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Tunable Diode Laser Technology

Direct Adsorbtion

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AAS Regional Sales Manager

Presentation Overview

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TDL Basics-How does it work

What can be measured

Types of installations

Products

Combustion Control

Tunable Diode Lasers

How Do They Work

Diode Laser

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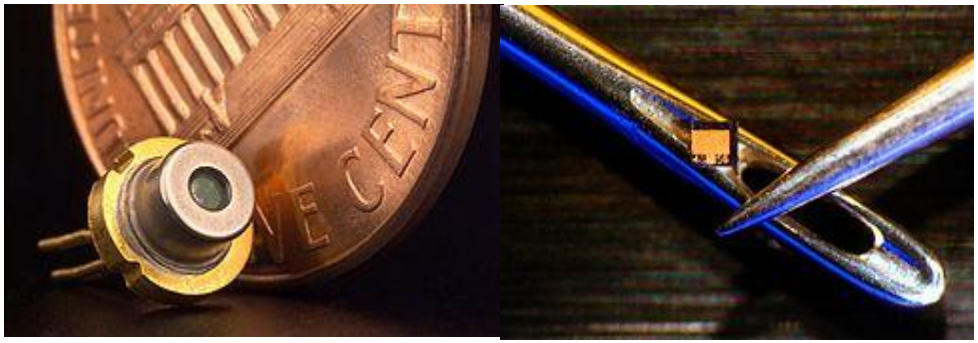
- "A **laser diode**, or **LD**, is an electrically pumped semiconductor laser in which the active medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode.
- The laser diode is the most common type of laser produced. Laser diodes have a very wide range of uses that include, are not limited to, fiber optic communications, barcode readers, laser pointers, CD/DVD/Blu-ray reading and recording, laser printing, scanning and increasingly directional lighting sources.[1]



[1]Text and pictured from (http://en.wikipedia.org/wiki/Laser_diode)

TruePeak - General Layout TDLS200

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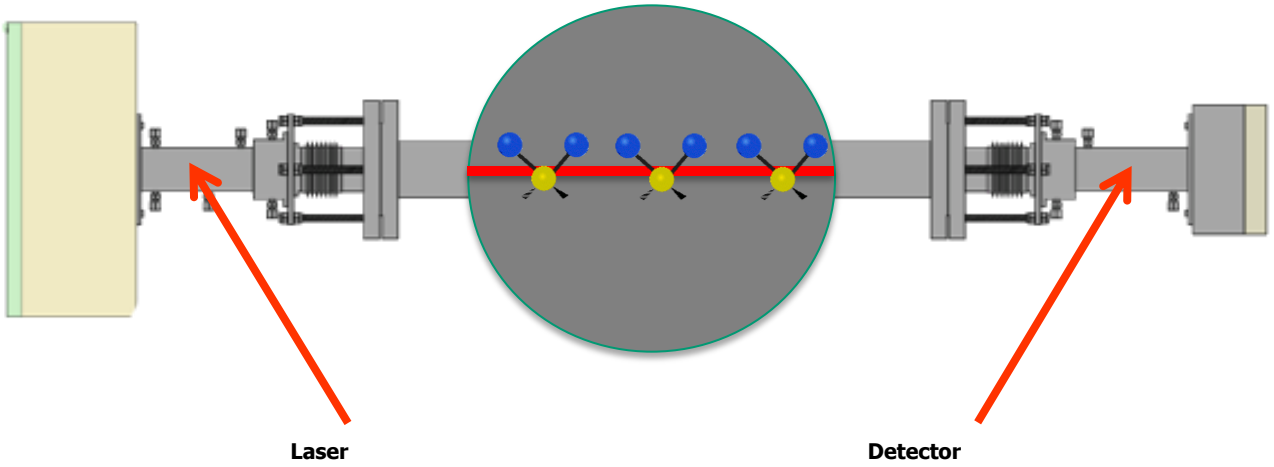

- Basic Requirements
  - Laser
  - Detector
  - Optics
  - Electronics
  - Pressure
  - Temperature

Single Peak Spectroscopy

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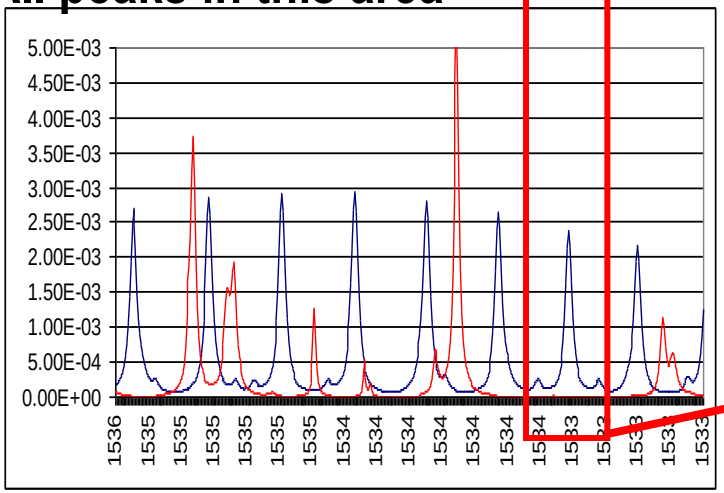
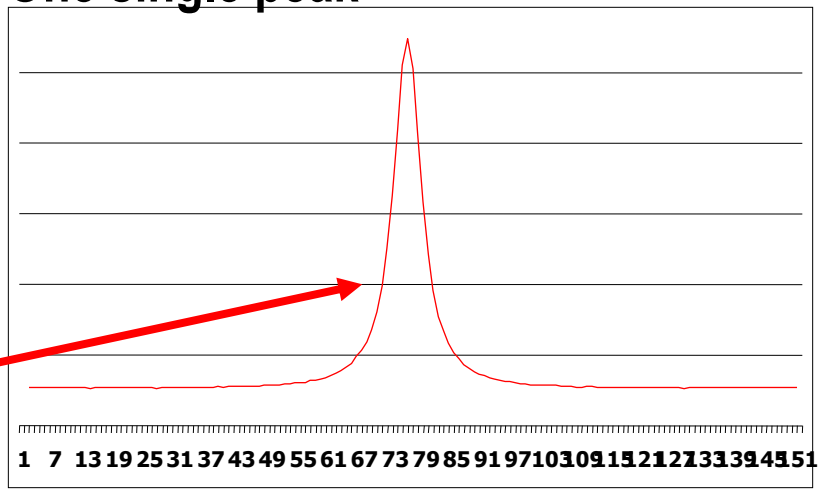
What does a filter photometer measure?

All peaks in this area



What does a TDL Spectrometer measure

One single peak



The Tunable Diode lasers have very narrow wavelength emission

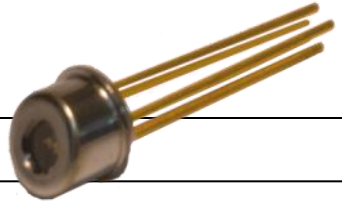
The linewidth is typically only around 0.00004nm

The laser scans the bandwidth, measuring the peak & baseline

TRUEPEAK 200/ 220 performs **1000 scans per second**

Direct Peak Area integration: accurate regardless of shape of peak

Operation – TruePeak TDL



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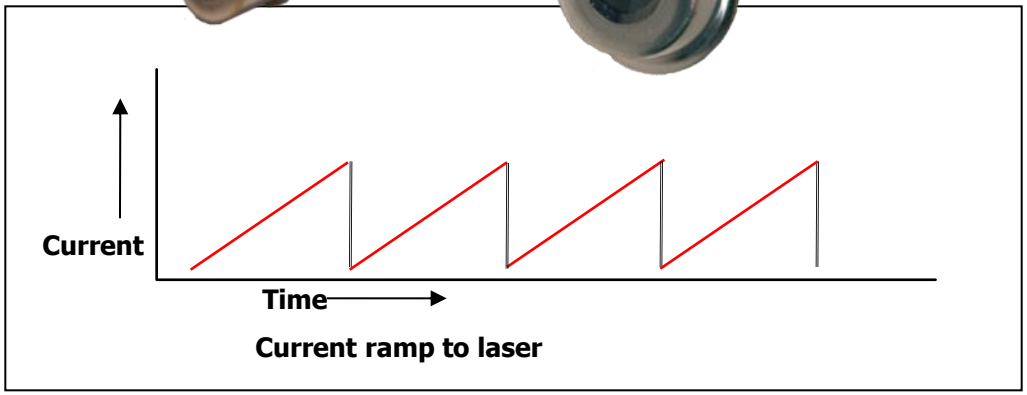
Coarse wavelength adjustment
Laser @ a fixed temperature
Cooler@ a fixed temperature

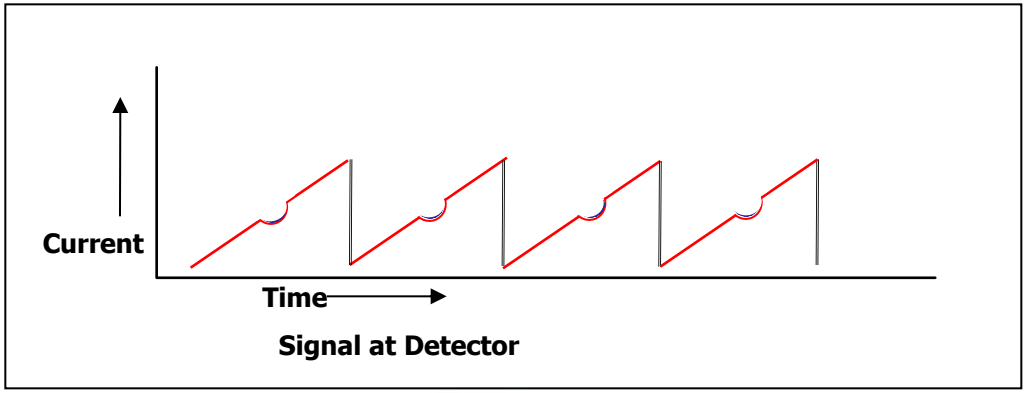
Fine wavelength adjustment
A current ramp is fed to the laser



