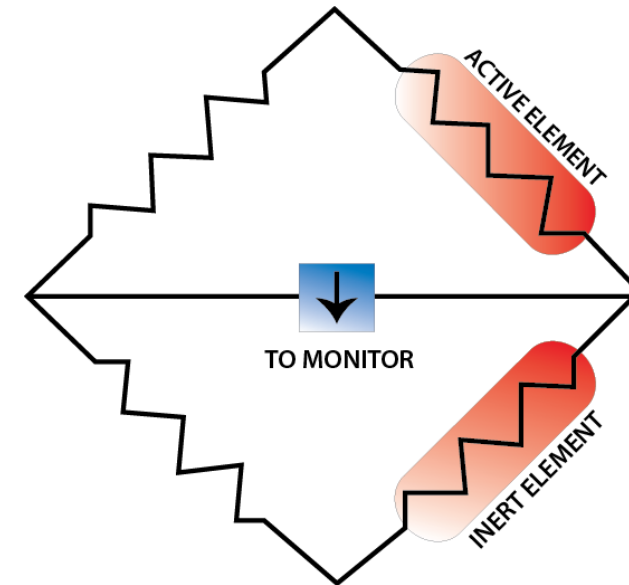
- If flammability analyzers are in use, the margin can be decreased from 4:1, or 25% LFL, to 2:1 or 50% LFL.
- The analyzers **MUST** be:
  - Continuous
  - Real-time
  - Fast-response
  - Interlocked to a system capable of taking immediate corrective action upon alarm in order to prevent upset (e-stop)
  - Calibrated properly and maintained



- Catalytic Sensor (CAT)
- Infrared Absorption (IR)
- Flame Ionization Detector (FID)
- Flame Temperature (FTA)

# Sensor Technology: Catalytic Bead

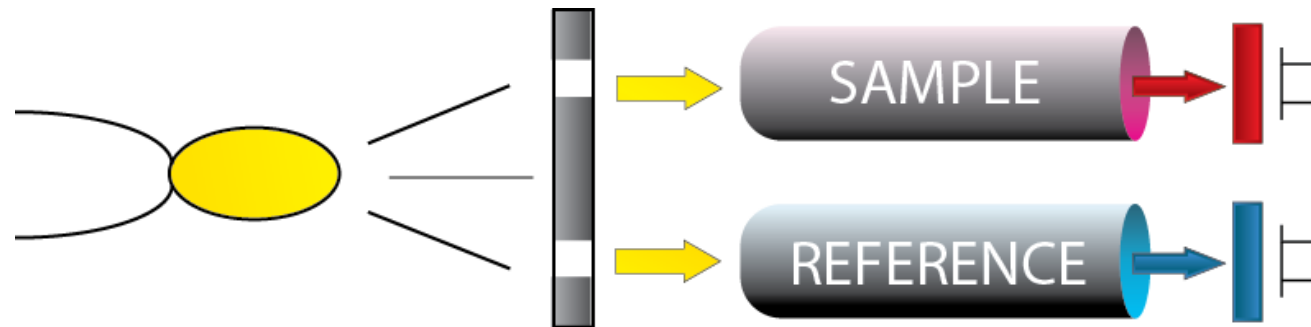
- Wheatstone Bridge is constructed of 2 small coils.
- Active coil is covered with a catalyst.
- Coil catalytically oxidizes the gas.
- This reaction causes an increase in the sensor's temperature
- The resulting electrical change is displayed in terms of %LFL



Ideally suited to leak detection - ambient air monitoring

# Sensor Technology: Infrared

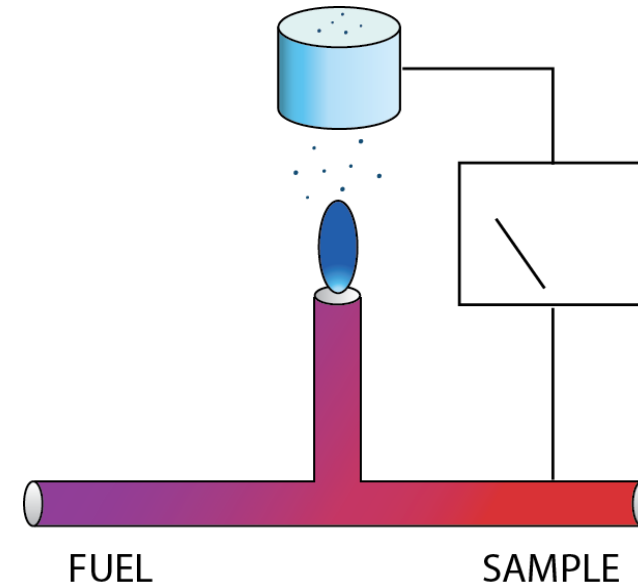
- Combustible gases enter sensor
- IR energy is passed through sample
- This wavelength compares to reference IR source
- The amount of energy absorbed determines gas concentration



