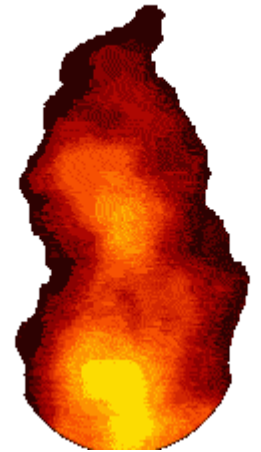


Combustion optimization by Tunable Diode Laser Spectroscopy

***Burn Less
...Earn More***



Arthur Groenbos
Product Manager Gas Analyzers
Yokogawa Europe BV
arthur.groenbos@nl.yokogawa.com

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Agenda

- Introduction Yokogawa
- What is TDLS?
- Basics of combustion
- Example from the field
- Conclusion

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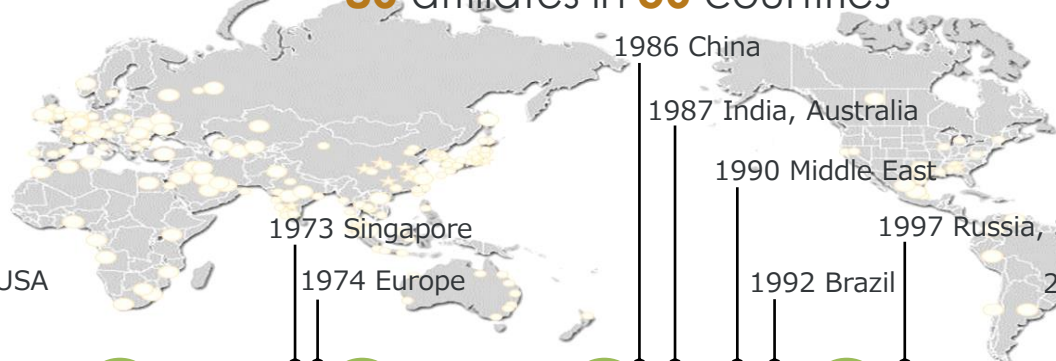
Yokogawa's 100 year history

Global business expansion

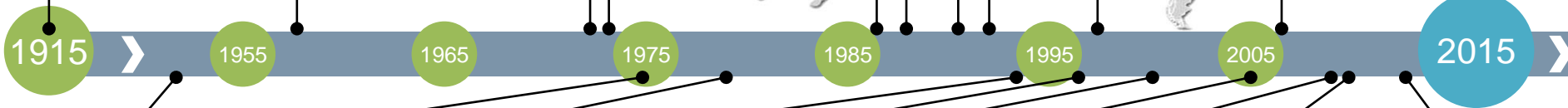


1915
Founded by
Dr. Tamisuke
Yokogawa

86 affiliates in 56 countries



100th
ANNIVERSARY 1915-2015



1950
First
electronic
recorders
in Japan



1975
World's 1st
DCS: CENTUM



1979
World's 1st
vortex
flowmeter



1994
World's 1st
fully digital
transmitter
with silicon
resonant
sensor



1996
World's largest
DCS-PJT

2000
World's 1st
MAC-PJT



2005
World's 1st
Integrated
DCS-SIS

2009
World's 1st
ISA95
compliant
real-time
MES package

**Real-time
Production
Organizer.™**

2010
World's 1st
ISA100
compliant
field devices



2014
World's 1st
smart
configurable
I/O:
CENTUM VP



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Worldwide Business Operations

Global network supporting business growth

Number of Employees

Worldwide : 19,685 / Outside Japan : 11,089

● Regional Head Quarters

15 subsidiaries and 1 affiliate in Japan

69 subsidiaries and 2 affiliates outside Japan



Yokogawa Europe
(The Netherlands)



Yokogawa China
(China)



World Headquarters
Yokogawa Electric Corporation
(Japan)



Yokogawa Middle East & Africa
(Bahrain)



Yokogawa Electric International
Yokogawa Engineering Asia
(Singapore)



Yokogawa Corporation of America
(USA)

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Yokogawa portfolio Industrial Automation & Control

Corporate Management (ERP*)
Integrated business operation systems

Production Management (MES*)

Systems for advanced control, simulation, production management, and scheduling

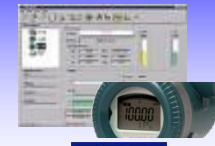
APC & OWA Advanced Process Control & Operational Work Assistance

Exasmoc
Exarqe
Exaplog
Exapilot



CAMS for HIS

Asset Management



PPM
Plant Resource Management

PIMS Process Data Acquisition & Management



Exaquantum

Production Control System

Production control systems

DCS Integrated Production Control System



CENTUM VP

Network Based Control System



Network-based Control System
STARDEM

Safety Instrumented System



ProSafe-RS

Differential Pressure Transmitter



EJA/EJX

Magnetic Flowmeter



AXF

Digital Vortex Flowmeter



DYF

Zirconia Oxygen Analyzer



ZR

Tunable Diode Laser Spectrometer



TDL8000

Process Gas Chromatograph



GC8000

Advanced Valve Positioner



YVP

Temperature Transmitter



YTA50/70 YTA100/300

Field Instruments

Field instruments, sensors, measuring instruments, analyzers and other equipment

* ERP = Enterprise Resource Planning
* MES = Manufacturing Execution System

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What is TDLS?

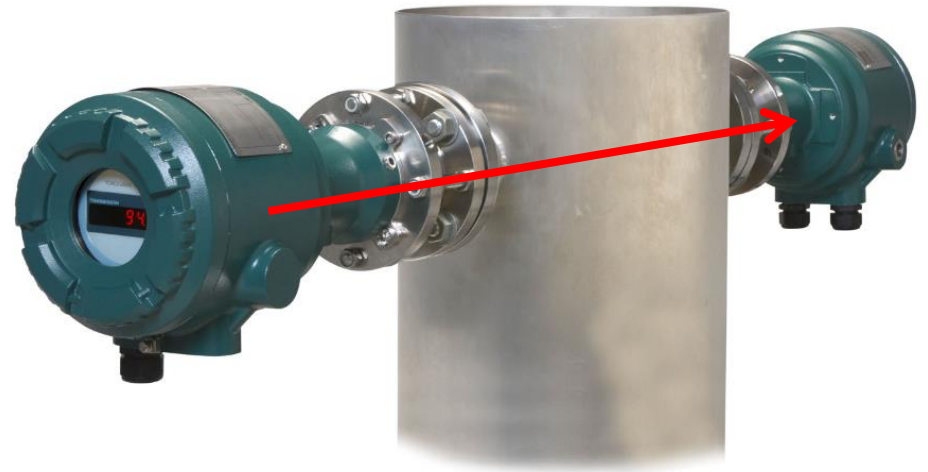
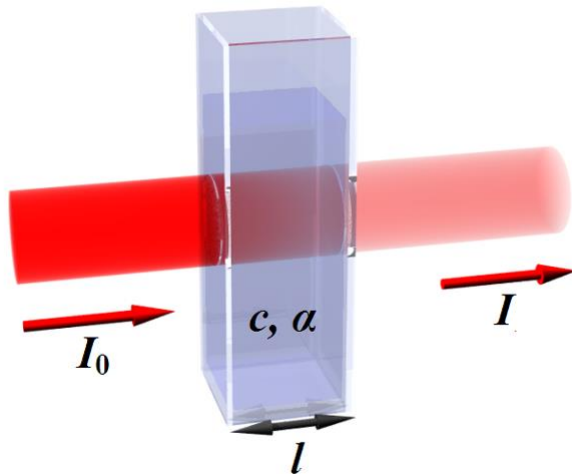
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What is TDL Spectroscopy?

- TDL: Tunable Diode Laser
- Based on absorption spectroscopy; measuring the amount of light that is absorbed as it travels through the sample being measured
- Absorption equals concentration: Lambert-Beer's law

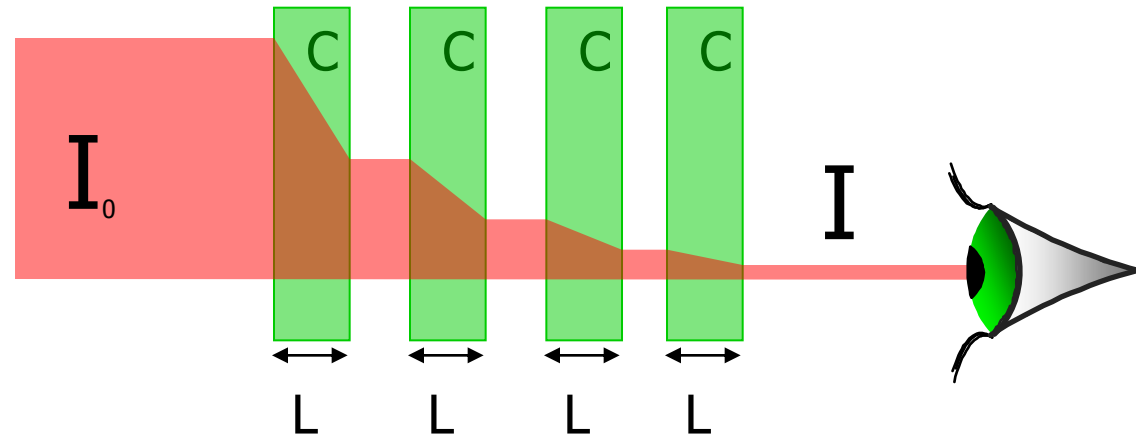
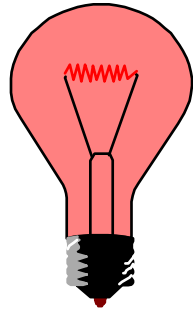