Current ramp to laser

Light is transmitted
It passes through gas to be measured

Lets Measure Oxygen (O2)



Signal at Detector

Light is absorbed by the target gas
The amount = analyte concentration

The light is then focused on the detector
The amount of light at detector = gas concentration

It also provides Diagnostics on the measurement

YOKOGAWA

Operation – TruePeak TDLS….. Page 2

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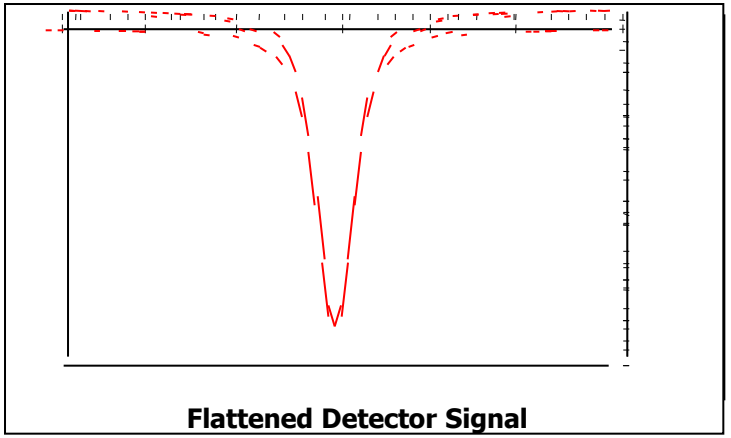
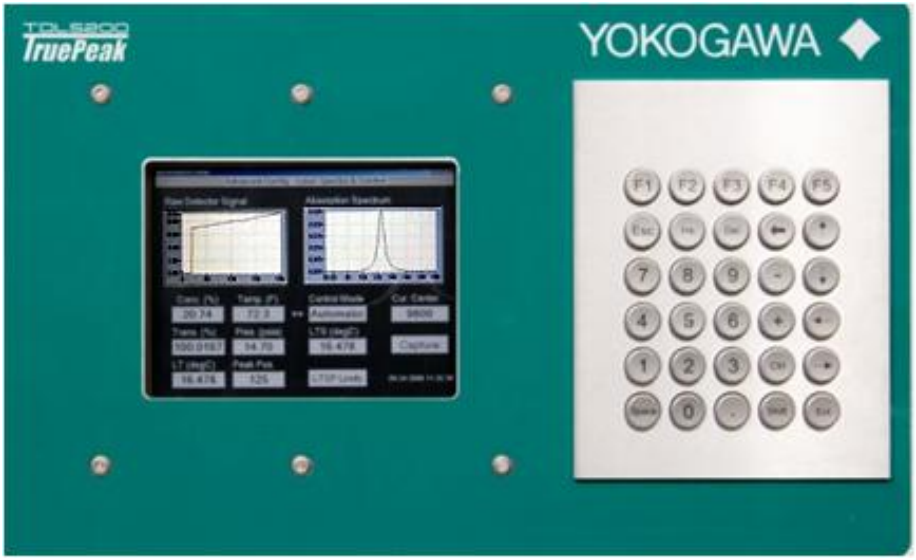
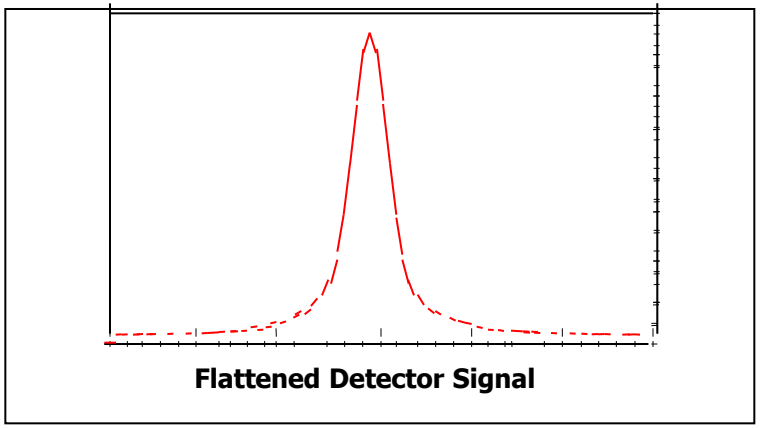
Light absorbed by the target (Peak)
The peak is proportional to the analyte concentration



Enlarged to show concentration detail





Analyzer flips the Peak. Why?
Makes it easier to comprehend

2nd. Gen Tuneable Diode Lasers

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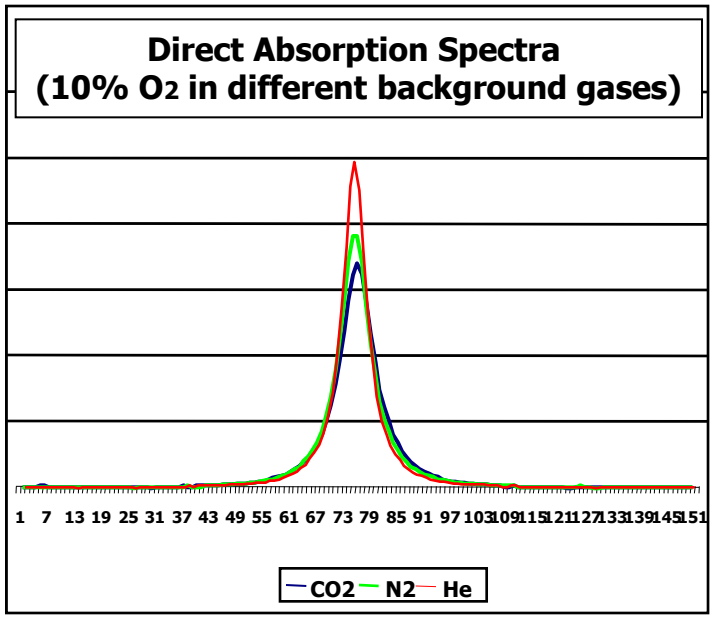
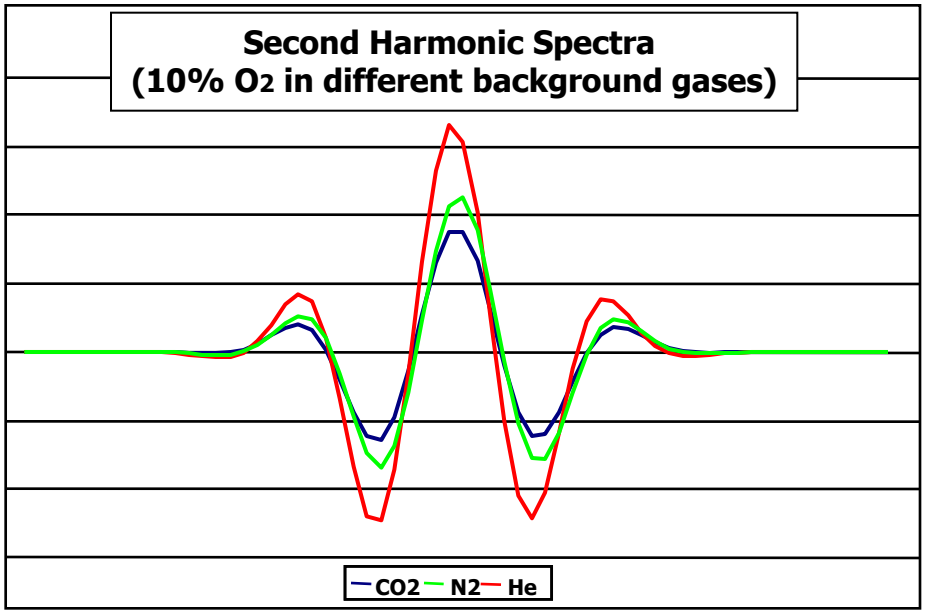
There are 2 highly common measurement techniques. They are-

Direct Absorption (left spectra) and Second Harmonic or 2f (right spectra)





Changes in background gases affect the shape of the absorption peak

Competitor's Second Harmonic (2f) peak height is AFFECTED

TruePeak uses Direct Absorption and Peak Area is UNAFFECTED

Direct Absorption = Area under Peak Stays the Same

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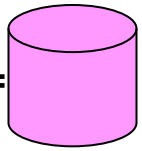
Area under Peak = 

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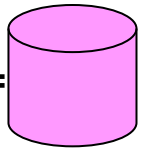
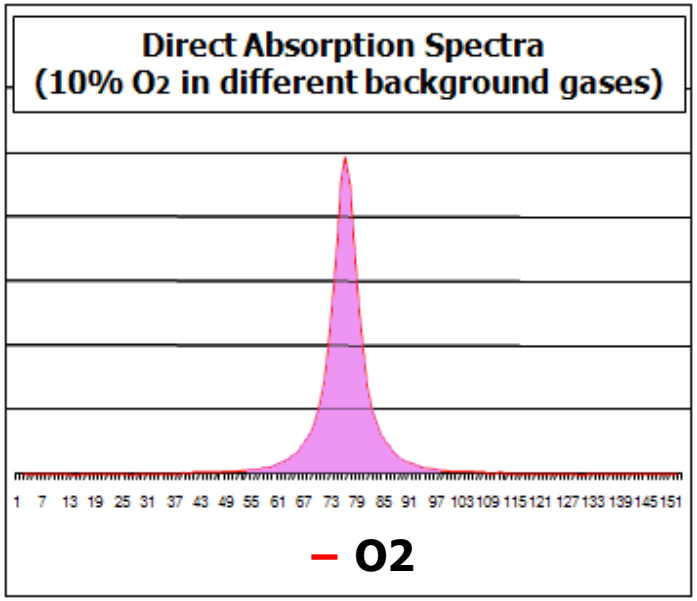
Area under Peak = 



