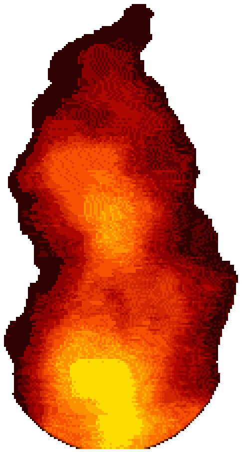
Combustion optimization by Tunable Diode Laser Spectroscopy

Burn Less ...Earn More



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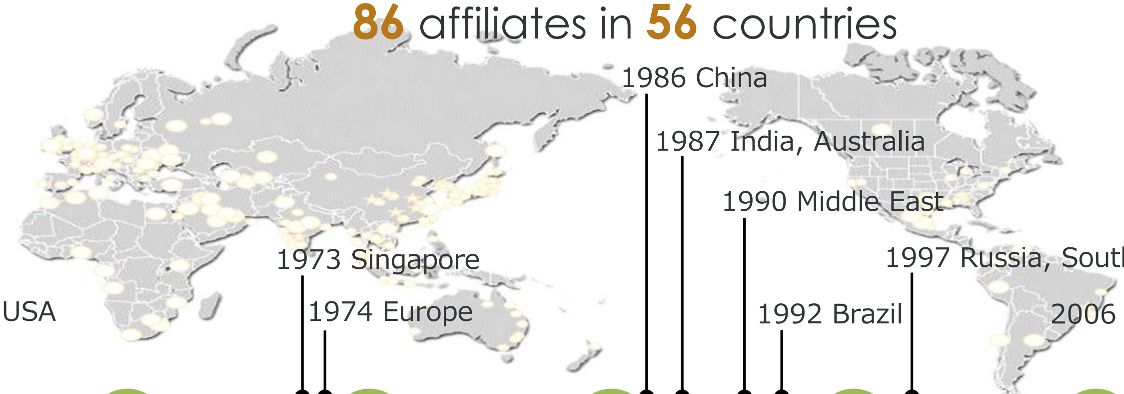
Agenda

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

Yokogawa's 100 year history

Global business expansion



86 affiliates in **56** countries

1915
Founded by
Dr. Tamisuke
Yokogawa

- 1957 USA
- 1973 Singapore
- 1974 Europe
- 1986 China
- 1987 India, Australia
- 1990 Middle East
- 1992 Brazil
- 1997 Russia, South Africa
- 2006 Saudi Arabia

100th ANNIVERSARY 1915-2015

1915 › 1955 › 1965 › 1975 › 1985 › 1995 › 2005 › 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

ISA 100 WIRELESS COMPLIANCE INSTITUTE

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

Worldwide Business Operations

Global network supporting business growth

● Regional Head Quarters

15 subsidiaries and 1 affiliate in Japan
69 subsidiaries and 2 affiliates outside Japan

Number of Employees
Worldwide : 19,685 / Outside Japan : 11,089

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**: PRM (Plant Resource Manager)
- **PIMS** – Process Data Acquisition & Management: Exaquantum

Production Control System

Production control systems

- **DCS** – Integrated Production Control System: CENTUM VP
- **Network Based Control System**: STARDOM (Network-based Control System)
- **Safety Instrumented System**: ProSafe-RS

Field Instruments

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

- Differential Pressure Transmitter: EJA/ EJX
- Magnetic Flowmeter: AXF
- Digital Vortex Flowmeter: DYF
- Zirconia Oxygen Analyzer: ZR
- Tunable Diode Laser Spectrometer: TDLS8000
- Process Gas Chromatograph: GC8000
- Advanced Valve Positioner: YVP
- Temperature Transmitter: YTA50/ 70, YTA100/300