- Absorption is not related to flammability; it is NOT a direct measure of LFL
- Must be calibrated for ONE gas *or* gases similar responses
- Multiple/unknown gases can result in inaccurate readings
- Optical system; may become fouled by process environment and moisture
- Not suitable for use in high temperatures (> 65°C/150°F)
- Typical sensor response time greater than 5 seconds

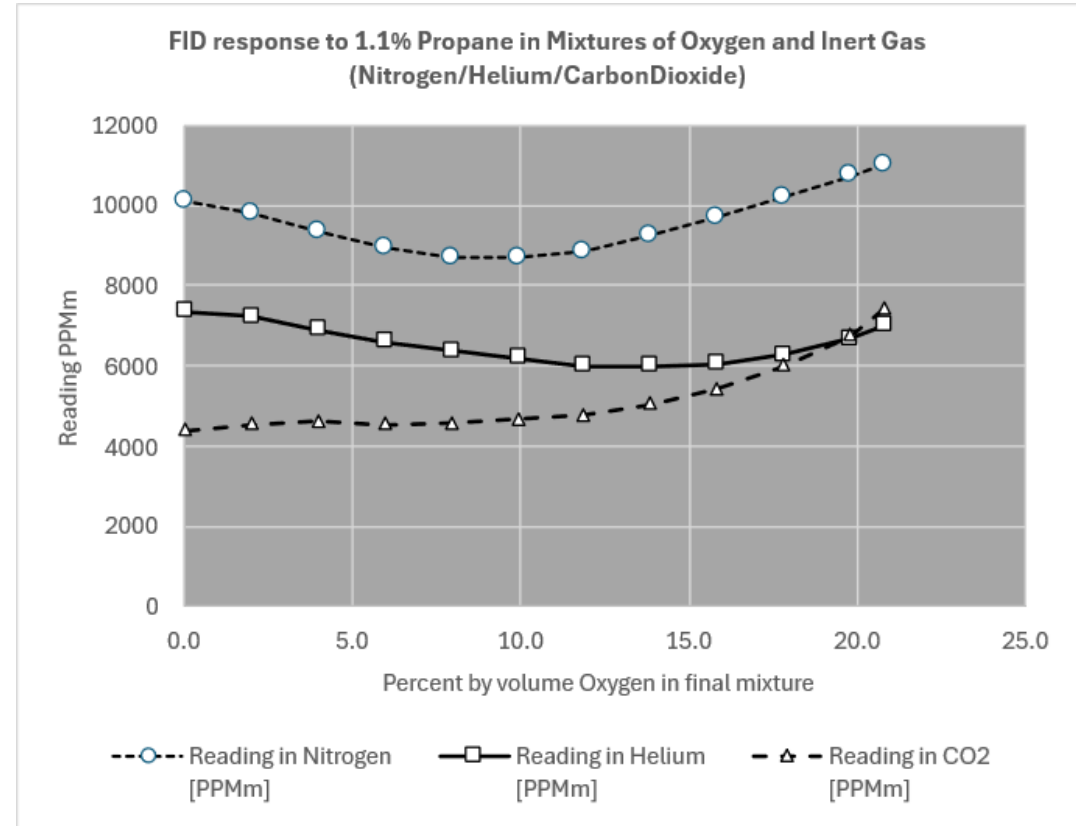
# Sensor Technologies: FID - Flame Ionization Detector

- Fuel is premixed with the sample and incinerated by H<sub>2</sub> flame
- By-product of combustion ionizes the carbons
- Readout reflecting the number of carbons present
- Not a measure of flammability at all (example: Butyl Alcohol)