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Lambert Beers' Law



Transmission: $T = I/I_0$

Absorption: $A = \log 1/T = \epsilon \cdot C \cdot L$

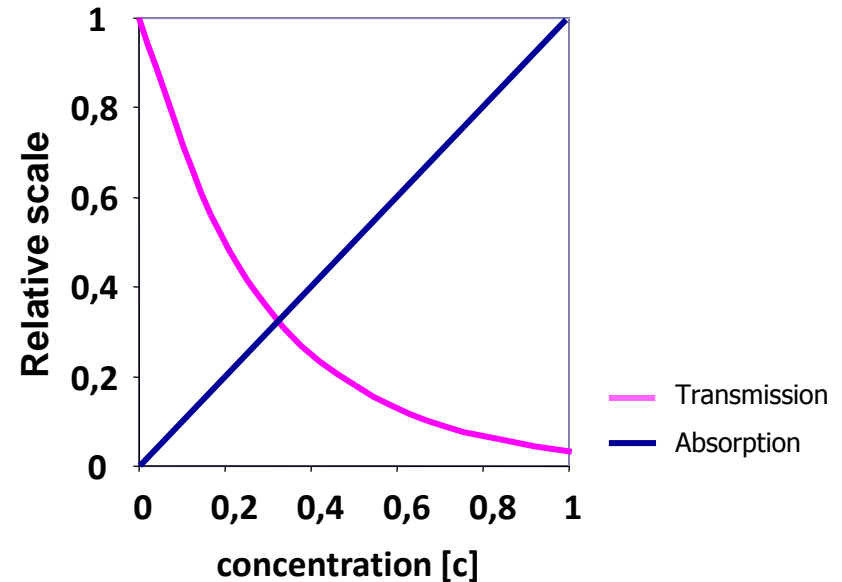
$C = A / \epsilon \cdot L$

C = concentration

A = absorption

ϵ = extinction coefficient

L = optical path length



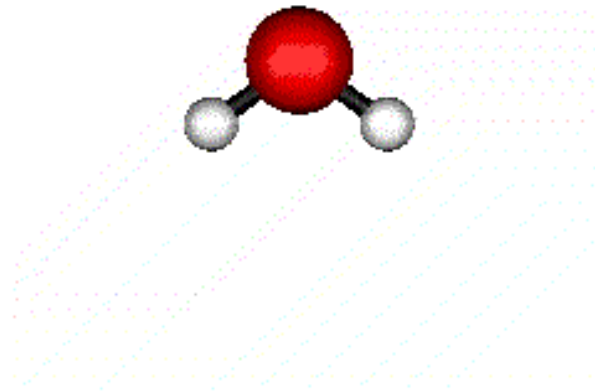
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Fundamental Vibration of the Water Molecule

- Molecules can be considered oscillators
- The bonds correlate to springs and the atoms are mass balls
- The molecules vibrate by absorbing heat energy from the ambient



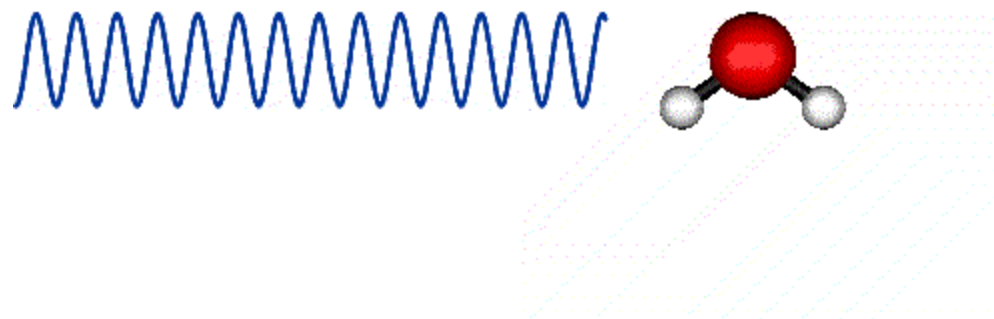
What will happen, if we radiate the molecules with the resonance frequency?

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Absorption of IR-Radiation

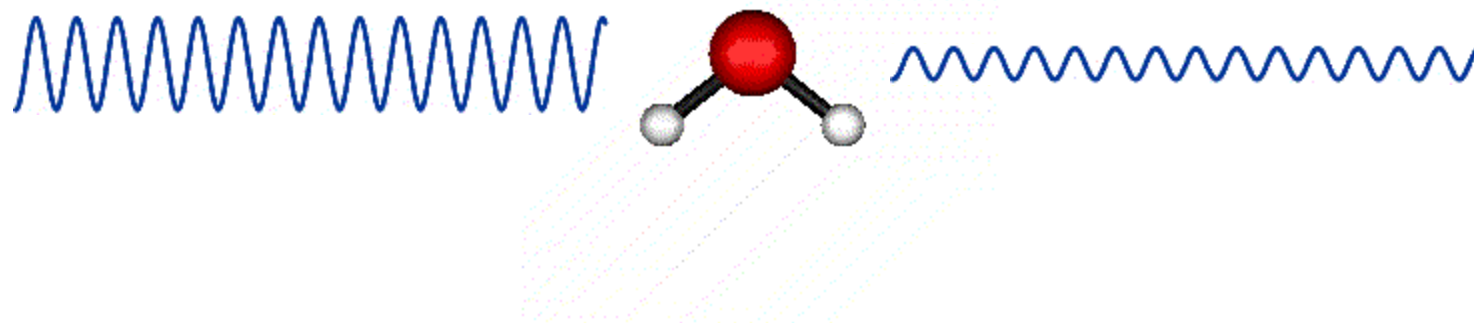


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Absorption of IR-Radiation



IR radiation will be attenuated

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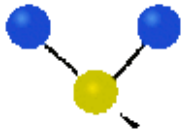
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TDLS: an IR analyzer that measures also Oxygen

Stretching and bending of the bonds within molecules occurs at a frequency that is specific to that particular bond. If the vibration causes a change in dipole of the molecule then light at a particular frequency in the infrared band will be absorbed.