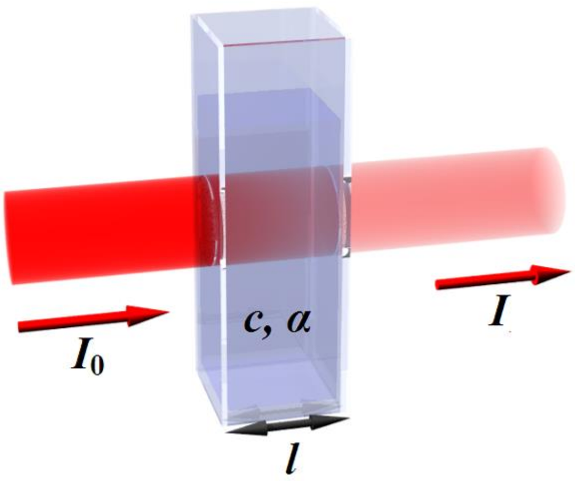
* ERP = Enterprise Resource Planning

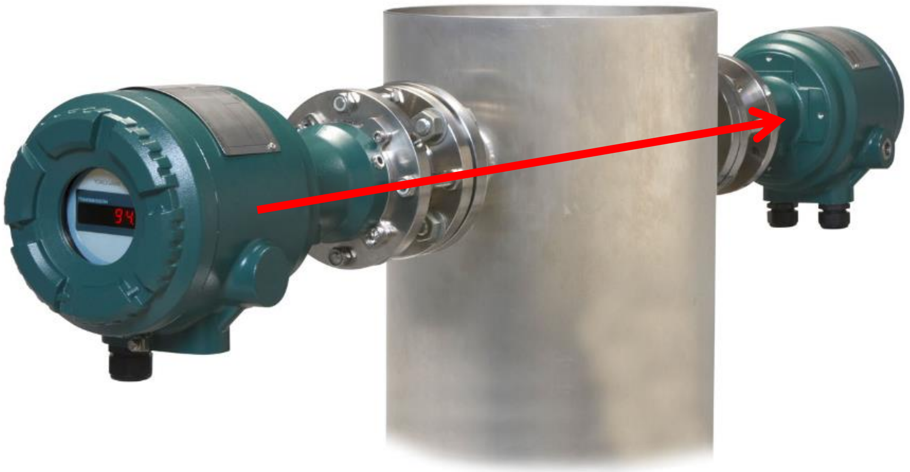
* MES = Manufacturing Execution System

What is TDLS?

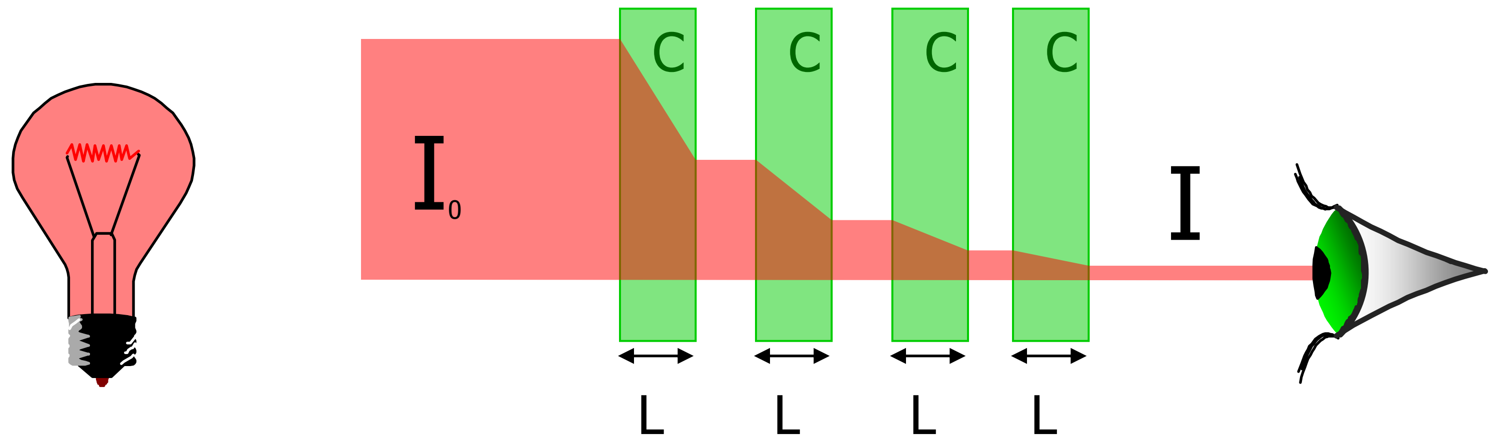
What is TDL Spectroscopy?