Ideally suited environmental projects - carbon emissions

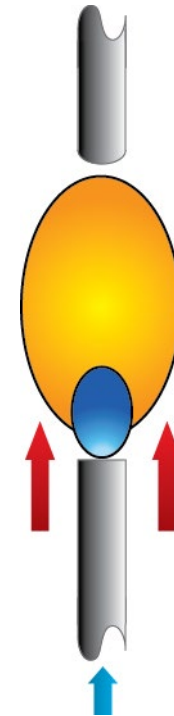
- Oxygen effects can be present due to physical properties of gas flow through capillary
- Changes in type of inert gas can also alter the amount of sample reaching the flame
- CO<sub>2</sub> restricts gas flow, while helium increases transport time



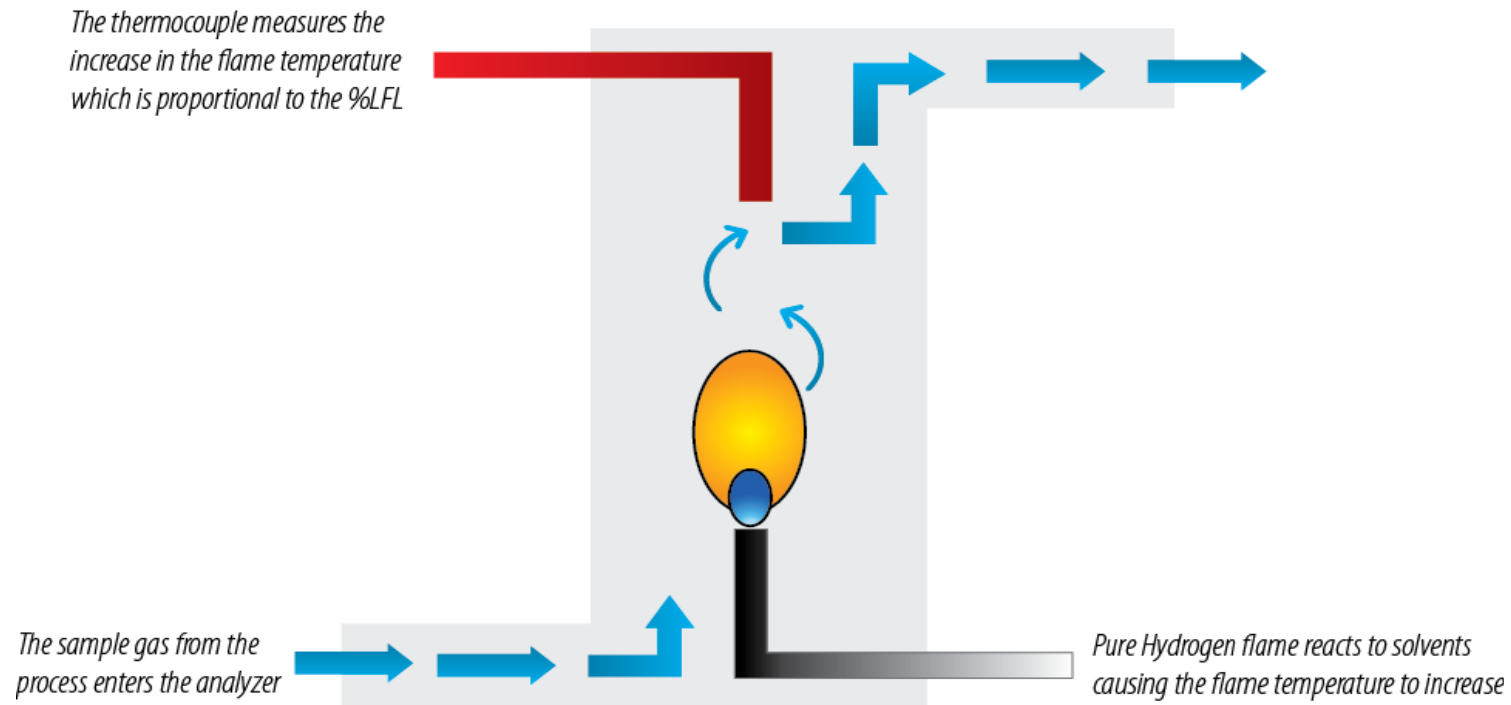
Ideally suited environmental projects - carbon emissions