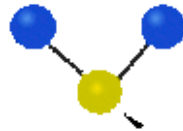
Symmetrical stretching



Antisymmetrical stretching



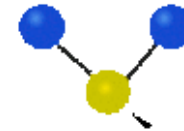
Scissoring



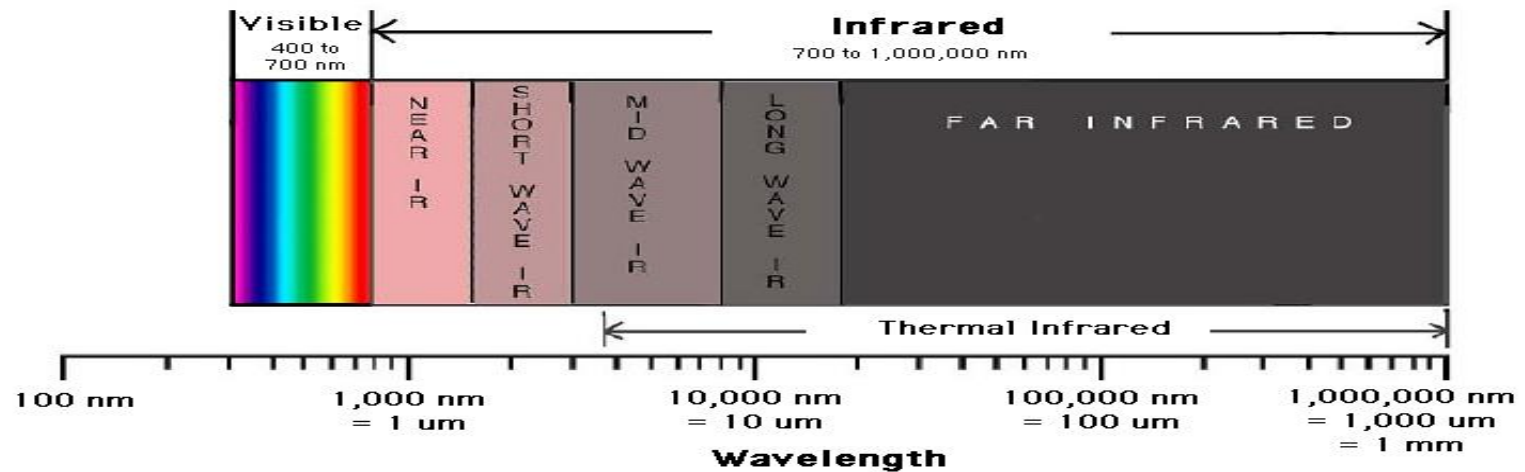
Rocking



Wagging



Twisting

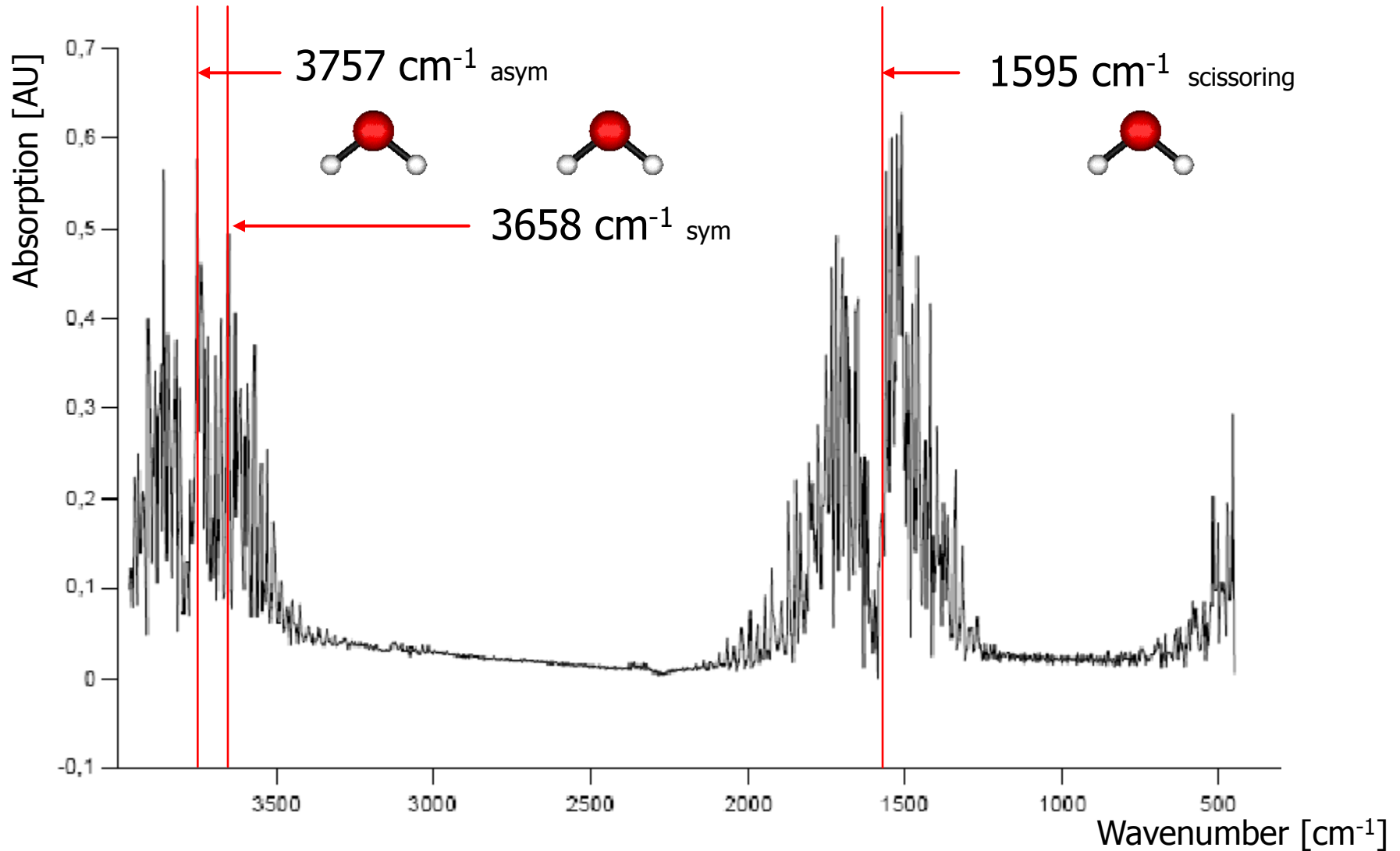


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IR Spectrum of Water

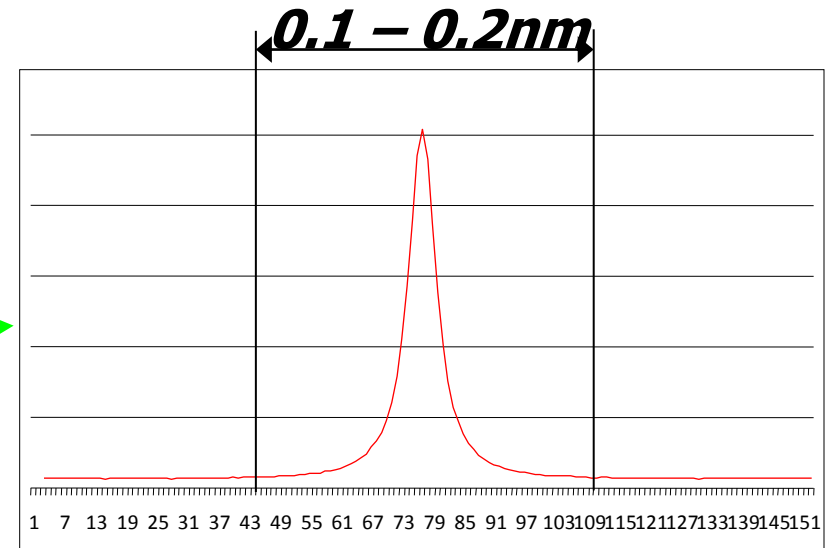
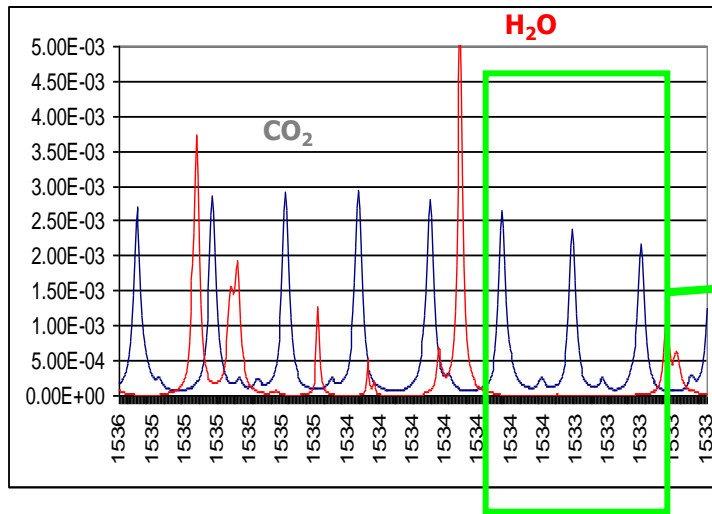


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Single peak Spectroscopy



- Diode lasers have very narrow wavelength emission (line width), typically 0.00004nm (0.04 pm = $0.04 \cdot 10^{-12}$ m) wide which allows hundreds or thousands of data points across the peak.
- Therefore, they can focus on a single defined peak that has no overlap
- The laser scans the bandwidth, measuring the peak and baseline

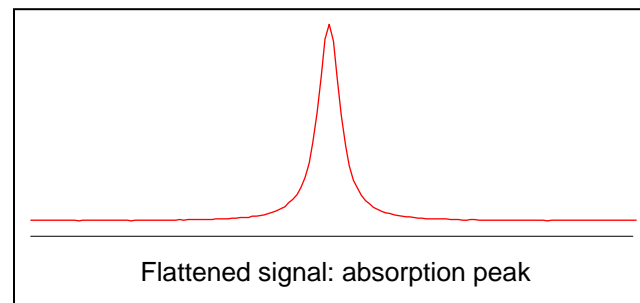
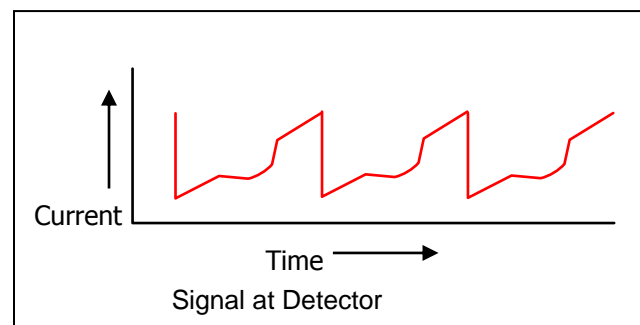
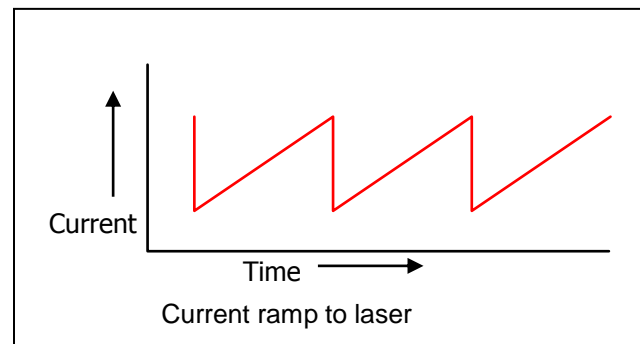
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Operation Yokogawa TDLS

1. The laser is held at a fixed temperature as a coarse wavelength adjustment
2. A current ramp is fed to the laser as the fine wavelength adjustment. The collimated light passes through the gas to be measured. The amount of light absorbed by the peak is proportional to the analyte concentration
3. The light is then focused on a detector and this direct signal is used to quantify the light absorbed by the analyte



New TDLS8000

“Simple and Robust”

SIL 2 Certified

Intuitive Color
Touch Screen

HART and Modbus TCP
Communication Standard

Smart Laser
Module

8-Stage
Auto Gain



Reference Cell

Easy Installation

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What are the benefits?

1. Easy operation and installation
 - ✓ Color touch screen
 - ✓ Display at both ends
2. Adaption to difficult applications
 - ✓ Auto gain
 - ✓ Reference cell
3. Safety design with SIL 2 certificate
4. Meets various network communication needs
 - ✓ Modbus/TCP and HART
5. Exd housing (size and optimized utility consumption)
6. Fully field repairable and fast diagnosis
 - ✓ Modular boards and smart laser design
 - ✓ 50 days of data and spectrum storage



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Basics of combustion

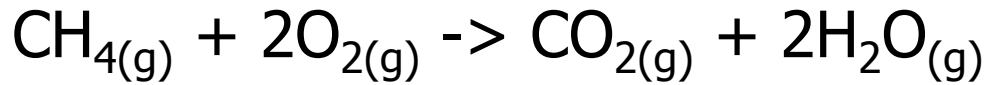
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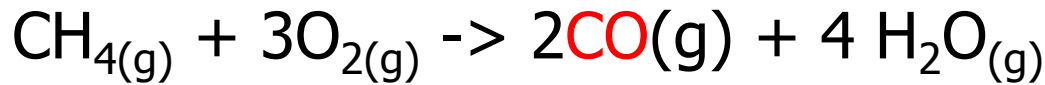


What is combustion?

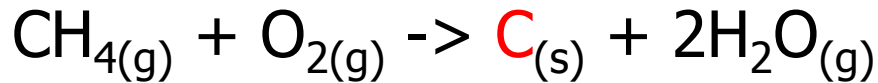
- *Complete* combustion:



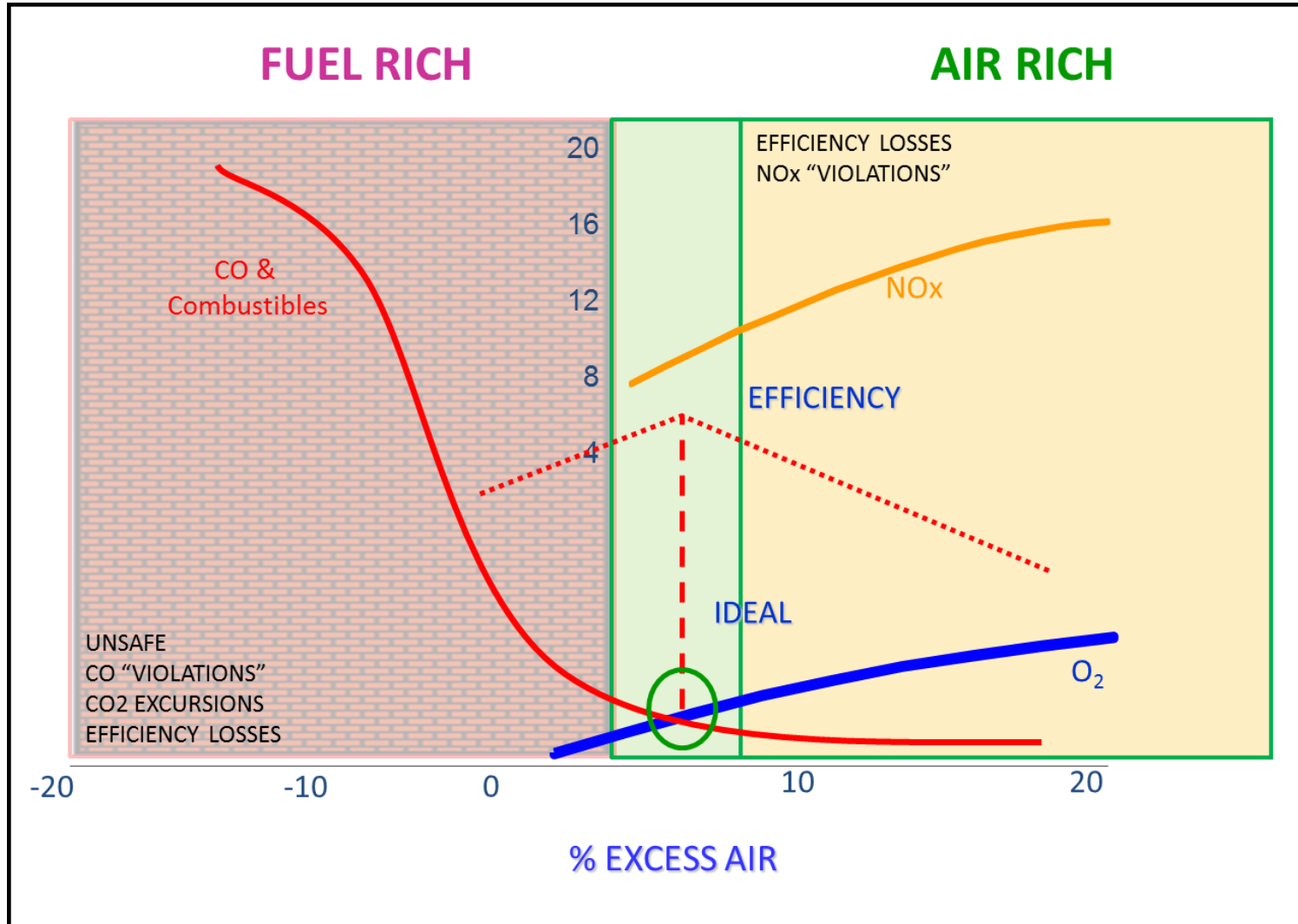
- *Incomplete* combustion:



or



Combustion: theory

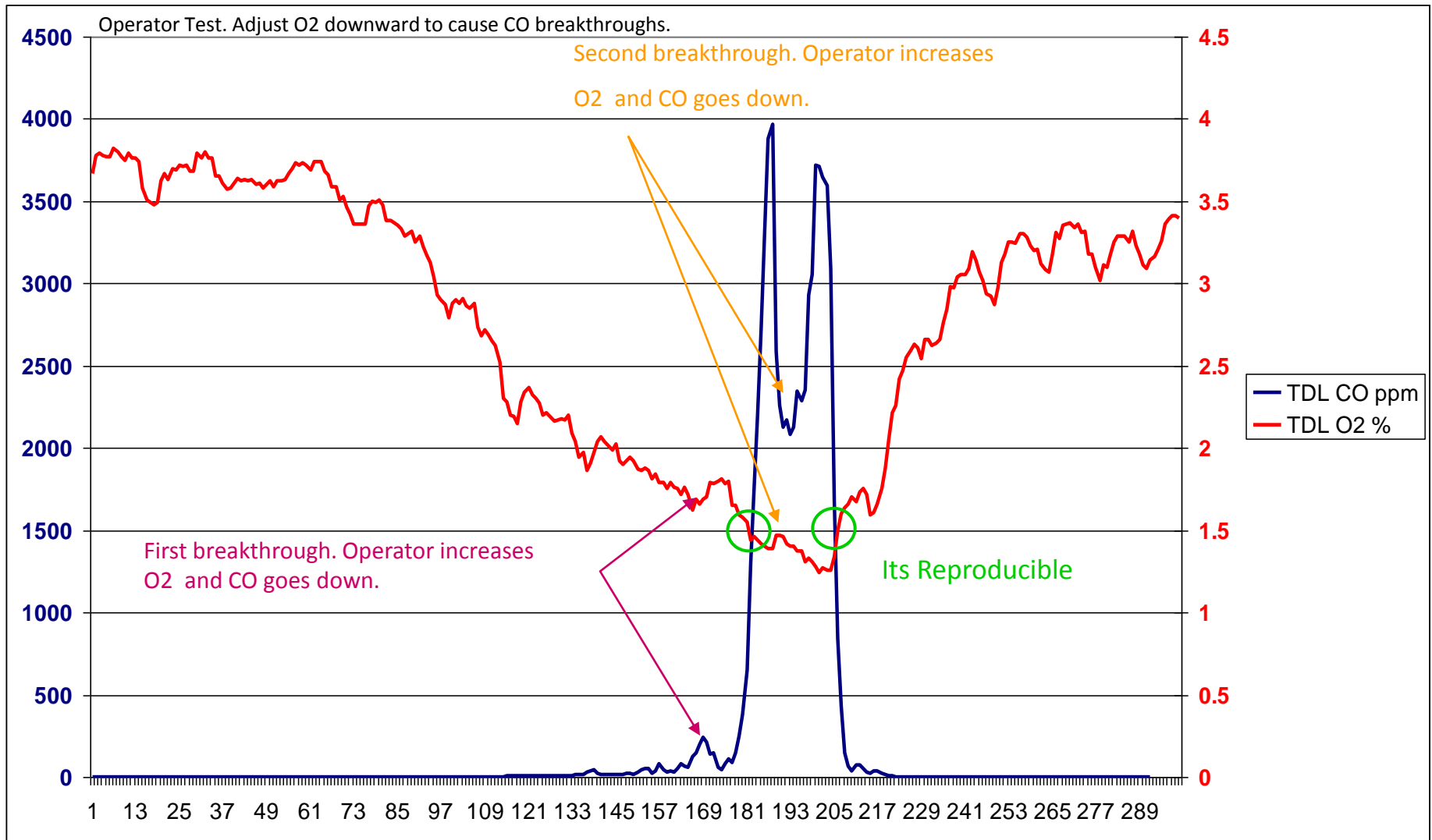


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Combustion: practice



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Fired heater

Fired heaters are widely used in oil refining and petrochemical industry, providing heat for a main process or cracking reaction by fuel combustion



Picture brochure "Fired Heaters" 2013, Foster Wheeler

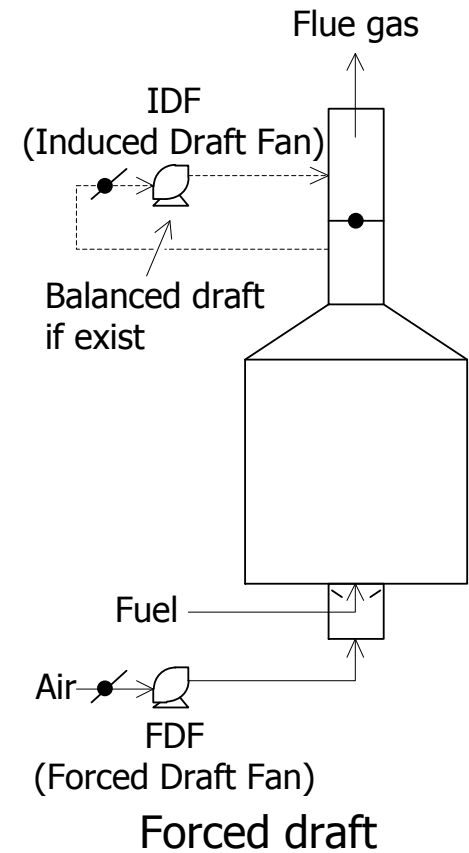
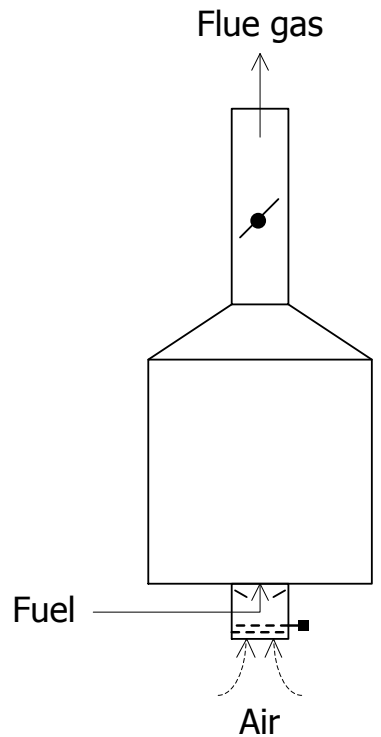
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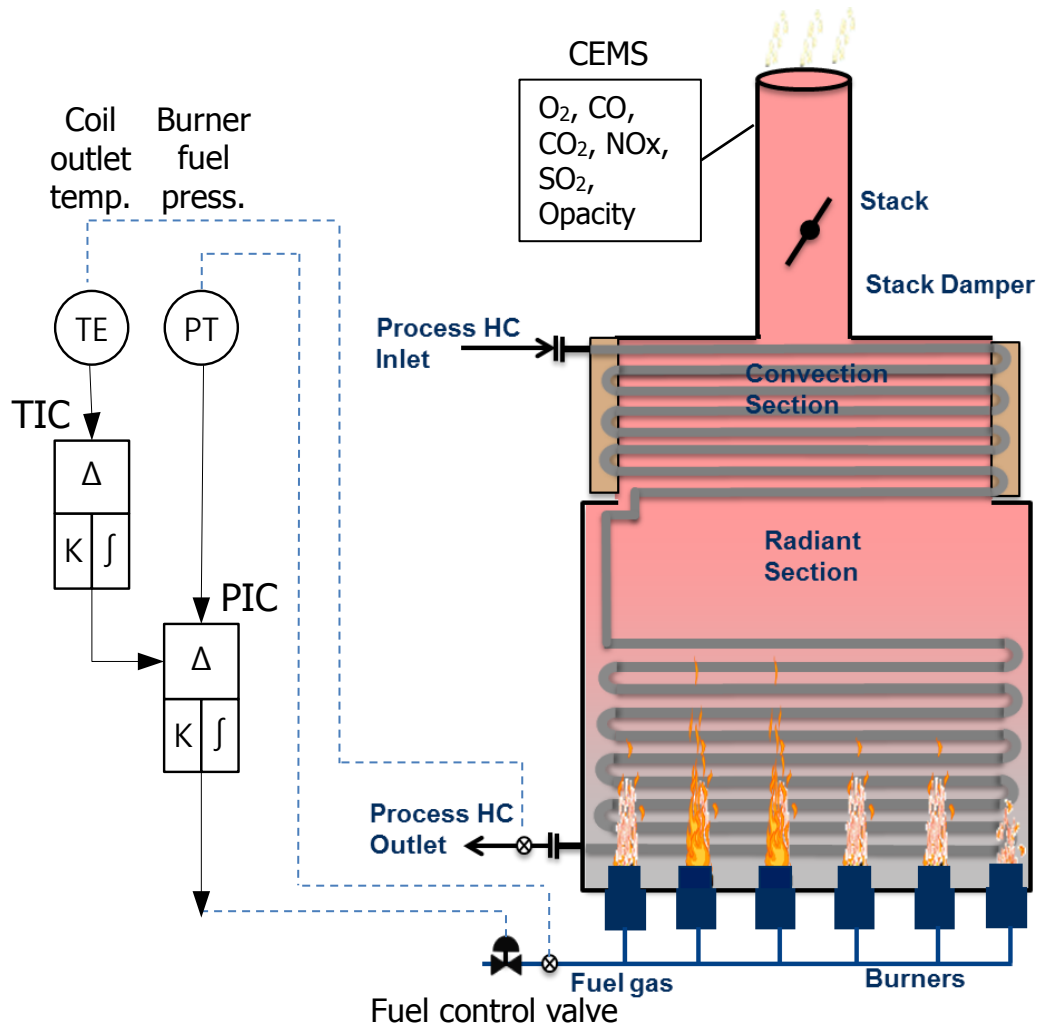