- 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





Lambert Beers` Law

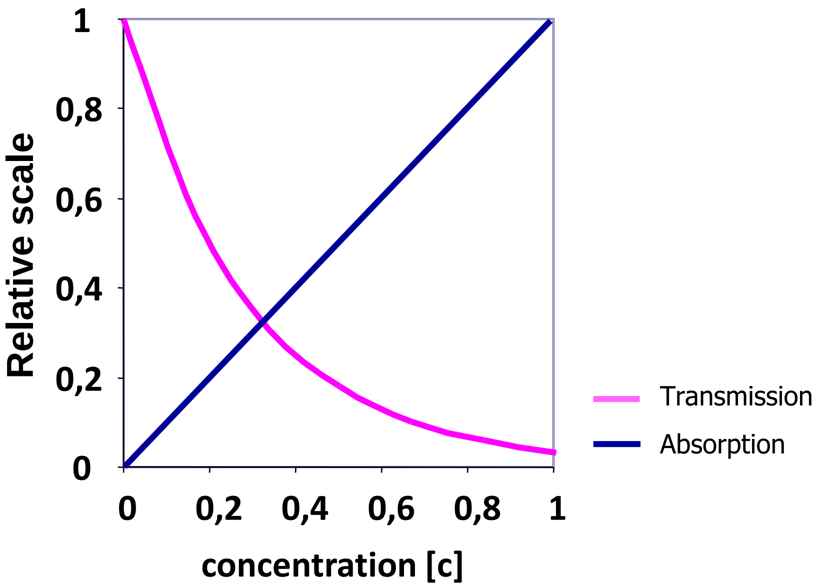


Transmission: $T = I/I_0$

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

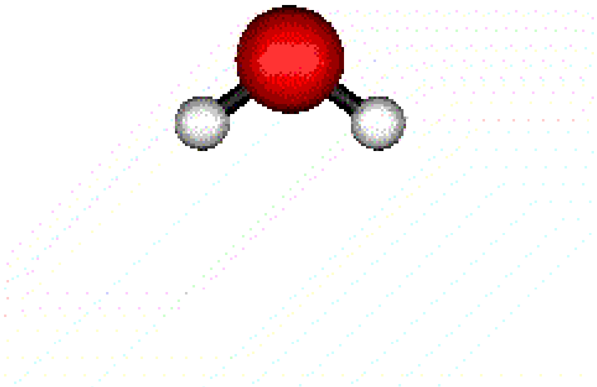
$C = A / \varepsilon \cdot L$

C = concentration
A = absorption
Ɛ = extinction coefficient
L = optical path length



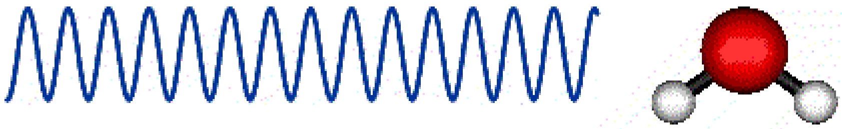
Fundamental Vibration of the Water Molecule

- 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

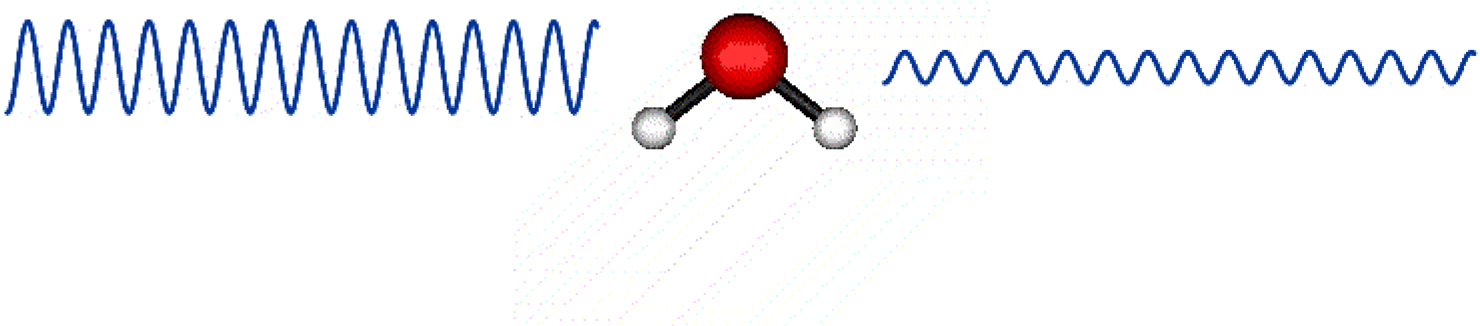


What will happen, if we radiate the molecules with the resonance frequency?