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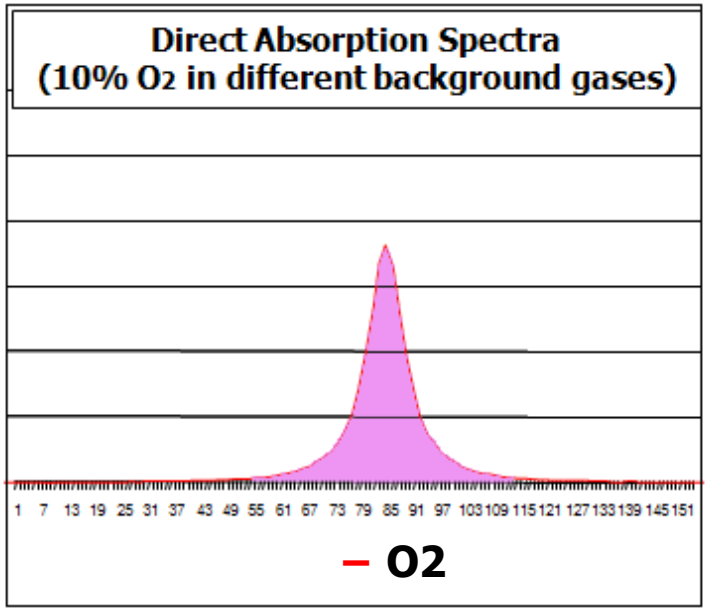
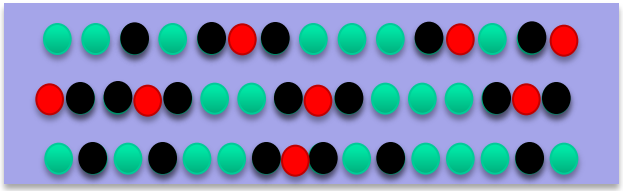


TruePeak



Process Gases

O2 in changing background gas concentrations

Second Harmonic (2f). Peak height is affected

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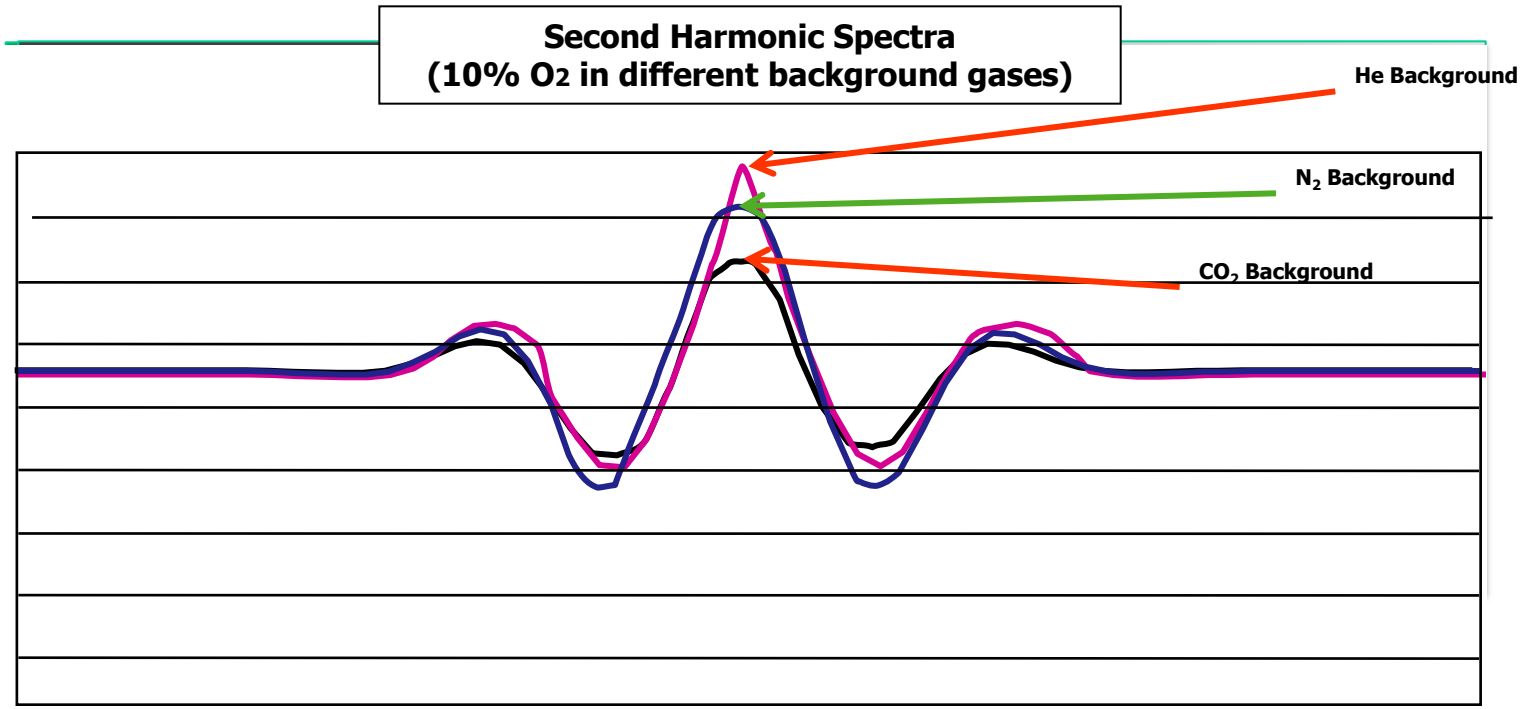
Yes you can try to fit changes into lab determined curves to adjust for changes in:

Background gases * Process Temperature * Process Pressure

Clearly this is not perfect. It is however better than doing nothing

It does however lead to false hopes that the compensation is working correctly

Who can predict what samples are the proper ones to take?



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TruePeak - Length Does Matter

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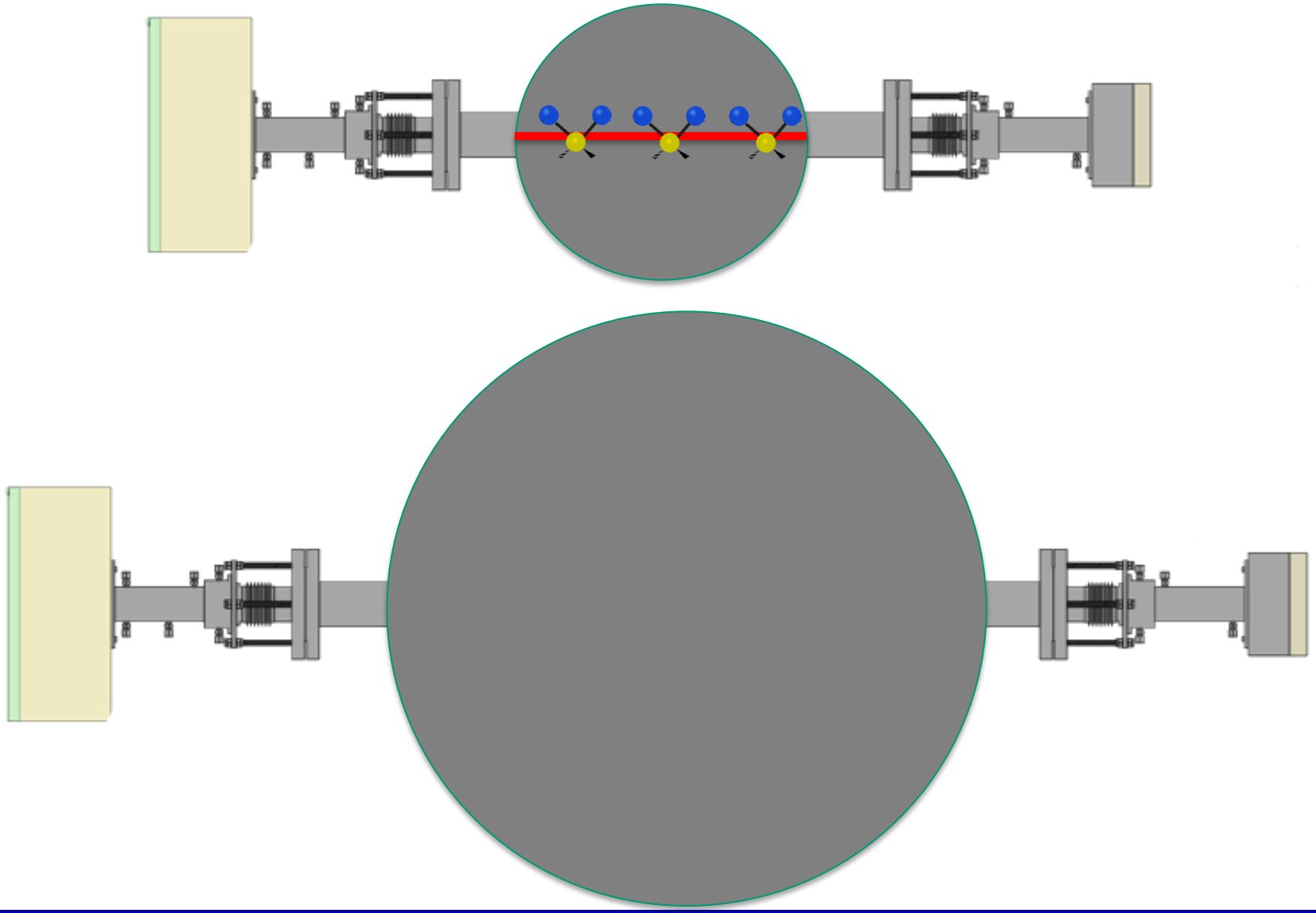

What Can TDL Measure?