Different types fired heaters

- Fuels
 - Plant off gas ($C_1 \sim C_5$, H_2 , H_2S ... **composition varies**)
 - Natural gas
 - Fuel oil
- Draft system
 - Natural draft
 - Forced draft
 - Balance draft



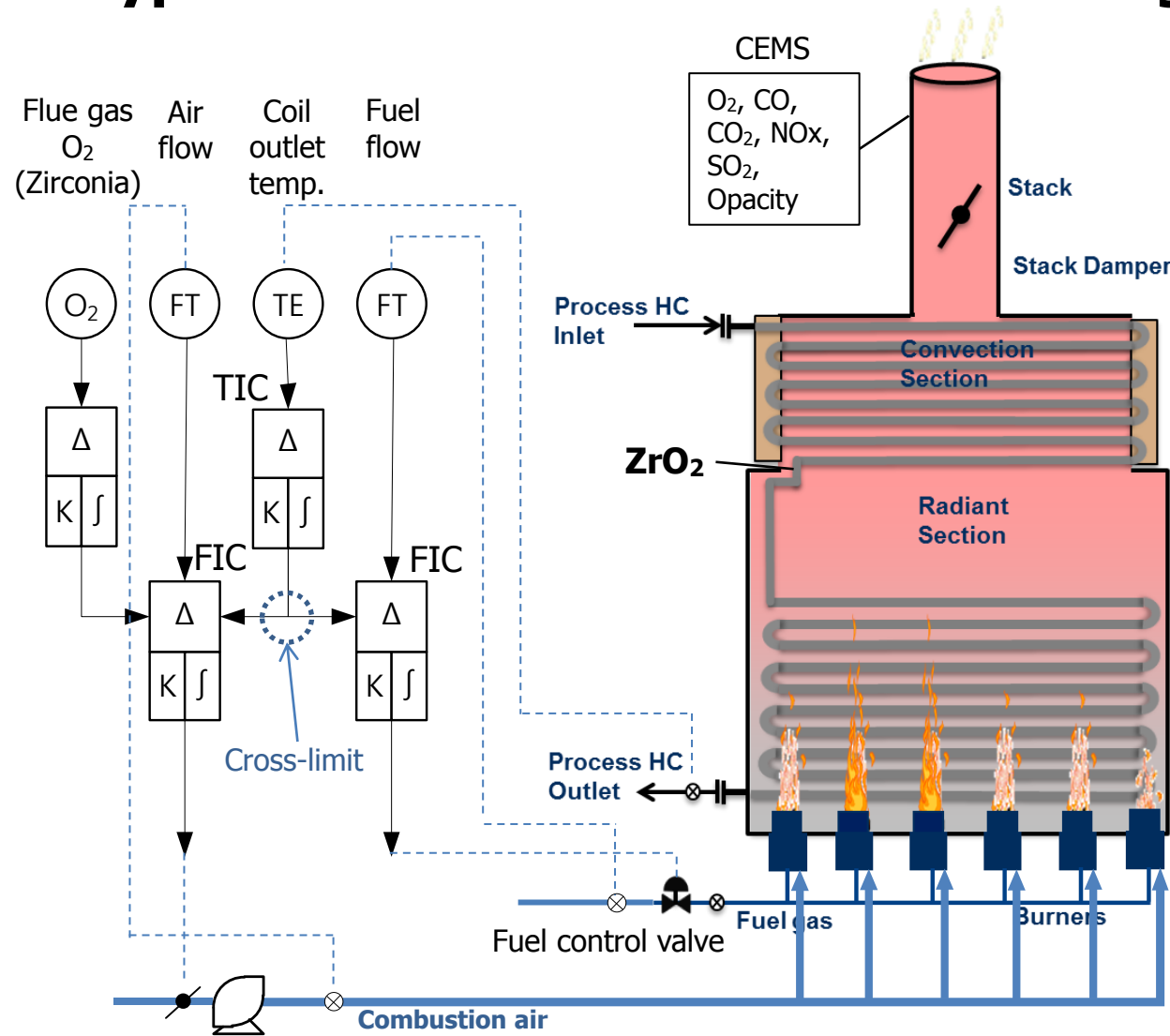
Traditional fired heater control



- Coil outlet temperature controlled by burner fuel pressure
- (Natural draft) No air flow measurement & control
- (Forced / Balanced draft) Air flow control but no follow up to fuel amount sometime
- Flue gas measurement for emission monitoring



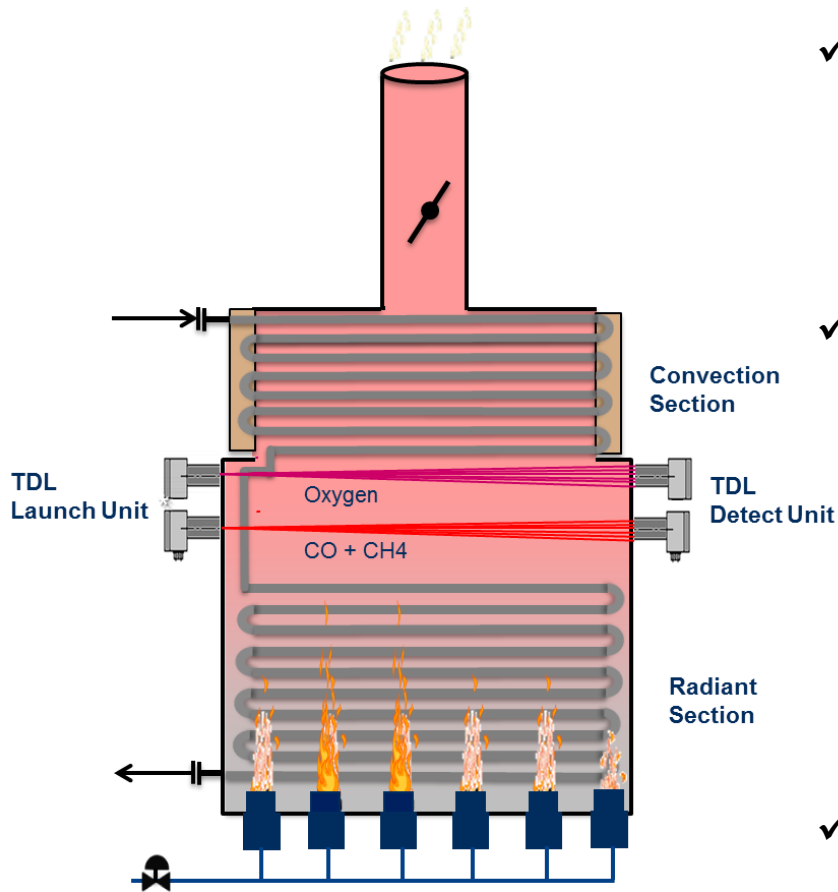
Typical fired heater control with flue gas O₂ control



- Coil outlet temperature control by fuel flow
- Burner fuel pressure control by limiting fuel control valve opening
- Coil outlet temperature controller sends set point to both air and fuel flow
- Air/fuel cross-limit may be configured
- Flue gas measurement for emission monitoring
- ZrO₂ sensor is installed for flue gas O₂ control



Fired heater optimization by TDLS for O₂, CO/CH₄



TDLS enables:

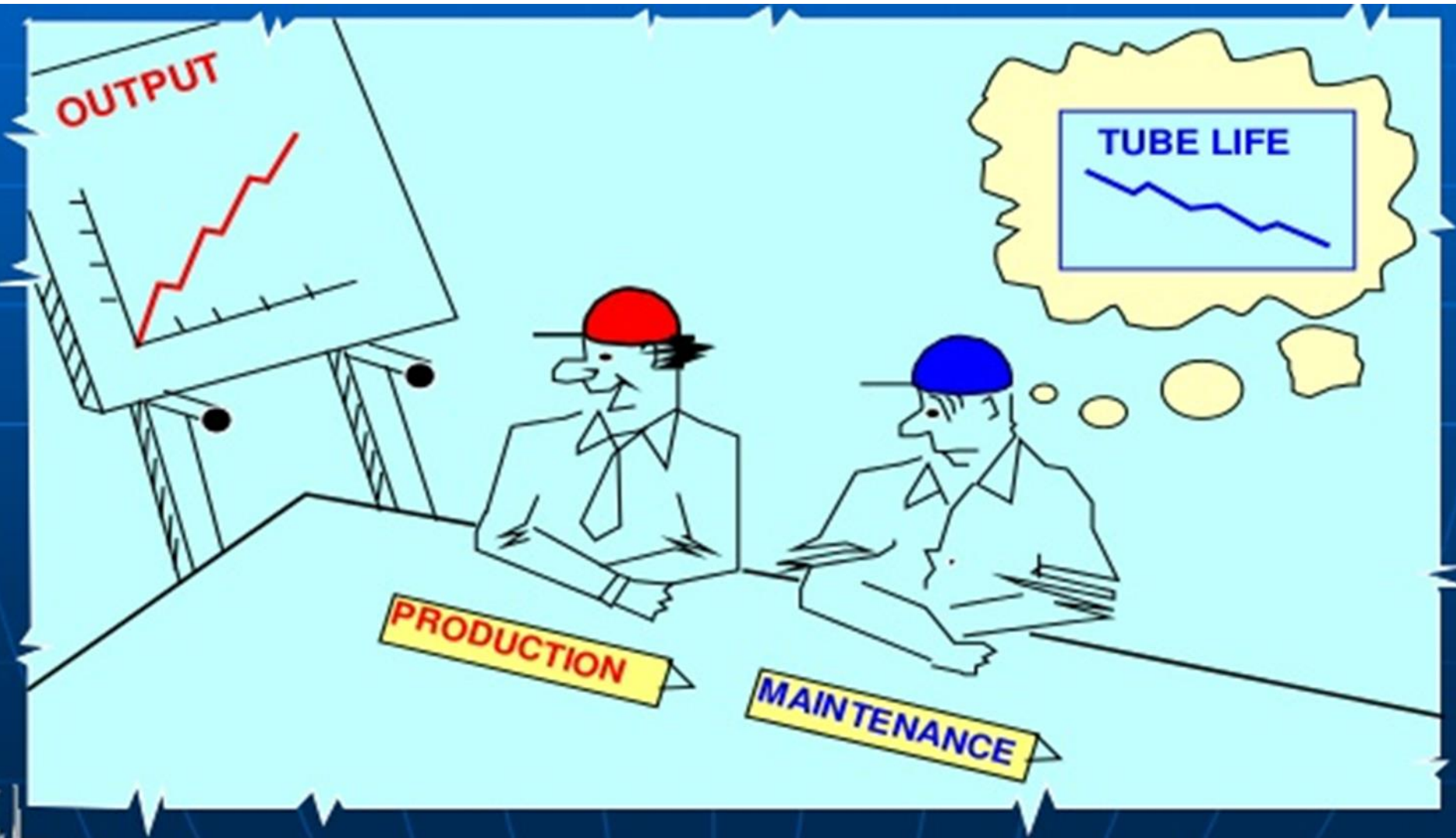
- ✓ Measurement near combustion zone
 - Before CO is diluted by tramp air and afterburning
 - Up to 1500 degC
- ✓ Measurement with cross firebox coverage
 - Improve accuracy against uneven combustion of the burners
 - Detect malfunction of burner by CH₄
 - Breakthrough of CO
 - Fast response: 2 seconds or less
 - High sensitivity for CO: less than 10 ppm
- ✓ O₂/CO measurement "matching"
 - Same location, same condition

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Output increase vs lifetime assets

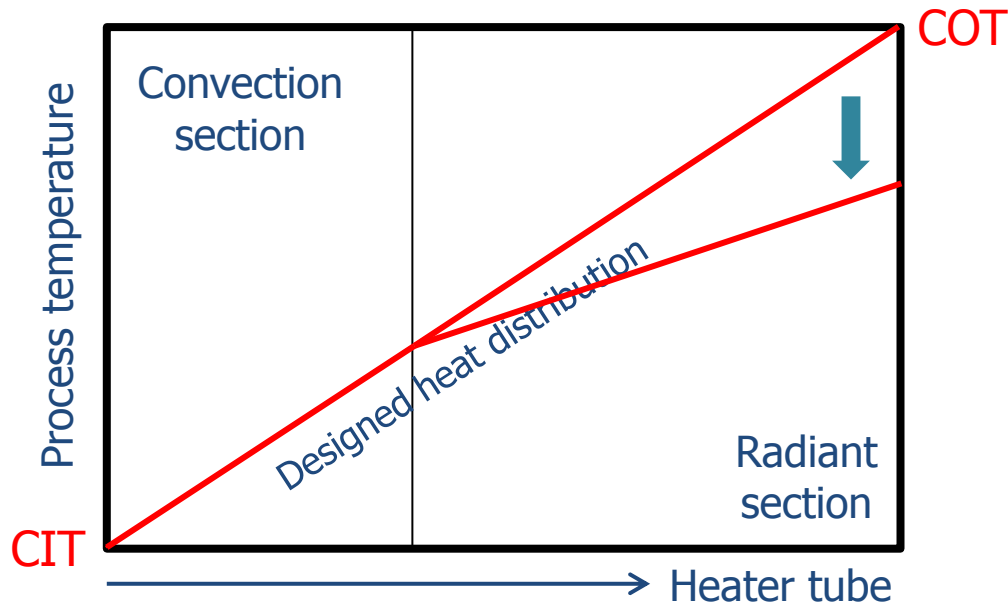


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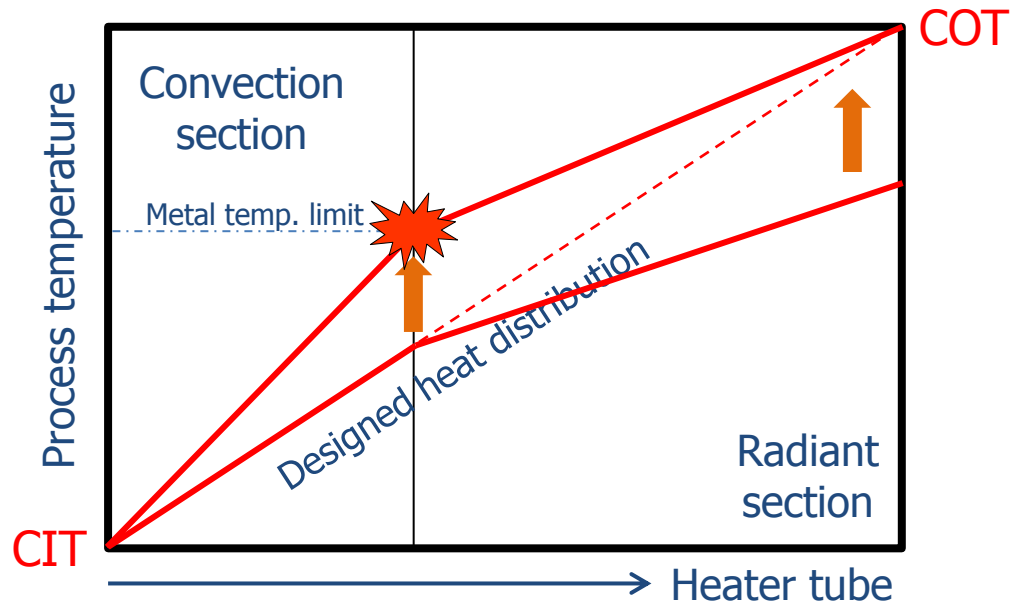
Impact of high excess air on heater lifecycle



- Efficiency of heat transfer depends on flue gas composition
- O₂ and N₂ have poor emissivity
- CO₂ and H₂O have better emissivity
- High excess air dilute CO₂ and H₂O: heat efficiency decreases



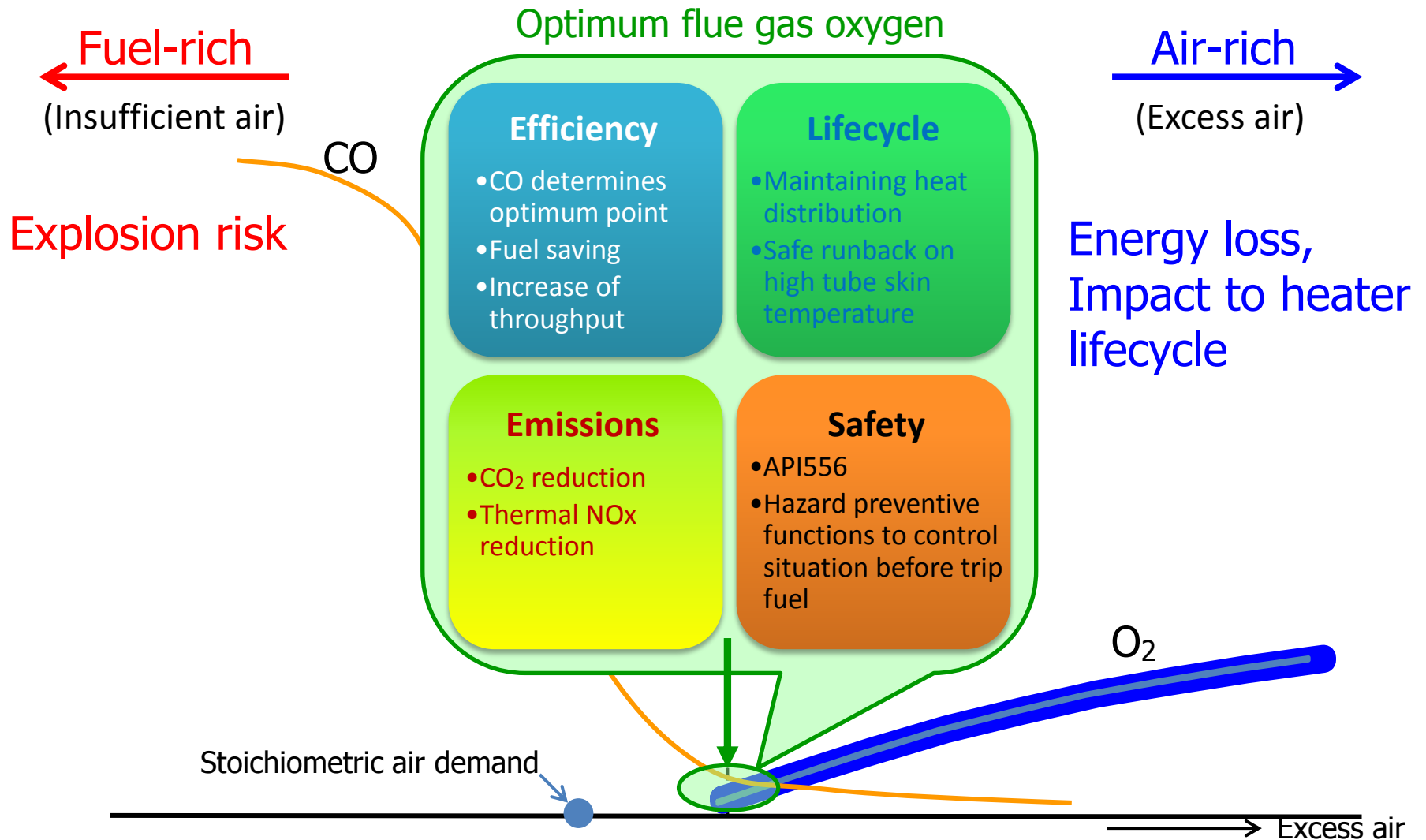
Impact of high excess air on heater lifecycle