Absorption of IR-Radiation



Absorption of IR-Radiation

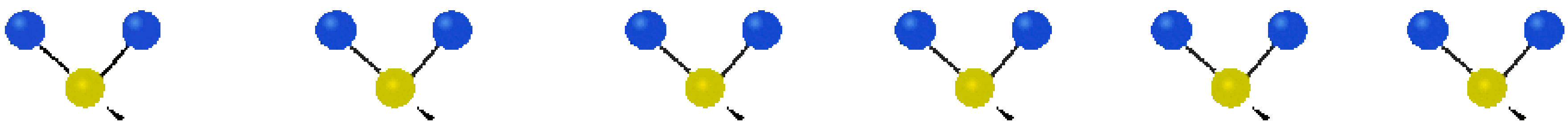


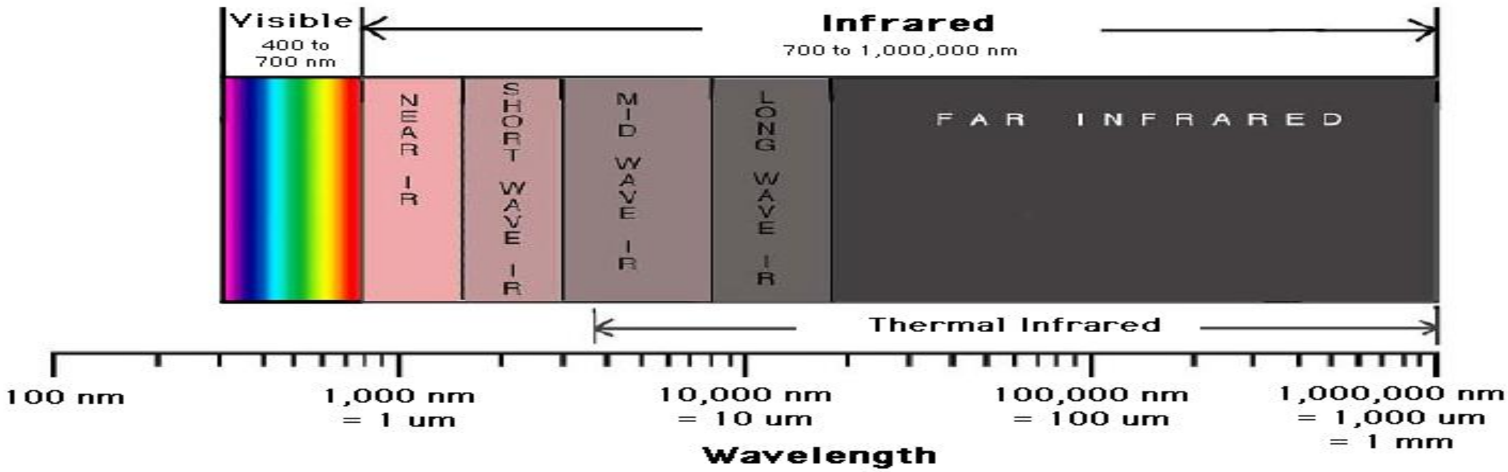
IR radiation will be attenuated

TDLS: an IR analyzer that measures also Oxygen

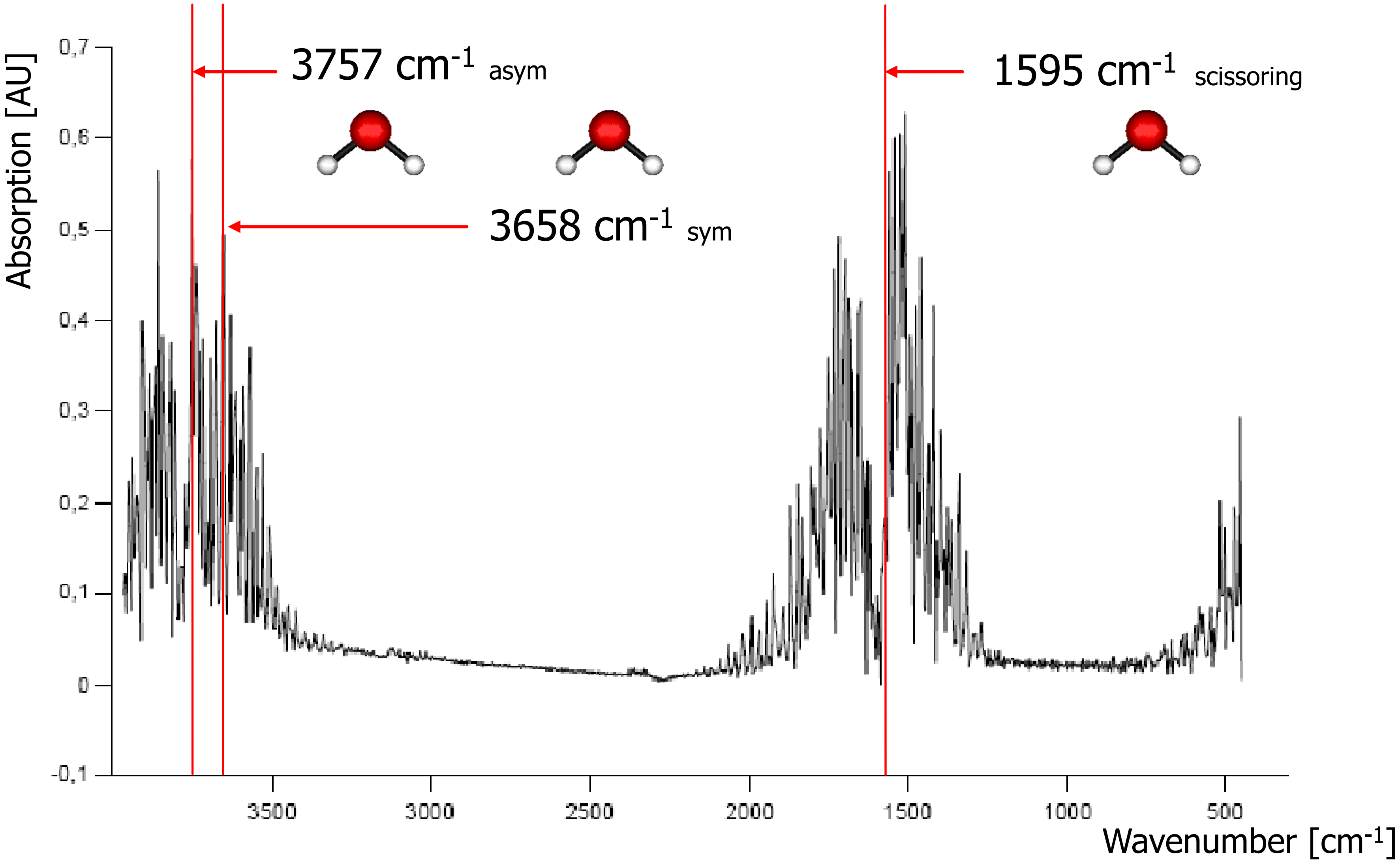
Stretching and bending of the bonds within molecules occurs at a frequency that is specific to that particular bond. If the vibration causes a change in dipole of the molecule then light at a particular frequency in the infrared band will be absorbed.

Symmetrical stretching | **Antisymmetrical stretching** | **Scissoring** | **Rocking** | **Wagging** | **Twisting**