TDLS200

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In Situ Analysis without sample conditioning – May be configured as Extractive

Fast Response (5-20 seconds)

Interference Rejection (high and variable light obstruction)

Process Pressures up to 20 Bar (Application Dependent)

Process Temperature up to 1500°C+ (Application Dependent)

Optical Measurement, no sensor contact with process

Aggressive Options EX: high particulate content, corrosives etc

Flexible Installation Options

Class 1, Div 2 Group B, C, D when purged

ATEX Category 3 Zone2

Safety Integrity Level:

SIL 1 Assessed

Gases measured:

O_2, CO, CH_4, CO_2, H_2S, NH_3, HCN,
HCl, HF, C_2H_2, H_2O, CO%+CO_2%,
NH_3ppm + H_2O%, CO+CH_4

TDLS220

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Extractive Analysis sample conditioning may be needed

Fast Response (5-20 seconds)

Interference Rejection (high and variable light obstruction)

Sample gas temperature up to 120˚C (248˚F)

(When ambient temperature is ≤ 40˚C)

Sample Pressures up to 7 Bar (100psi)

Optical Measurement, no sensor contact with process

Aggressive Options EX: high particulate content, corrosives etc

Flexible Installation Options

Class 1, Div 2 Group B, C, D when purged

Gases measured: O_2

Max Range 0-100%, Min Range 0-1%

More gas measurements to come

YOKOGAWA

TDLS500

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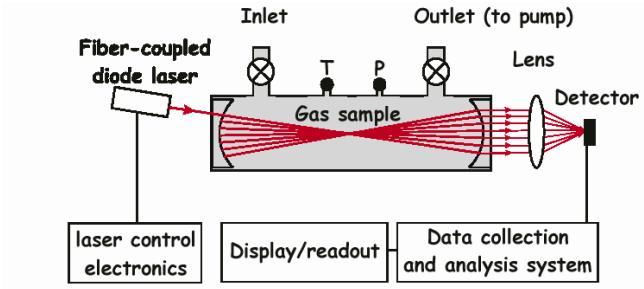
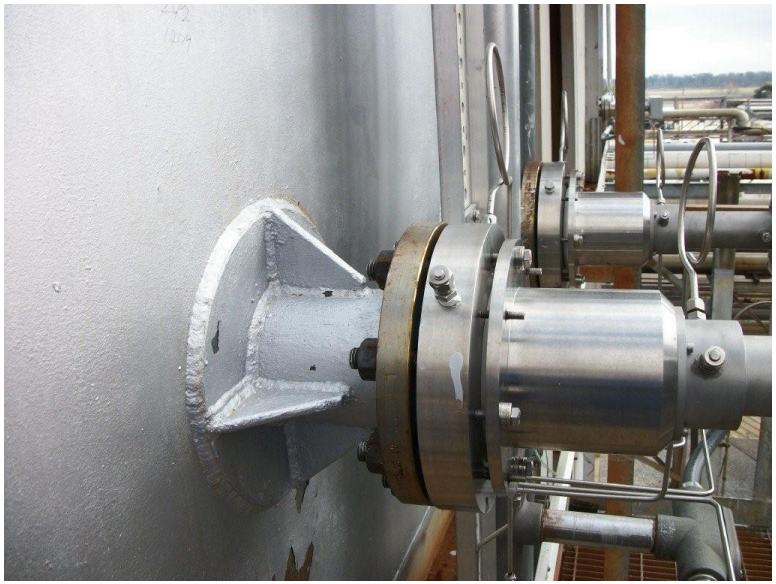
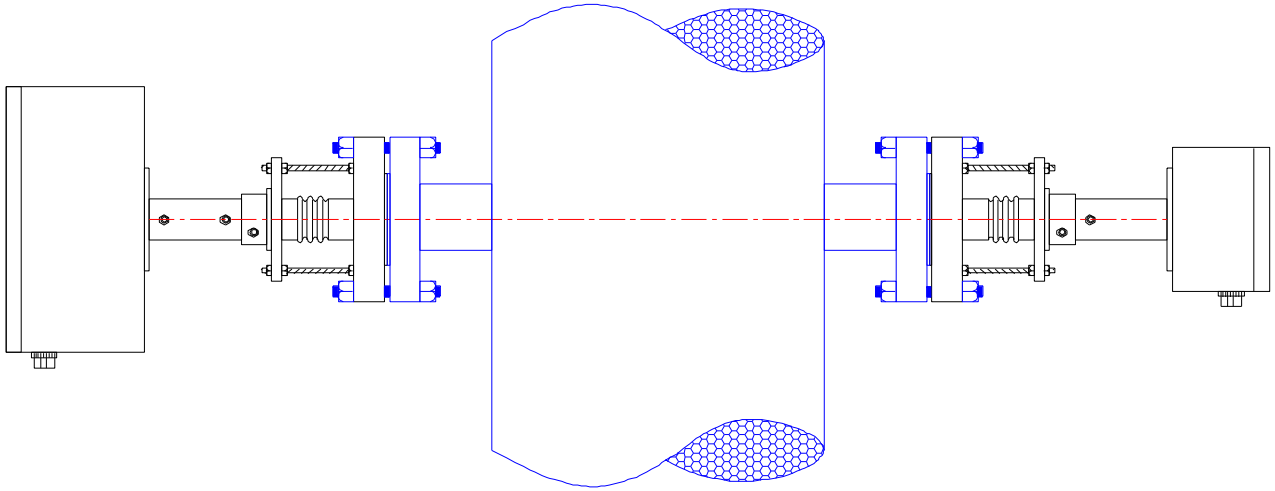
- Extractive Analysis sample conditioning may be needed
- Fast Response (7-20 seconds)
- Interference Rejection (high and variable light obstruction)
- Sample gas temperature up to 100˚C (212˚F)
- Ambient temperature upper limit is 40˚C – Designed for controlled environment
- Sample Pressures up to 7 Bar (100psi)
- Optical Measurement, no sensor contact with process
- Multi-pass Integrated Cavity Output Spectroscopy (ICOS)
  - Optical Path Lengths up to 10,000 meters for high sensitivity
  - Sub-ppb detection limits
- Flexible Installation Options
- Class 1, Div 2 Group B, C, D when purged
- Gases measured:
  - C_2H_2, NH_3, CO, H_2S
  - C_2H_2 + m-C_2H_2
  - C_2H_2 + NH_3



Installation Options

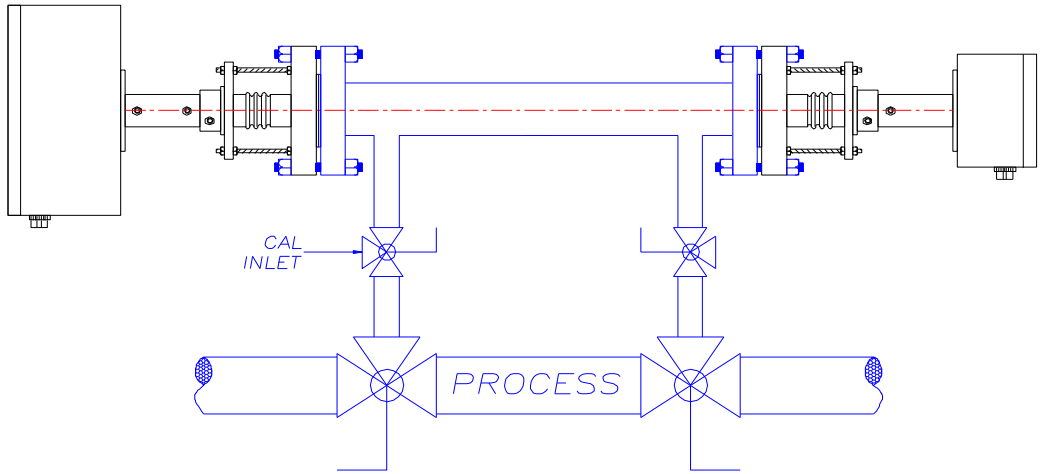


Installation Options



- **CROSS STACK/PIPE (IN-SITU)**
  - Measurement across the process
  - Path integrated measurement
  - Validation options
    - » Off line verification/calibration with calibration cell
    - » On line verification with dynamic spiking (bump cell)