# Sensor Technologies: Flame Temperature

- A carefully metered flame burns at a constant reference temperature
- A sample, drawn from the process is passed through the cell
- A thermocouple measures change in flame temperature
- The increase in temperature is directly proportional to the increase in flammability (LFL)



## Flame Temperature Analyzer



# Sensor Technologies: Flame Temperature Analyzer

- Direct measure of flammability
- Most accurate technology in the industry for measuring flammability in the % LFL range
- Universal Calibration - Highly uniform response to a wide variety of solvents
- Fast Response - Less than 1 second
- Failsafe
- Advanced self-diagnostics
- Mounts directly to process ductwork

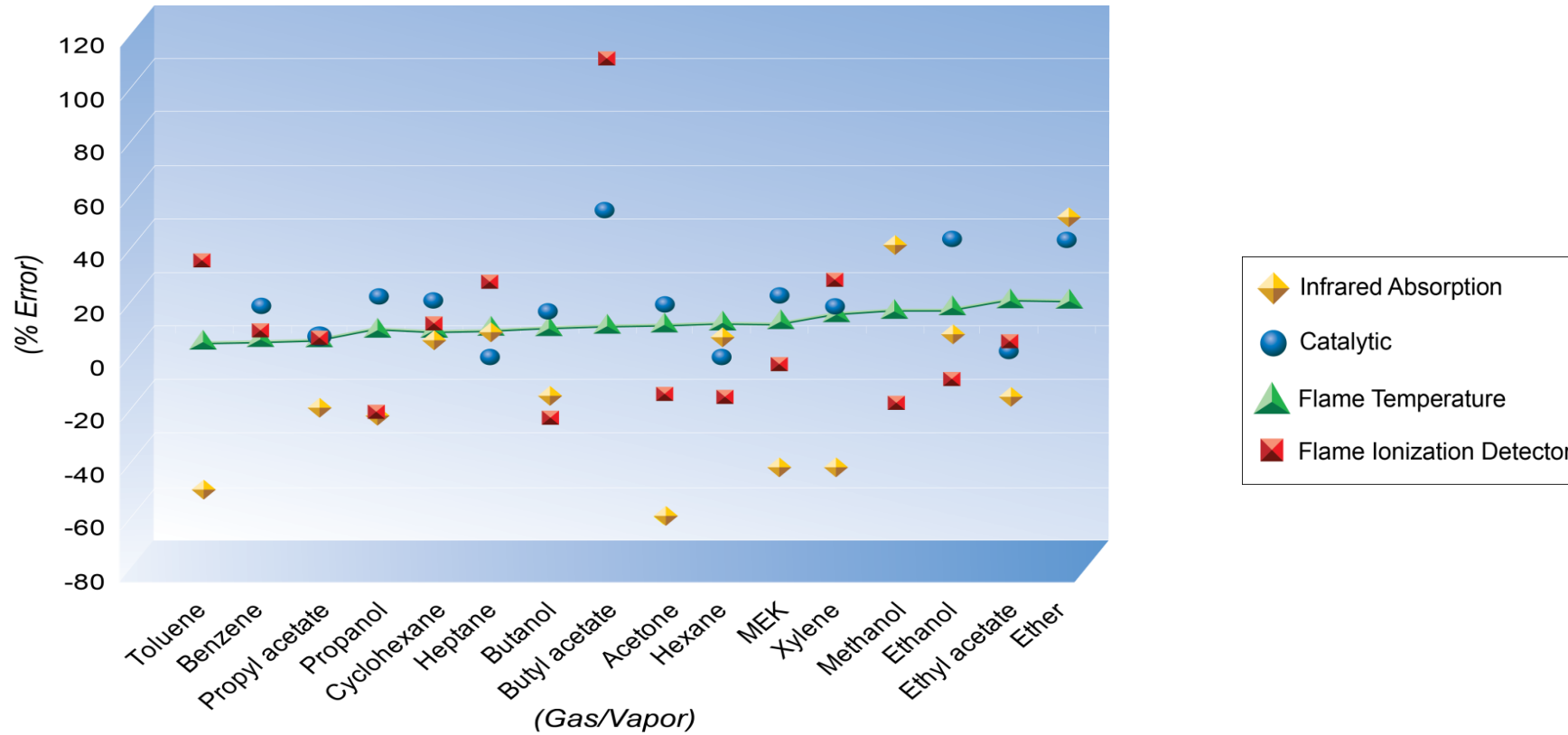


DIRECT Measurement of Flammability – for complex VOC gas streams

NFPA-86 comments regarding these technologies:

- Catalytic - Calibration can vary significantly
- Flame Ionization - Rapid response, but the calibration varies for some solvent types; best suited for PPM
- Infrared - Its area of application is single solvent where poisoning can be a problem
- Flame Temperature - Contamination is NOT a problem and calibration is relatively constant for various solvents

# Comparing All Flammable Measurement Technologies

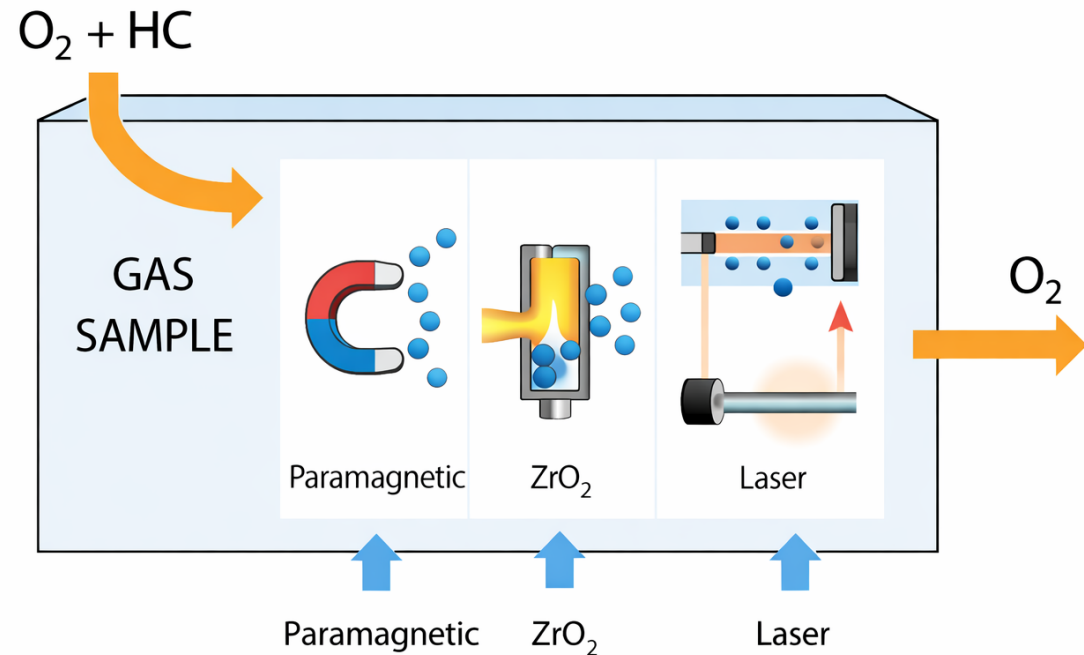


# Oxygen Detection vs LOC in Hydrocarbon Systems

- Continuous oxygen measurement
- Supports inerting & safety systems
- Enables low O<sub>2</sub> operation

## WHAT THEY DO NOT MEASURE

- LOC directly
- Hydrocarbon reactivity
- Mixture explosion limits
- Rapid Air intake could be dangerous



Sensors measure O<sub>2</sub> reliably — but LOC is a moving target. Design with safety margins and process understanding.