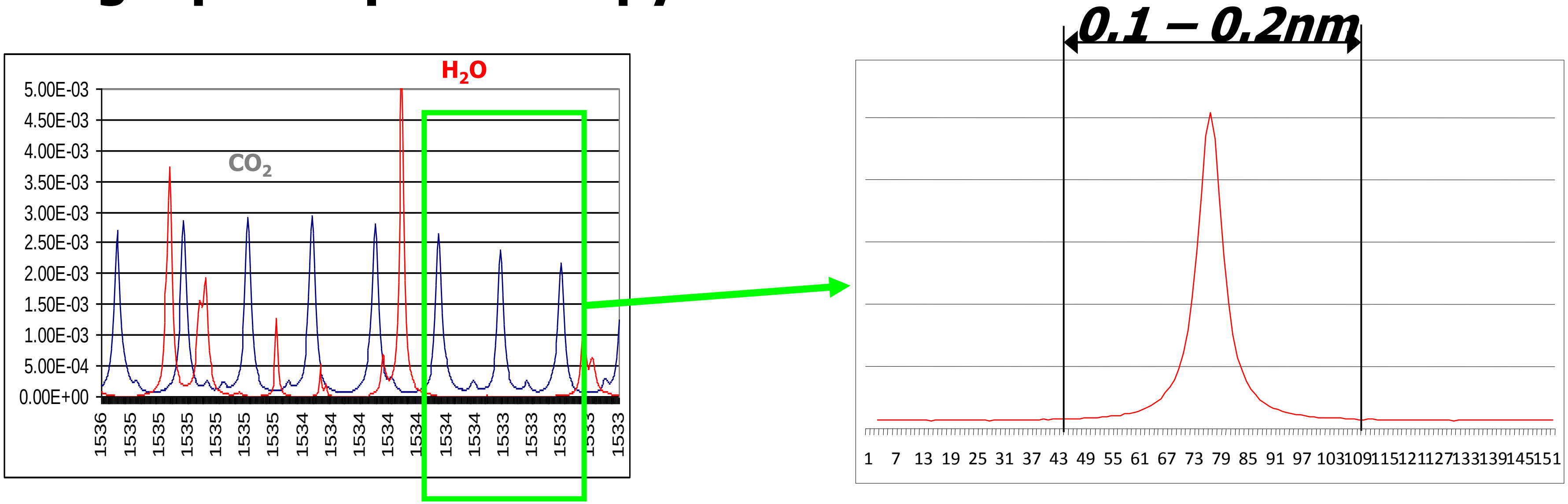




IR Spectrum of Water



Single peak Spectroscopy



- Diode lasers have very narrow wavelength emission (line width), typically 0.00004nm (0.04 pm = 0.04 $*10^{-12}$ 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

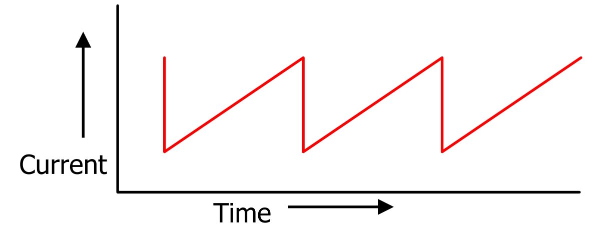
- The laser scans the bandwidth, measuring the peak and baseline

Operation Yokogawa TDLS

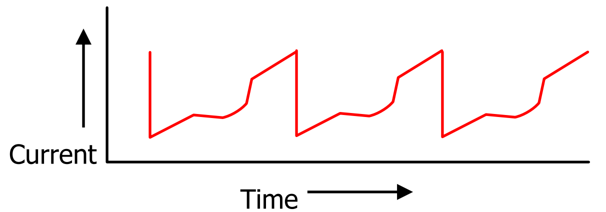
1. The laser is held at a fixed temperature as a coarse wavelength adjustment

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

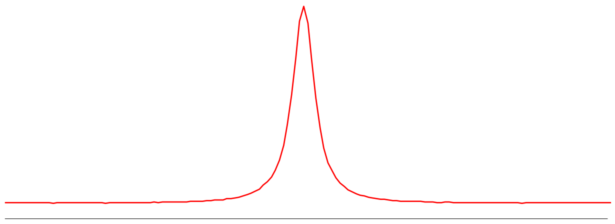
3. The light is then focused on a detector and this direct signal is used to quantify the light absorbed by the analyte



Current ramp to laser



Signal at Detector


Flattened signal: absorption peak

New TDLS8000

"Simple and Robust"

SIL 2 Certified

Intuitive Color Touch Screen

HART and Modbus TCP Communication Standard

TDLS8000

Smart Laser Module

Reference Cell

8-Stage Auto Gain

Easy Installation

What are the benefits?

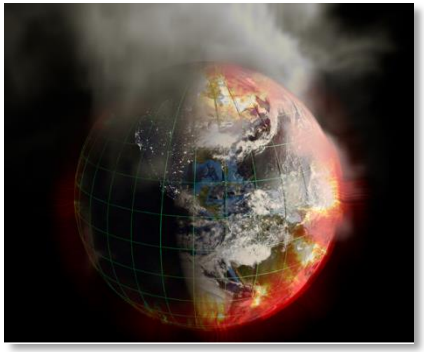
1. Easy operation and installation
   - ✓ Color touch screen
   - ✓ Display at both ends
2. Adaption to difficult applications
   - ✓ Auto gain
   - ✓ Reference cell
3. Safety design with SIL 2 certificate
4. Meets various network communication needs
   - ✓ Modbus/TCP and HART
5. Exd housing (size and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

Basics of combustion

What is combustion?