Installation Options



BYPASS LEG

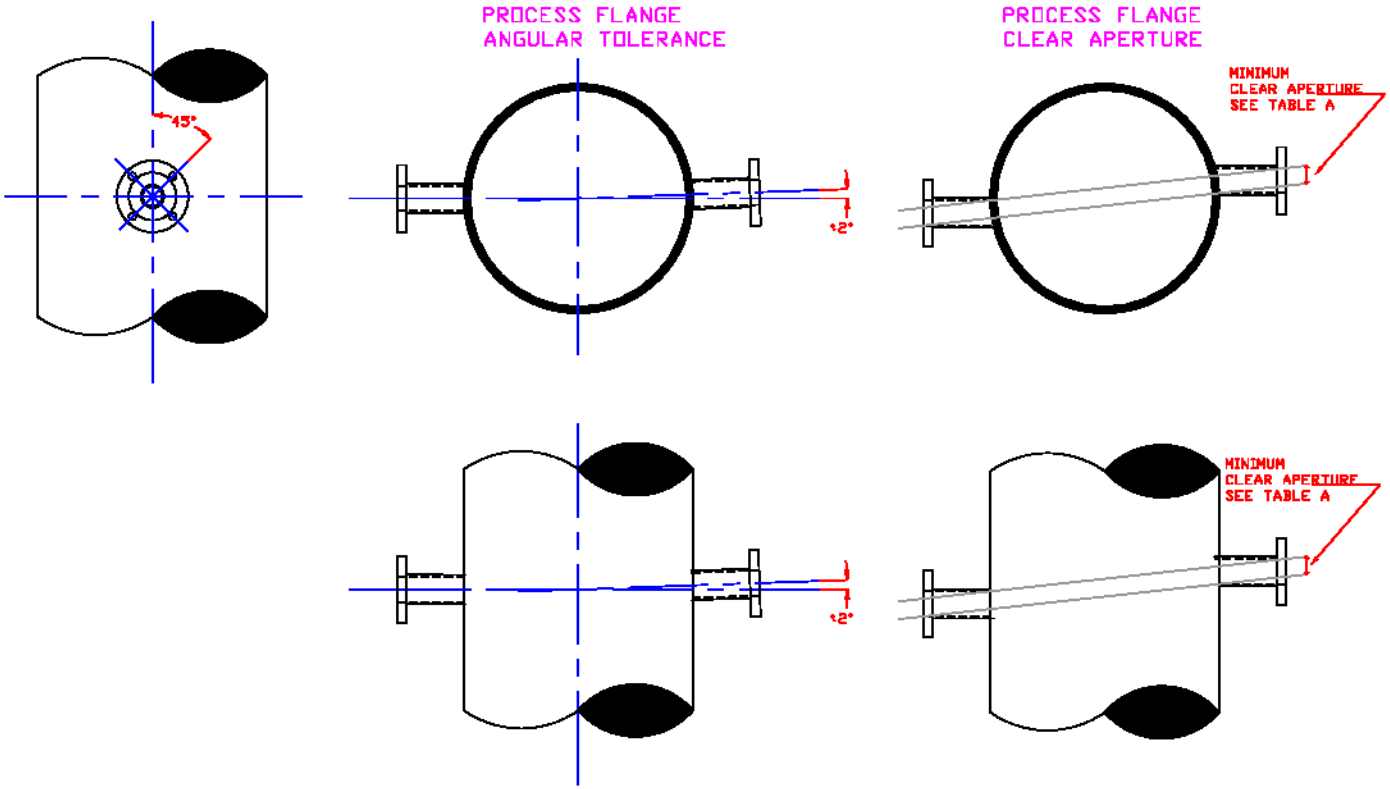
- Process flow through measurement leg
  - or-
- Process slipstream through measurement leg
- Allows isolation from process
- Validation options
- Large diameter pipe run
  - Isolate from process, flow gas standard
  - On line verification with dynamic spiking

FLOW CELL

- Pull or push sample through flow cell
- Validation options
  - Isolate from process, flow gas standard

INSITU ALINGMENT

- **The analyzer laser beam must be able to pass from one side of the process to the other.**
- **The flanges and nozzles must be within +/- 2 Degrees of center line**



The Direct Adsorption Advantage

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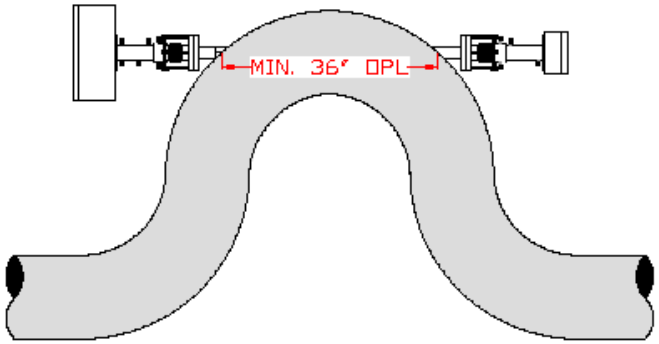

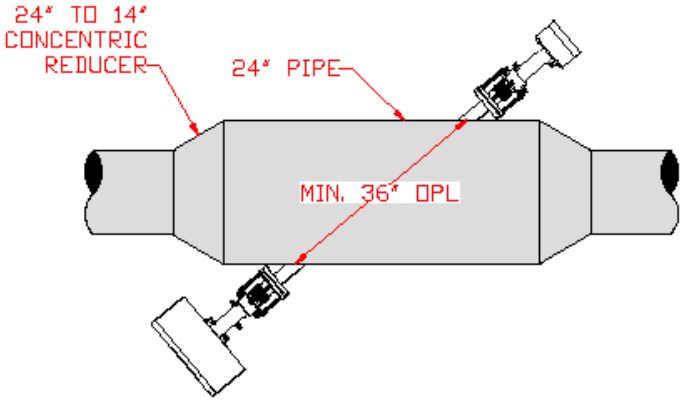

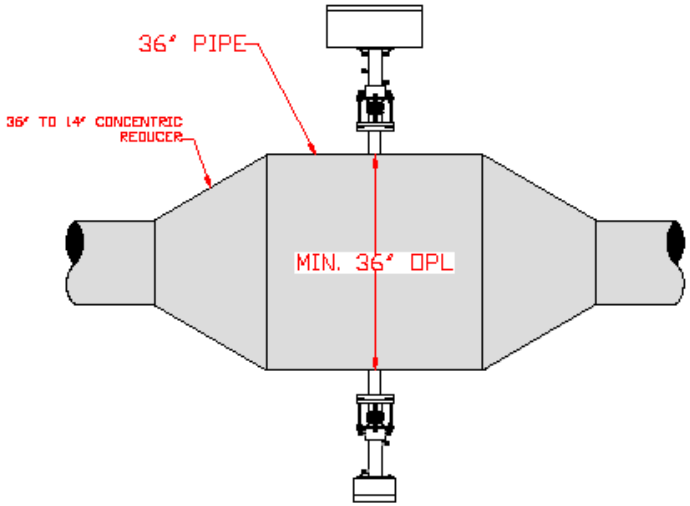

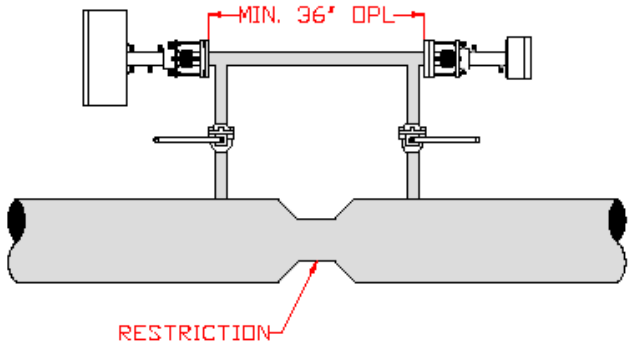

UTILITY PANEL

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- A **Utility Panel** provides a central location for:
  - Nitrogen supply for purges
  - Validation gas supply
  - Purge control
  - Validation control
  - 110 VAC line power in and 24VDC out to each analyzer
  - Analog signals
  - Digital signals
  - Analyzer interface

- Yokogawa supplies a single interconnect cable that connects the Utility Panel to the Launch unit for power and signal requirements

- Utility Panels for 1 to 4 analyzers are available

SINGLE UTILITY PANEL

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DUAL UTILITY PANEL

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Questions?

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Combustion Control Applications

Measurement and Control Goals

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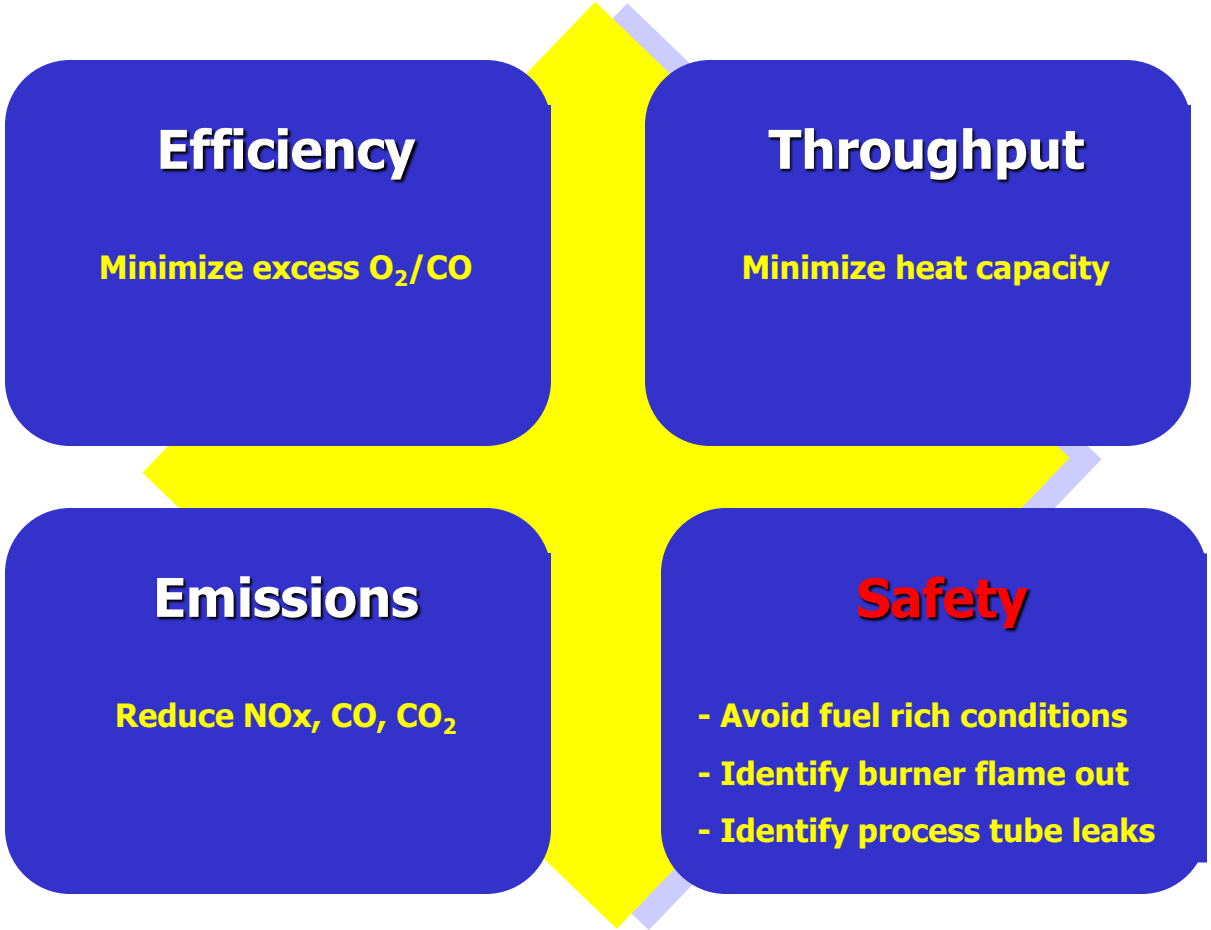