- Efficiency of heat transfer depends on flue gas composition
- O₂ and N₂ have poor emissivity
- CO₂ and H₂O have better emissivity
- High excess air dilute CO₂ and H₂O: heat efficiency decreases
- More heat needed to maintain COT
- Overheating system



FH optimization provides more on the typical



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Example from the field

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Installation examples



Furnace Radiant Section

Analyzer Installation Launch and Detect



Launch



Detect

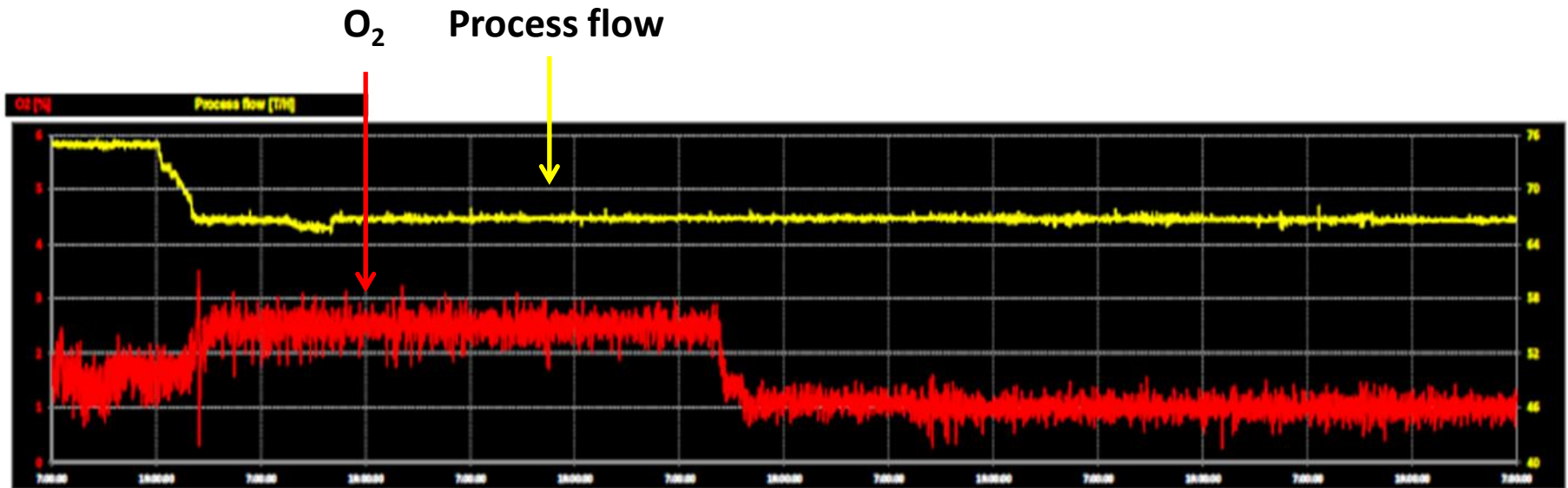
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Results from first application performance test

- ❖ Stable process
- ❖ Reduction of excess air: energy saving



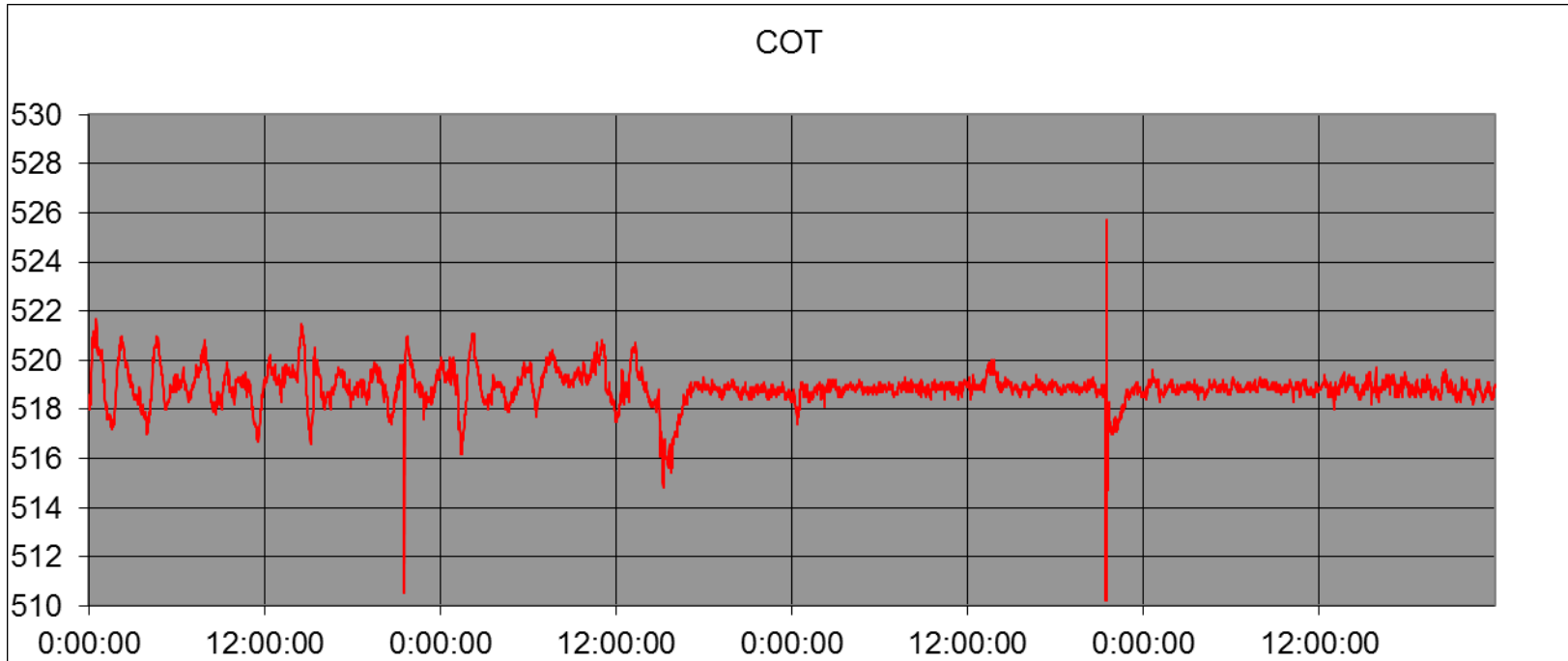
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And more results...

❖ More stable process parameters: COT(*)



(*) Coil Outlet Temperature

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And more...

❖ Stable process parameters

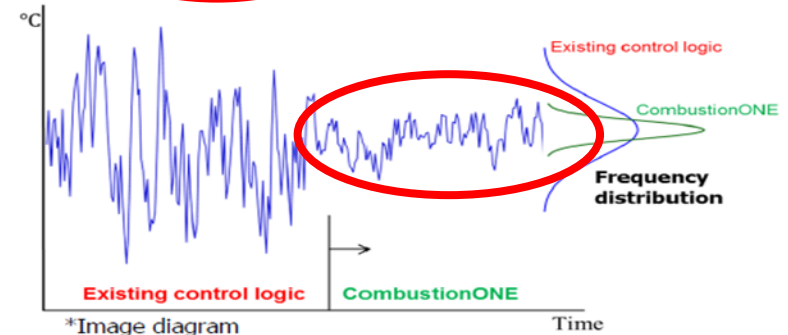
Benefit calculation

- ✓ Evaluate control stability

H21 coil outlet temperature(PTIC03.PV)	Existing control logic 7/15/13 0:00-7/17/13 23:59	CombustionONE 7/29/13 0:00-7/31/13 23:59
Number of data	4319	4319
Average	519.10	518.86
Standard deviation (σ)	0.700	0.200
Fluctuation ($\pm 3\sigma, 99.7\%$)	4.25 °C	1.74 °C

The results:

Achieved the coil outlet temperature stable by the fluctuation range reducing.

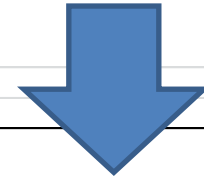


\$aving\$

Excess air / Oxygen level decreased from 3,5% to 1 %

(Note: always application and heater specific: never estimate the value based on theory)

SAVINGS



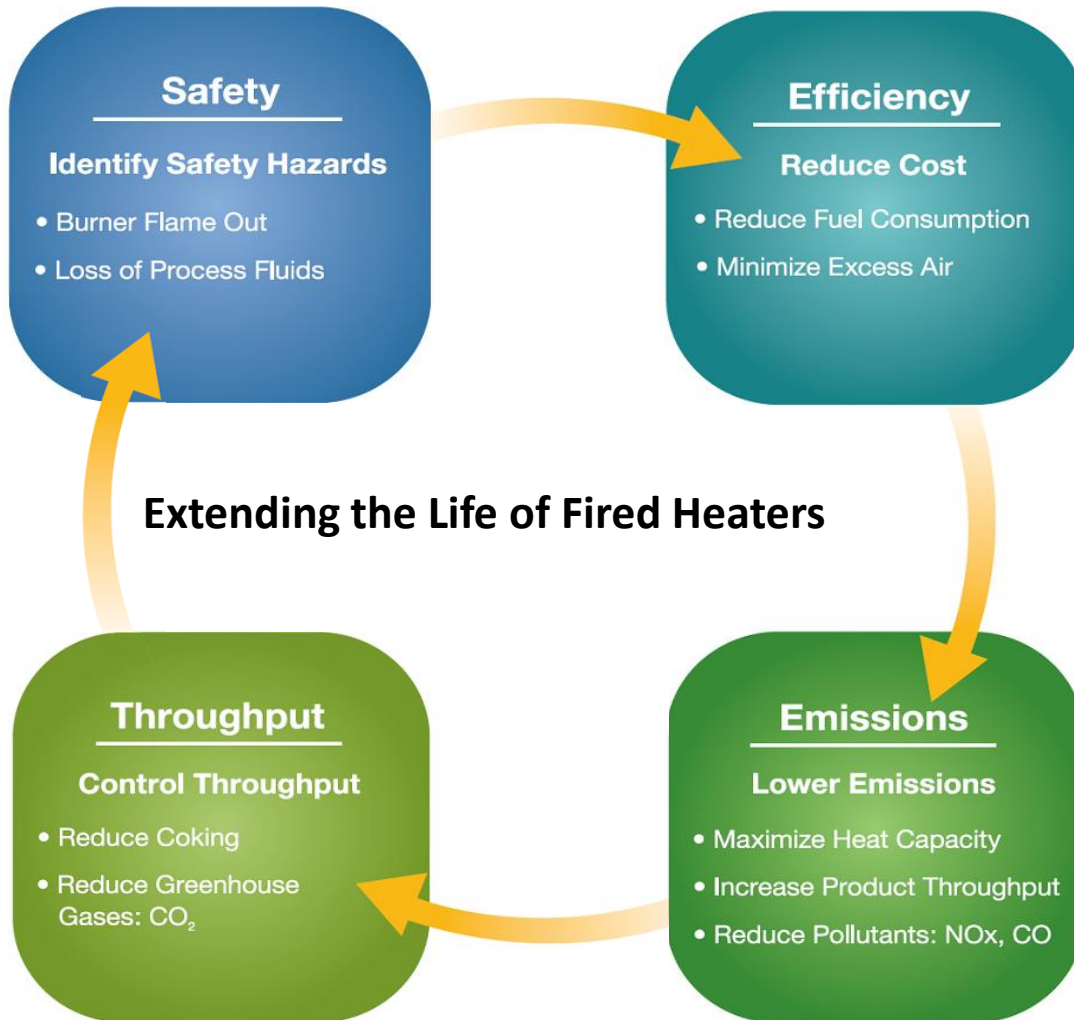
Performance test periode results					Calculations
Consumption					
48 hours test periode		48 hours test periode			
High O2 (4%)		Low O2 (1%)			
From 26th July 11:00	To 28th July 11:00	From 29th July 11:00	To 31st July 11:00		
Used fuelgas [KG]	67 836	64 506		5,7%	
Used heat value [GJ]	4 105	3 873			
2 days saving	3 330 kg				
Fuelgas reduction [T/day]	1,67	tones /day			
Fuelgas reduction [GJ/day]	116	GJ/day			
Savings based on fuelgas [HUF/H] (CO2)	Value can not be displayed, due to confidentiality agreement			xx	
Savings based on fuelgas [HUF/Year]				xx	
Savings based on fuelgas [EUR/Year]				xx	
Heat value reduction [GJ/H]				4,844	
Savings based on heat value [HUF/H] (Energy)				xx	
Savings based on heat value [HUF/Year]				xx	
Savings based on heat value [EUR/Year]				xx	
Total savings [HUF/Year]				xx	
Total savings [EUR/Year]				xx	