# Benefits & Tradeoffs of Technologies for Inert Streams

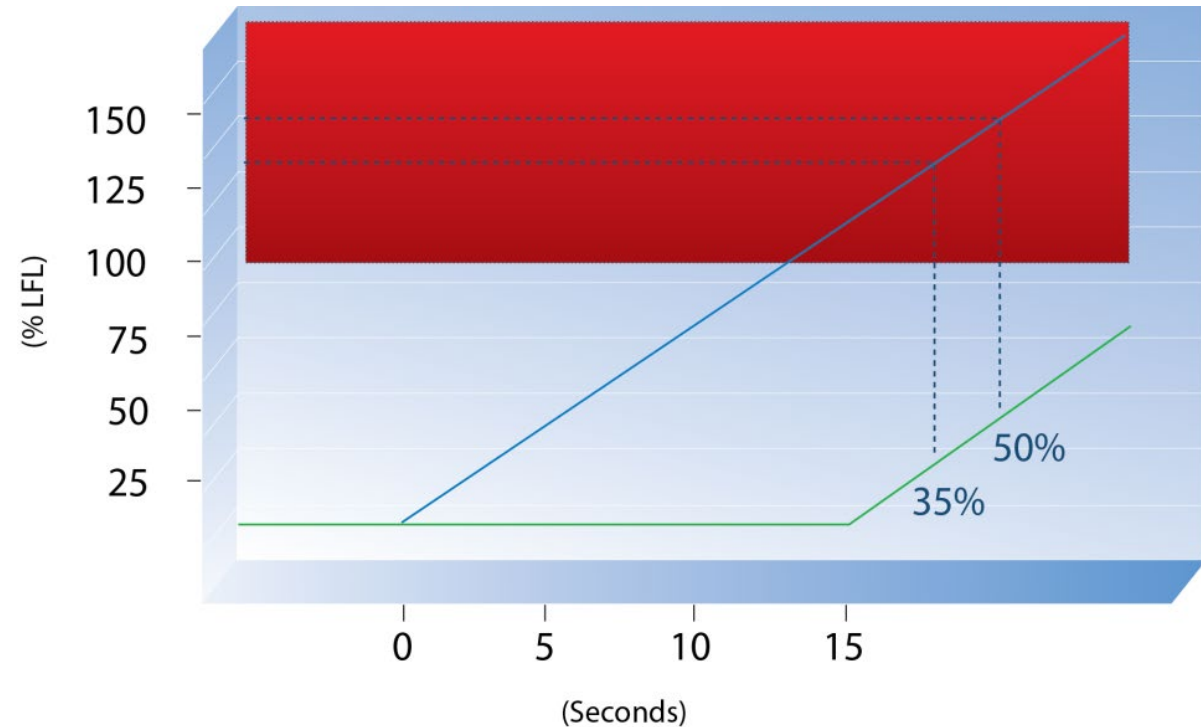
Technology	Measurement Principle	O <sub>2</sub> Sensitivity	VOC Composition Sensitivity	Key Strengths	Key Limitations / Tradeoffs	Typical Use in Inerted Systems
<b>Catalytic Bead (LEL)</b>	Oxidation of combustibles on heated catalyst; temperature rise proportional to fuel	High – requires O <sub>2</sub>	Moderate; relies on equivalency	Simple, fast response in air; widely used	Under-responds in low O <sub>2</sub> ; catalyst poisoning; misleading low LEL readings	Generally unsuitable unless O <sub>2</sub> is verified
<b>Infrared (IR)</b>	IR absorption by hydrocarbon bonds	Low–Moderate	High; gas-specific calibration	Independent of oxidation; stable in low O <sub>2</sub>	Equivalency errors in mixed VOCs; possible CO <sub>2</sub> interference	Fuel concentration trending
<b>Flame Ionization Detector (FID)</b>	Ionization of hydrocarbons in H <sub>2</sub> flame; signal ∝ total carbon	Low (independent of sample O <sub>2</sub> )	High; measures total hydrocarbons	Very sensitive; robust in inerted streams	Not a flammability measure; requires H <sub>2</sub> ; no LOC awareness	VOC loading and trend analysis
<b>PrevEx Flame Temperature (FTA)</b>	Change in flame temperature from combusting sample gas	Low (self-contained flame)	Low; uniform response to mixtures	Direct flammability indication; effective for variable VOCs; fail-safe diagnostics	Requires fuel and flame management; interpretation needed near LOC	Direct %LFL indication
<b>Oxygen Analyzer</b>	Direct O <sub>2</sub> concentration measurement	N/A	None	Direct link to combustion physics; fuel-independent	LOC varies with fuel, temperature, pressure; no fuel loading info	LOC-based inerting control

## Speed of Response

- To calculate the speed of response the following must be considered:
  - Sample delivery - the time it takes for the sample to reach the sensor
  - Sensor time to alarm
  - Safety relay functions
  - Corrective action