Oxygen Analysis Methods

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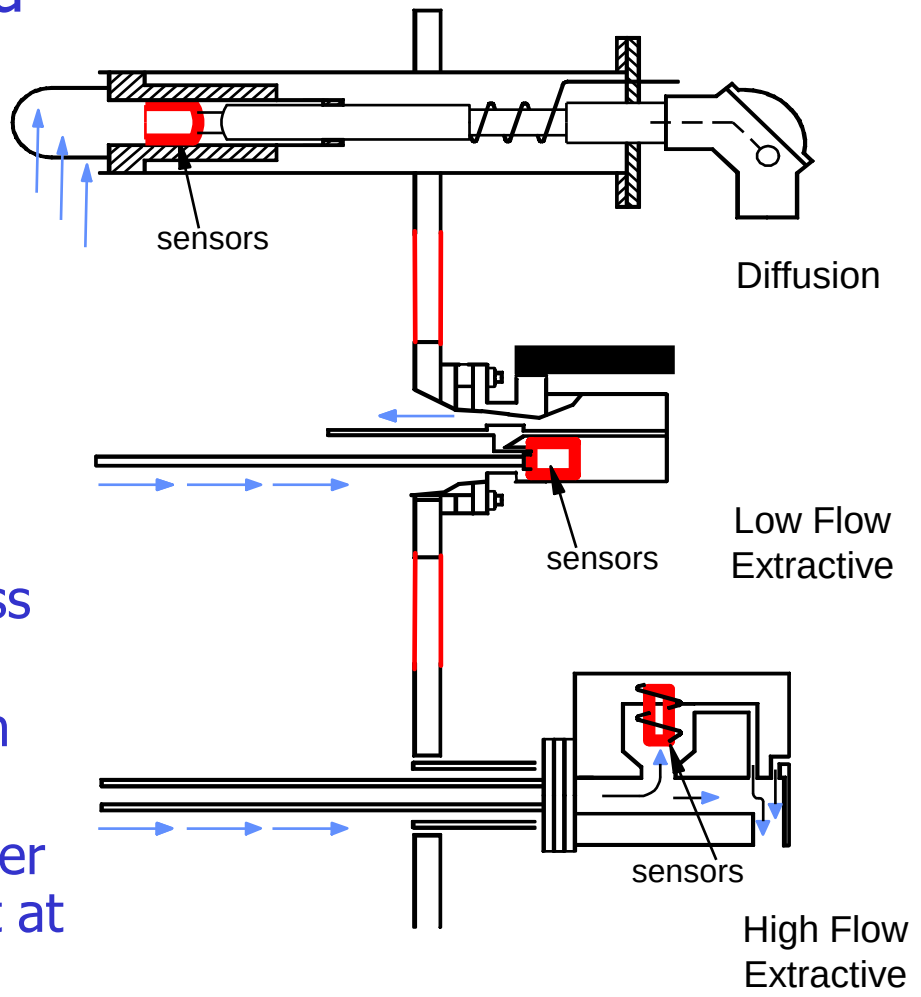
Combustion oxygen is dominated by **zirconia based analyzers**

Low cost, reliable

Analyzers generally divide into three types

- Close **coupled extractive** (CCE). Sensor is removed from the process to allow higher gas temperatures
- **In-situ with heater**. Sensor is in the process, limited to ~700° C
- **In-situ w/o heater**. Allows higher gas temperature, no measurement at lower gas temperatures



Zirconia Measurement Considerations

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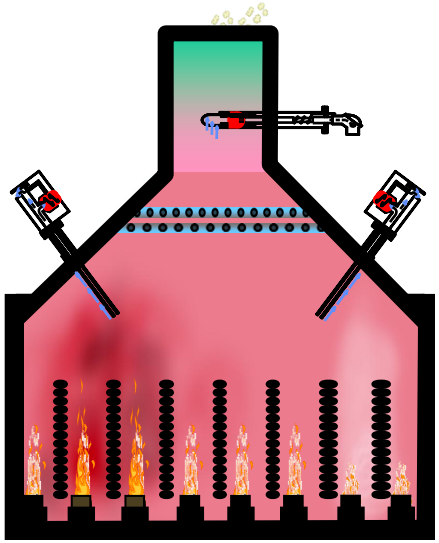
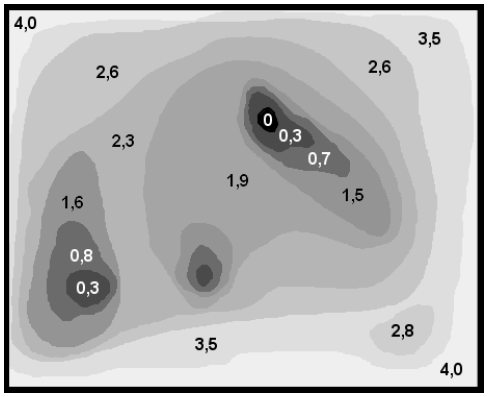
Placement

- Oxygen concentrations can have high distribution in large systems (vertical and horizontal)
- Vertical distribution is due to tramp air (air leaks)
- Horizontal distribution is due to burner variations and flow effects
- Placement is critical to allow control, distributions can be 50% to >100% of the average excess oxygen from the burners
- Errors for low temperature in-situ probes placed further away from the burners are dominated by tramp air effects
- Errors for high temperature CCE analyzers are dominated by burner effects. Multiple analyzers are typically installed. Decisions on which values to use are significant (low, average)





Zirconia Measurement Considerations

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Speed

- Sensors have fast response (5-10s typical). Filters and diffusion elements can significantly affect response time (can be tested).

Interferences

- Any combustible gases in the process (CO, HC's, H_2, etc) will burn with oxygen at the sensor, consuming oxygen and forcing the measurement low.

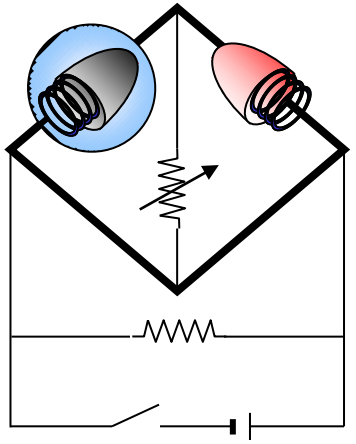
Example: (5% O_2 in the presence of 1% C_3H_8)

$$C_3H_8 + 5O_2 = 3CO_2 + 4H_20$$

5% O_2 level would read "**zero**"

CO Measurement Methods

The Past

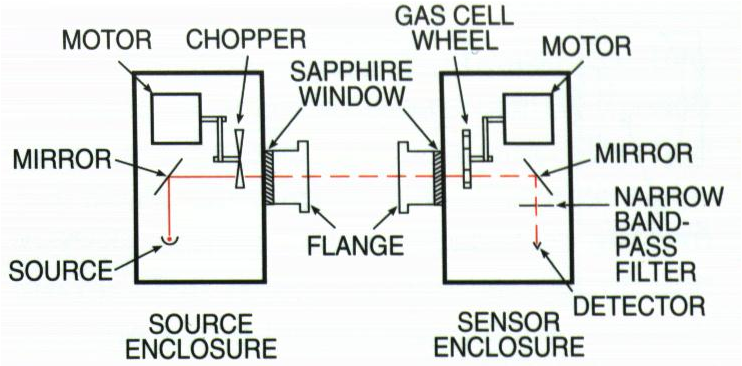


Solid State Sensors (combined with ZrO_2)

- Thick/thin film
- Catalytic bead

Optical

- NDIR , Gas Filter Correlation



Combustion Analysis

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Combustion systems are changing:

- Emissions limits are lower. Low NOx burners have reduced CO emissions. Measurement is more difficult.
- Furnaces are larger with more burners. Catching breakthrough from a "bad" burner requires improved sensitivity
- NOx emissions can limit system operations.
- Efficient combustion is critical in allowing maximum firing rates

Increasing cost of fuel and feedstock puts a higher emphasis on combustion control.