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Complete packed solution: CombustionOne



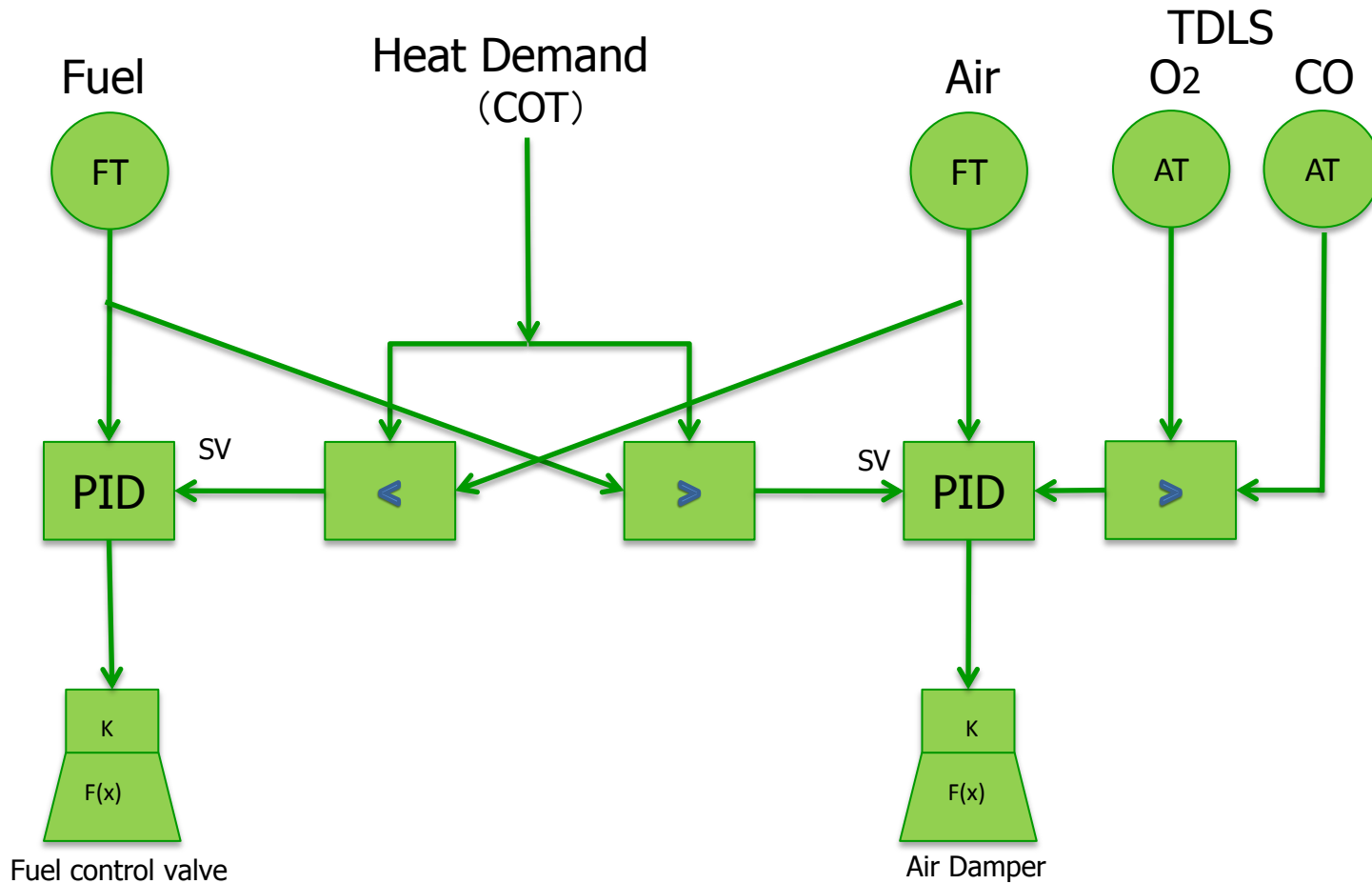
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[Control] of the Fired heaters Solution

Fuel/Air Cross Limit with O₂ Trim and CO Override Control



Conclusion on Combustion benefits

- TDLS measurements can provide combustion diagnostics:
 - CO measurement with cross firebox coverage
 - Average O₂ value from one analyzer
 - O₂/CO Matching for control
 - CH₄ and gas temperature measurements at high speed and across the firebox



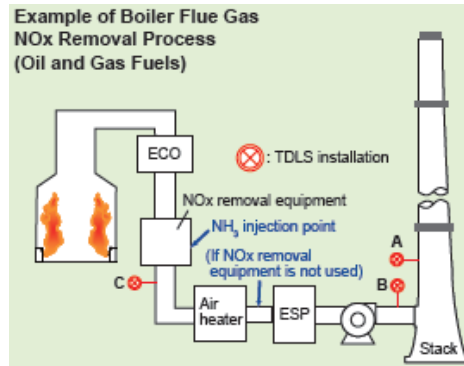
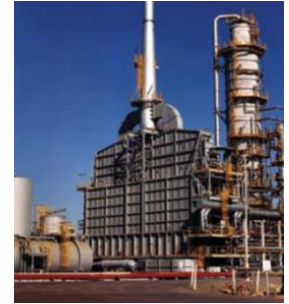
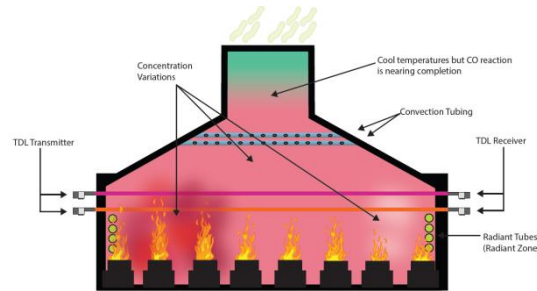
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Solutions provided by Yokogawa

- Fired heaters
 - Safety
 - Combustion optimization
 - Asset management
- Limited Oxygen Concentration
 - Safety
- Process Oxygen
- Ammonia slip
 - Emission
- Moisture
 - Process



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Publications

- <http://www.yokogawa.com/rd/pdf/TR/rd-te-r05301-004.pdf>
- <http://www.yokogawa.com/an/laser-gas/an-tdls8000-001en.htm>
- <http://www.yokogawa.com/us/products/manufacturing-operations-management/process-safety-management/fired-heater-safety-optimization.htm#downloads>

Optimum Combustion Control by TDLS200 Tunable Diode Laser Gas Analyzer

Optimum Combustion Control by TDLS200 Tunable Diode Laser Gas Analyzer

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The TDLS200 laser gas analyzer, which is based on tunable diode laser spectroscopy, is a new generation of process analyzers. Characterized by high sensitivity and long-term stability, it offers fast in-situ analysis of high-temperature or corrosive gas. This paper introduces the TDLS200's real-time measurement of carbon monoxide as it focuses its application for optimizing combustion control in the furnace, and its contribution to environmental preservation.

INTRODUCTION

Combustion furnaces such as heating furnaces and boilers in plants include various sizes and types, and serve as energy sources that is, they are core in all production activities. Because a large amount of fuel such as gas or fuel oil is consumed in plants, their combustion efficiency directly affects the performance and running cost of the plants. Since they generate large amounts of exhaust gas, its recent trend has become important to reduce various greenhouse gases including CO₂ in addition to coping with problems caused by nitrogen oxide, sulfur oxide, etc.

To maintain environmental balance such as gas emissions and heat dissipation while maintaining a stable supply of energy (heat) for plant operation, use of an air-fuel measurement and control technology is essential. Furnaces are major facilities, and so their operation is several decades and the energy conditions of such furnace vary with each industry, customer, factory and facility. Consequently, an early proper measurement and control of O₂ and CO has the advantage of multi-faceted issues are required. For example, operational conditions between high-temperature and low-temperature processes are not suitable. In addition, if an air-fuel control for combustion varies the furnace through cracks which are furnace affect bars, their combustion efficiency does not increase and it is considered to decrease.

In order to achieve safe and optimum combustion control of furnace, it is necessary to work out a strategy plus the comprehensive diagnosis and optimum combustion for the furnace. Because with improvement, diagnosis, proper measurement, control improvement, etc.), various the strategy plus, and time

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