# Response vs. Reaction Time

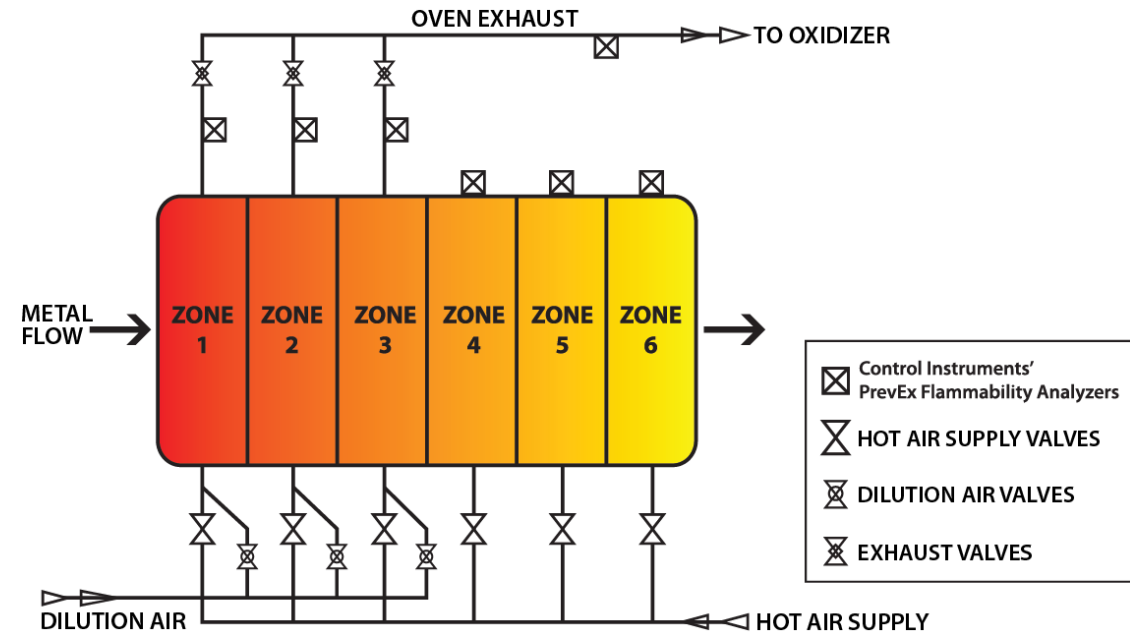
- The sample delivery line and the response time of some analyzer produce a 15 second delay. By the time the analyzer activated it's warning alarm set at 35% LFL, the true concentration in the process is already above 130% LFL.



- To ensure that the vapor concentration reaching the analyzer is exactly the same as the concentration at the point of origin, the sample must always be kept in a vapor state.
- The analyzer and sample line should be heated to a temperature above the flash points or condensation temperature of all the process compounds, including non-flammable ones.