Efficiency = Lower Fuel Costs + Higher System Throughput

CO Measurement for Efficiency

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CO breakthrough determines the ideal control point, prior to breakthrough:

- Highest efficiency
- Highest temperatures produced
- Combustibles are consumed

CO trim control can delivery optimum efficiency and flame temperature while remaining safe

CO levels from burners have been a moving target

- Older burners CO levels 100's of ppm
- Low NOx burners CO levels <50ppm
- Ultra low-NOx burners CO levels <10ppm

Efficiency Measurements

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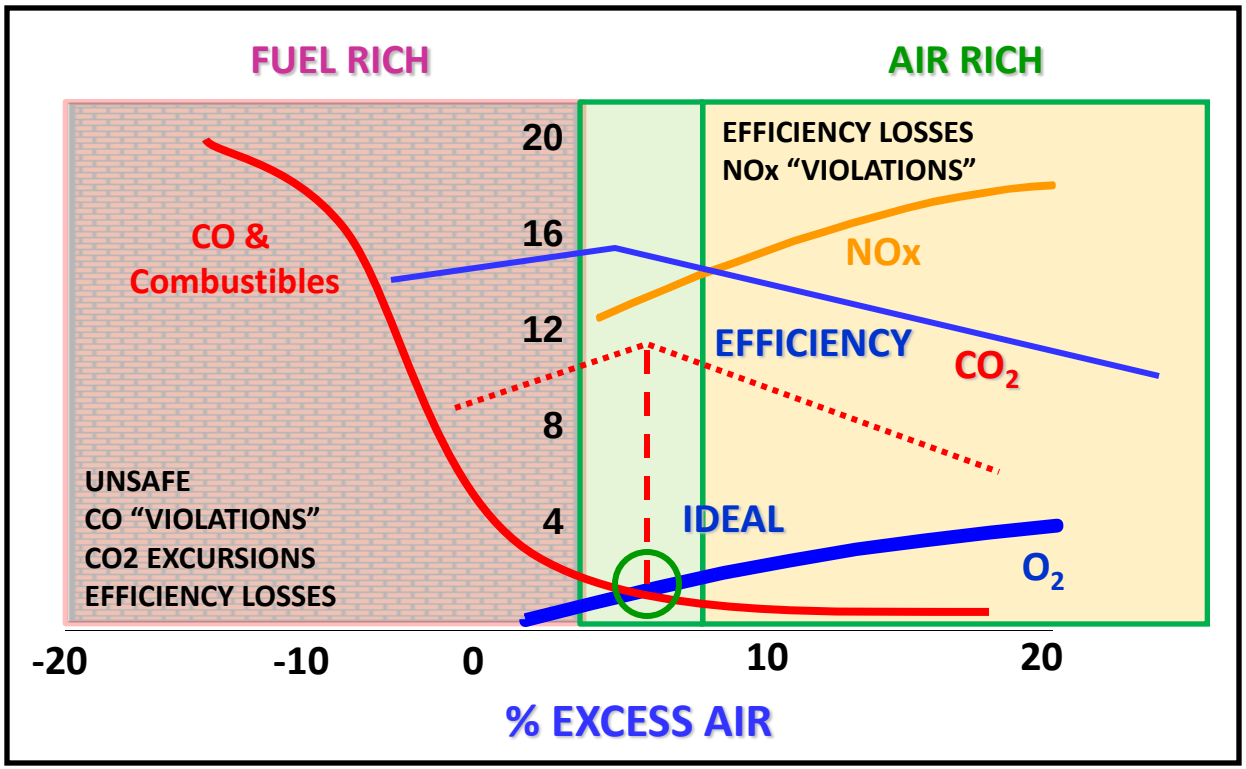
Oxygen

- Primary combustion efficiency measurement. Easy to use for control
- Typically also used as safety measurement

CO

- Ideal set point measurement (for excess air)
- Pre-cursor to combustibles breakthrough



What is the Correct Excess Oxygen Value ?

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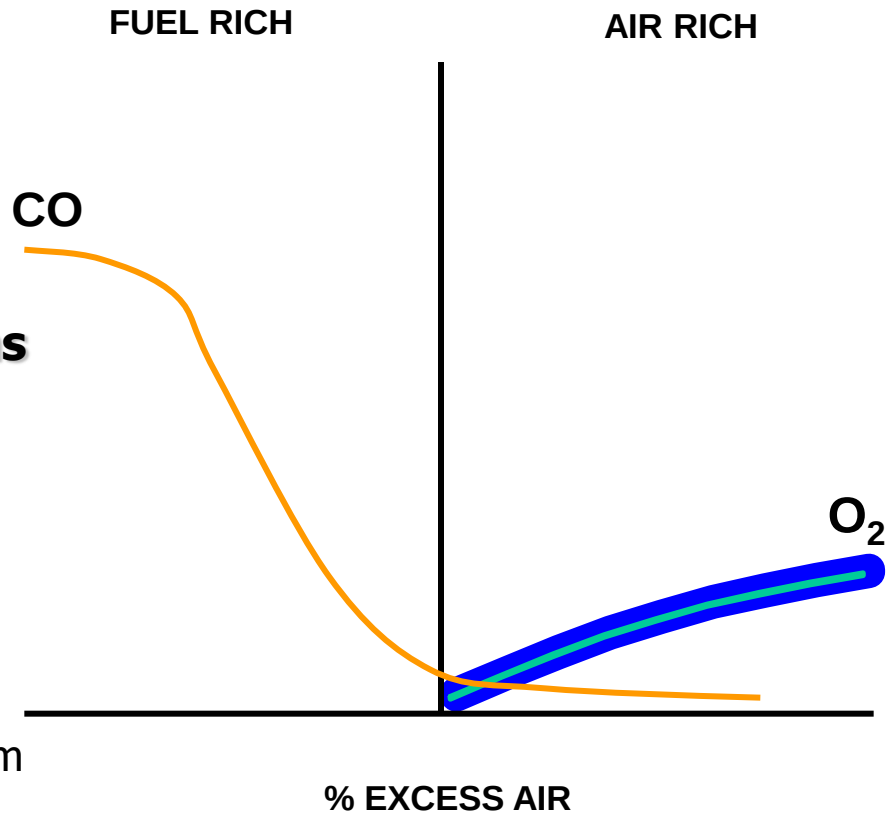
The lowest possible without:

- Compromising safety (combustibles)
- Generating CO

Absolute level depends on conditions

- Different fuels
- Variable heat content of fuel
- Type of burner
- Humidity changes
- Density variation
- Varying loads
- Fouling of burner system
- Mechanical wear of combustion system



CO Measurement can determine O_2 setpoint

TDL for Oxygen

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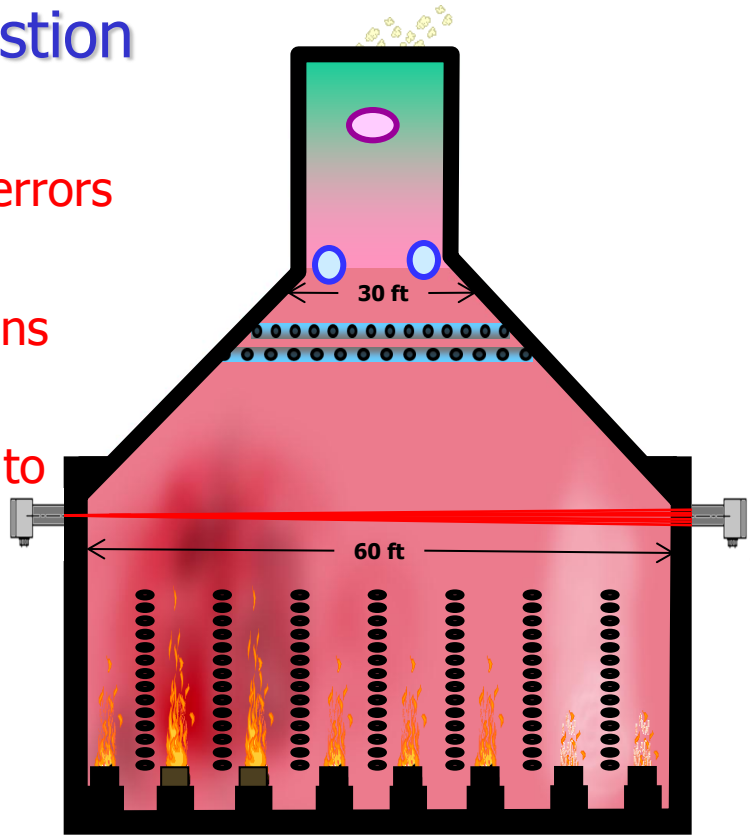
TDL is seeing increased use in combustion oxygen measurements

- Path average measurement reduces distribution errors
- No interference from combustibles or CO
- No potential ignition source during upset conditions
- Fast response (5 seconds)
- Ability to provide Measurement in Gas Temps up to 1500 C