# Technical Considerations

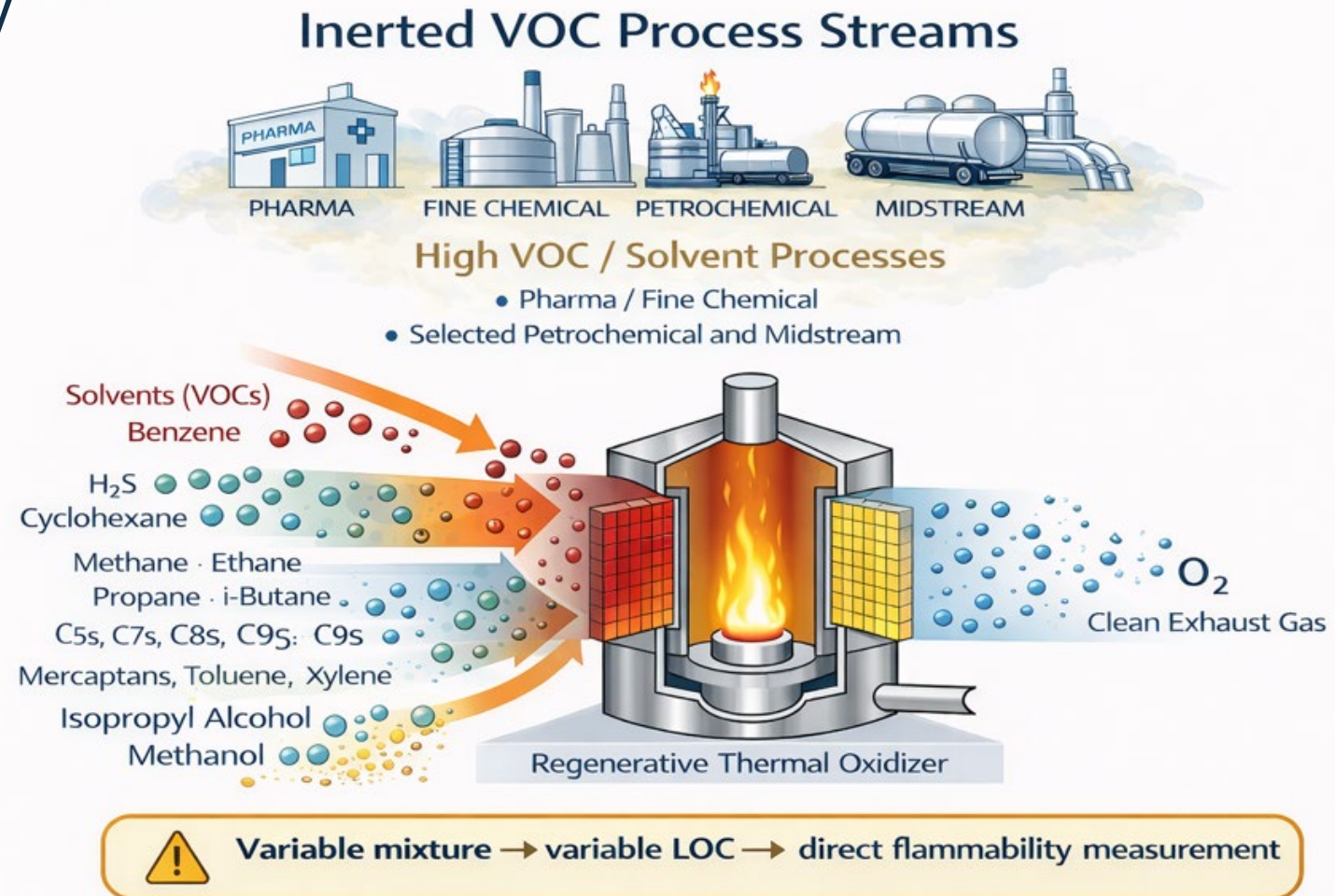
- Safety analyzer independent of the process control system
- Interlocks must be tested
- Reaction Time must be quick
- Fail-Safe Operation Required
- LFL Analyzer must be accurate
- Calibrated properly and maintained



- The minimum safety requirement is to have hard-wired contacts for Danger and Fault
- Effect a direct action (i.e. E-stop, full ventilation, open dampers, lift coating apparatus, etc.)
- This action should be independent of a PLC

# Case Example

- Widely used with heavy VOC loading
- Operating at elevated temperatures
- Complex Hydrocarbon Mixtures
- Quick Air Ingress can lead to operation in flammable zone; *NTE* 50% LFL
- Reliable, timely measurements with interlocks essential



# Flammability Measurement Considerations

- System-level approach
- Multi-parameter measurement philosophy
- Sampling System Design
- Alarm Management & Safety Interlocks
- Flammability = Integrated element of process safety

**Table 2. Flammability Measurement Considerations During Typical RTO Operating Conditions**

RTO Operating Condition	Typical Process Characteristics	Primary Flammability Concerns	Measurement Implications
Startup	Rapid temperature increase; unstable flow; variable VOC loading	Transient approach to flammable conditions before steady-state control is achieved	Fast response and conservative interlocks required; sampling lag can mask short-duration excursions
Steady-State Operation	Relatively stable temperature, flow, and composition	Sustained operation near design limits if process loading increases	Continuous monitoring required; reliance on single-parameter measurement may mask gradual risk escalation
Bed Switching / Valve Sequencing	Short-duration flow and pressure disturbances	Localized composition changes; potential dilution or enrichment effects	Measurement location and response time become critical to avoid misleading readings
Process Upset / Batch Release	Sudden increase in VOC concentration or air ingress	Rapid transition toward flammable conditions	Redundant or complementary measurements improve detection reliability
Shutdown	Declining temperature; changing flow paths; possible air intrusion	Loss of inerting margin as oxygen increases	Oxygen measurement <u>critical</u> ; fuel measurements alone may be insufficient



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Thank You for Listening,  
Any Questions