Measurement Suite using TDL

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Efficiency & Emissions

- O_2/CO to minimize excess air, maximize efficiency and reduce emissions

Fuel rich burner conditions

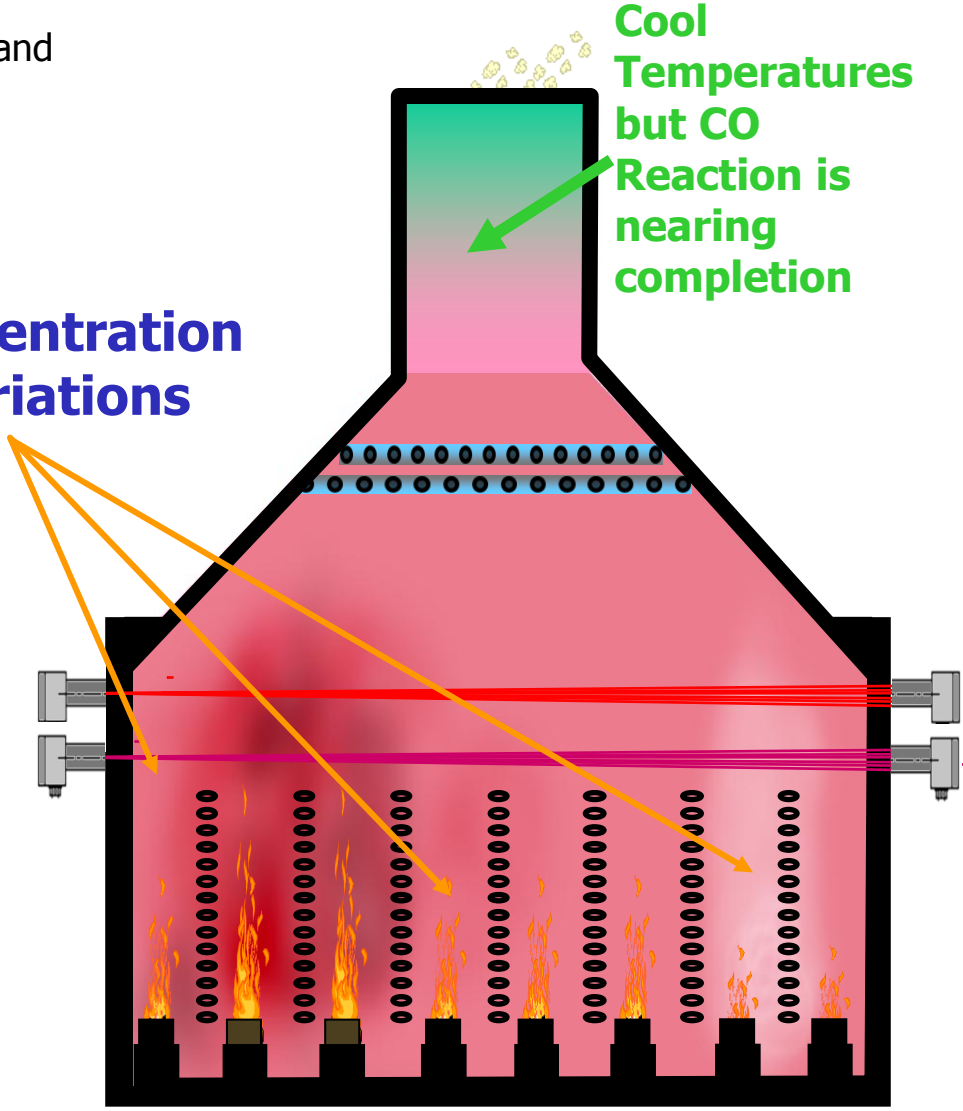
- CO levels increase as a precursor to hydrocarbon breakthrough

Burner flame out

- Temperature drops rapidly*
- Hydrocarbons (methane) increase rapidly
- Oxygen increases rapidly
- Moisture drops rapidly*

Process tube leaks

- Moisture may increase (steam cracking)*
- Hydrocarbons increase (methane)
- Oxygen may not change significantly
- Temperature may not change significantly*
- CO may not change significantly



*Consult Yokogawa for Temperature, CH4, and H_2O .
These are application dependant

Simultaneous TDL measurement of O_2 + CO

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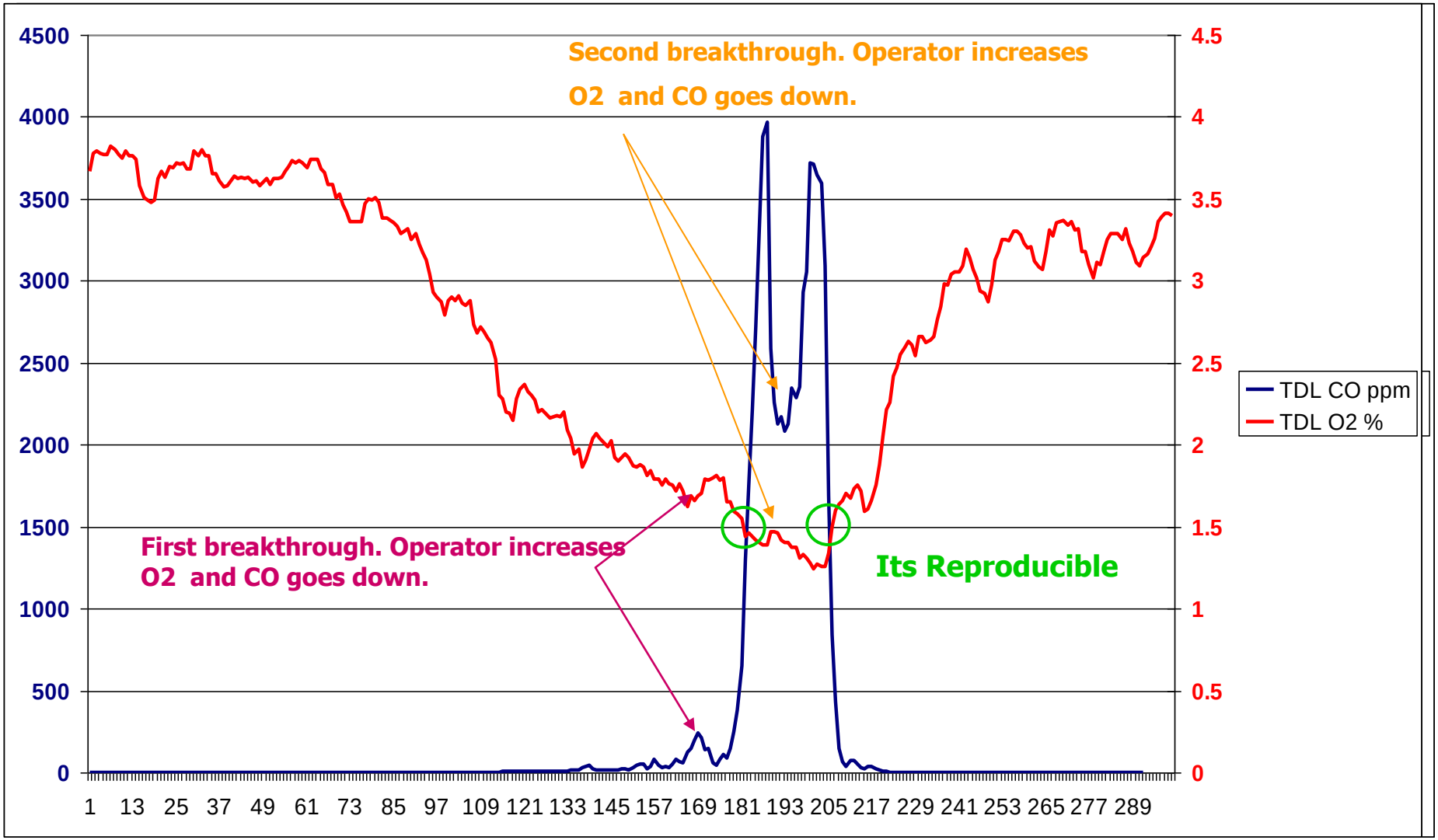
Operator Test. Adjust O2 downward to cause CO breakthroughs.



Emissions Reduction

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- NOx limits can result in firing rate (capacity) limits
- NOx credits can be sold
- NOx is formed in the combustion process through reaction of nitrogen and oxygen in burner air feed
- Reducing excess air, reduces nitrogen and oxygen, resulting in reduced NOx emissions
- CO_2 emissions are also reduced through efficiency improvements
- CO emissions can be measured and controlled near real time

Safety Monitoring

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Three Conditions present safety concerns . . .

- **Fuel rich burner conditions**
  - CO levels increase as a precursor to hydrocarbon breakthrough
- **Burner flame out**
  - Temperature drops rapidly
  - Oxygen increases rapidly
  - Hydrocarbons (methane) increase rapidly
  - Moisture drops rapidly
- **Process tube leaks**
  - Moisture may increase (steam cracking)
  - Oxygen may not change significantly
  - CO may not change significantly
  - Hydrocarbons increase (methane)
  - Temperature may not change significantly

- Measuring and understanding furnace conditions (indicated in red) can help identify safety concerns and their causes.
- This can only be accomplished by having enough measurements points to discriminate between differing safety concerns.
- O_2 and CO measurements are not sufficient.

Solution: Measurement Suite using TDL (Patent pending)

Large Scale Combustion (Furnaces and Heaters)

- **Path vs. Point** decision (O_2 and CO)
- Measurement location (**distribution, tramp air**)
- **Response time** needs (safety + control)
- **Control method** (single air control, multiple fuel controls)
- **Safety issues** (Ignition sources, combustibles measurement)

CO Measurement for Efficiency

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CO breakthrough determines the ideal control point, prior to breakthrough:

- Highest efficiency
- Highest temperatures produced
- Combustibles are consumed

CO trim control can delivery optimum efficiency and flame temperature while remaining safe

CO levels from burners have been a moving target

- Older burners CO levels 100's of ppm
- Low NOx burners CO levels <50ppm
- Ultra low-NOx burners CO levels <10ppm

Conclusion

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Combustion systems are changing, we need to adapt to the new issues:

- Emissions limits are lower.
- Low NOx burners have reduced CO emissions. Measurement is more difficult.
- Furnaces are larger with more burners. Catching breakthrough from a "bad" burner requires improved sensitivity
- NOx emissions can limit system operations. Efficient combustion is critical in allowing maximum firing rates

Increasing cost of fuel and feedstock puts a higher emphasis on combustion control.

~ Lower Fuel Costs + Higher System Throughput ~

Questions

CO

TDL

O_2

O_2

CO_2

TDL