- *Complete* combustion:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$



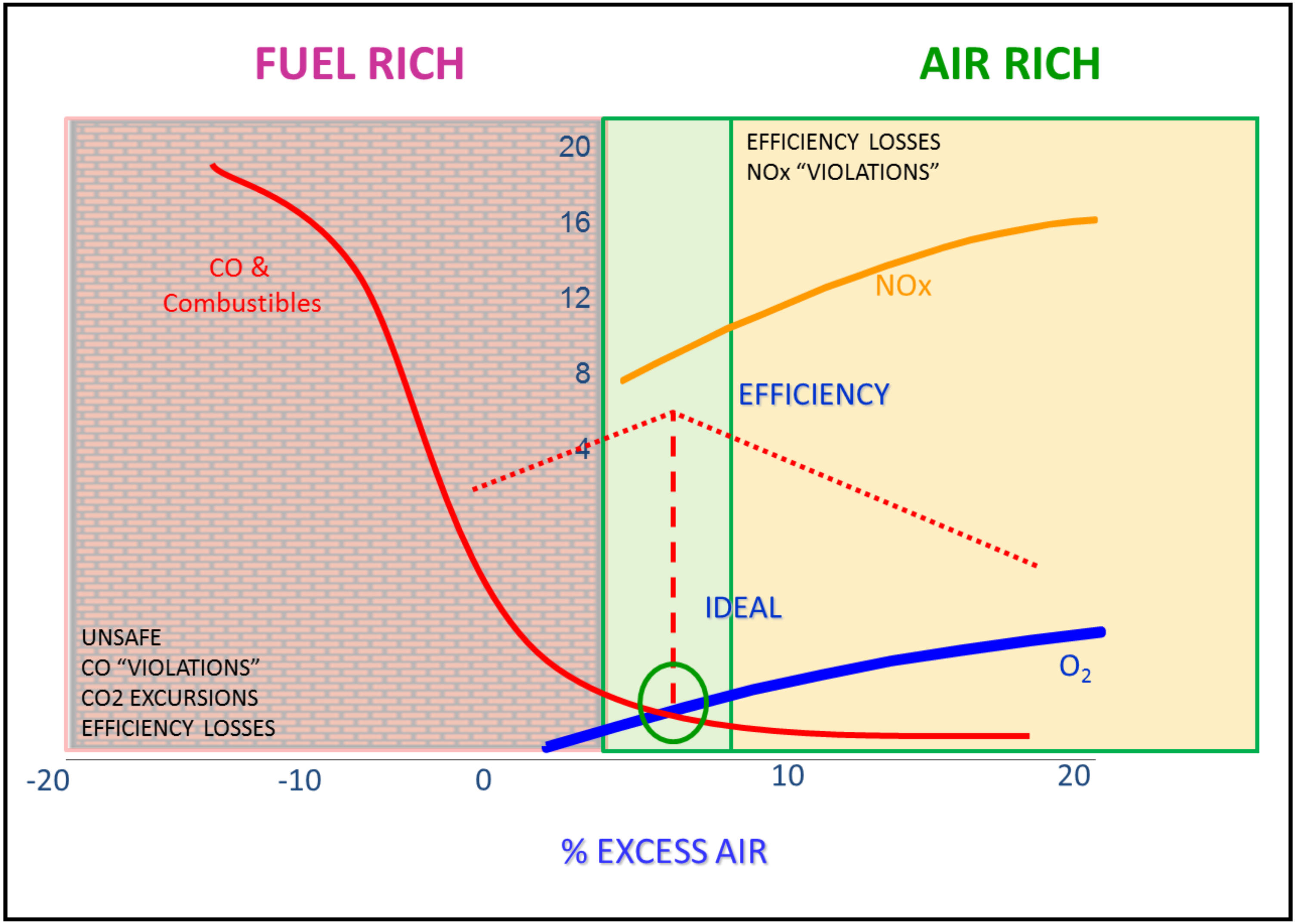
- *Incomplete* combustion:

$$CH_{4(g)} + 3O_{2(g)} \rightarrow 2CO(g) + 4\,H_2O_{(g)}$$

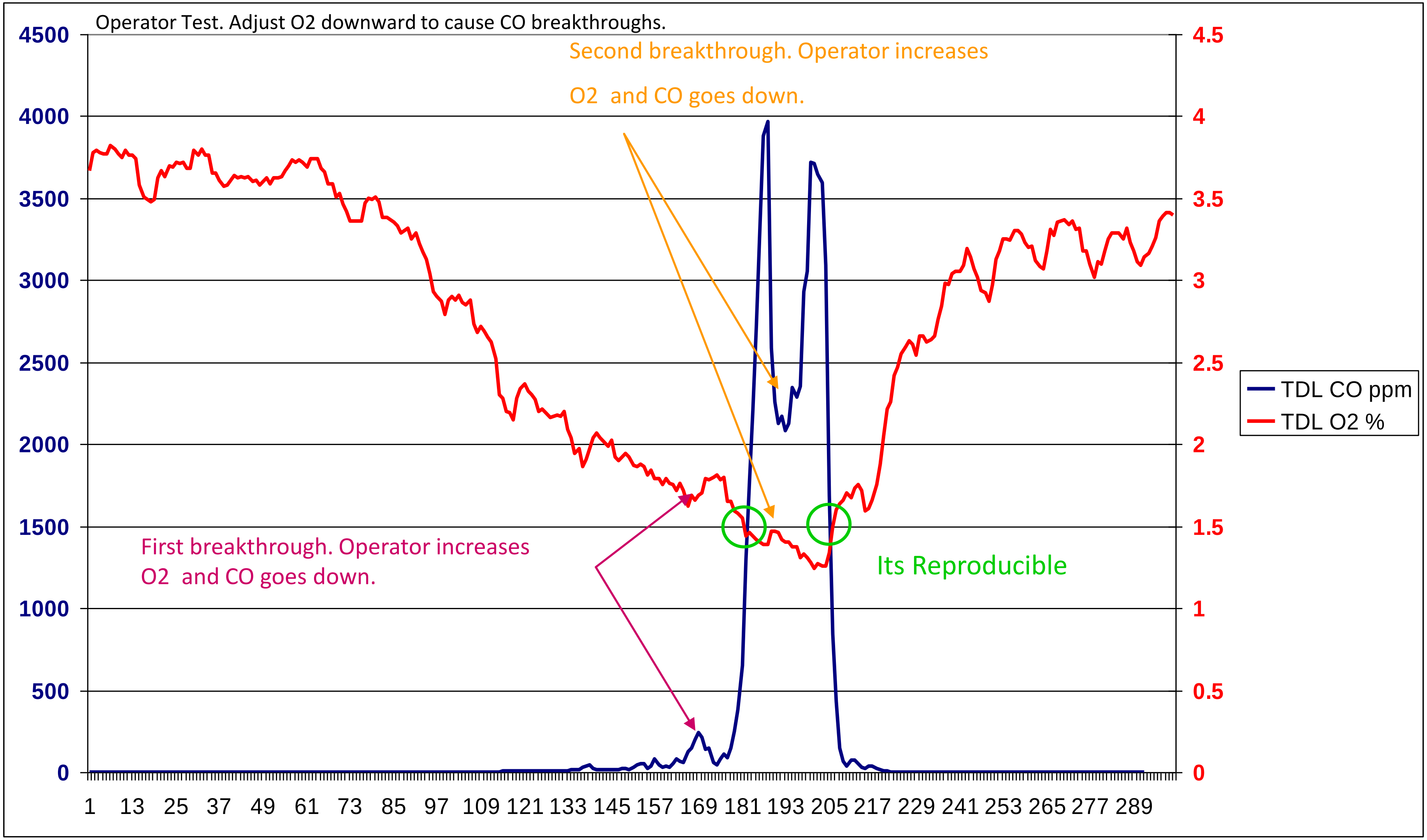
or

$$CH_{4(g)} + O_{2(g)} \rightarrow C_{(s)} + 2H_2O_{(g)}$$

Combustion: theory



Combustion: practice



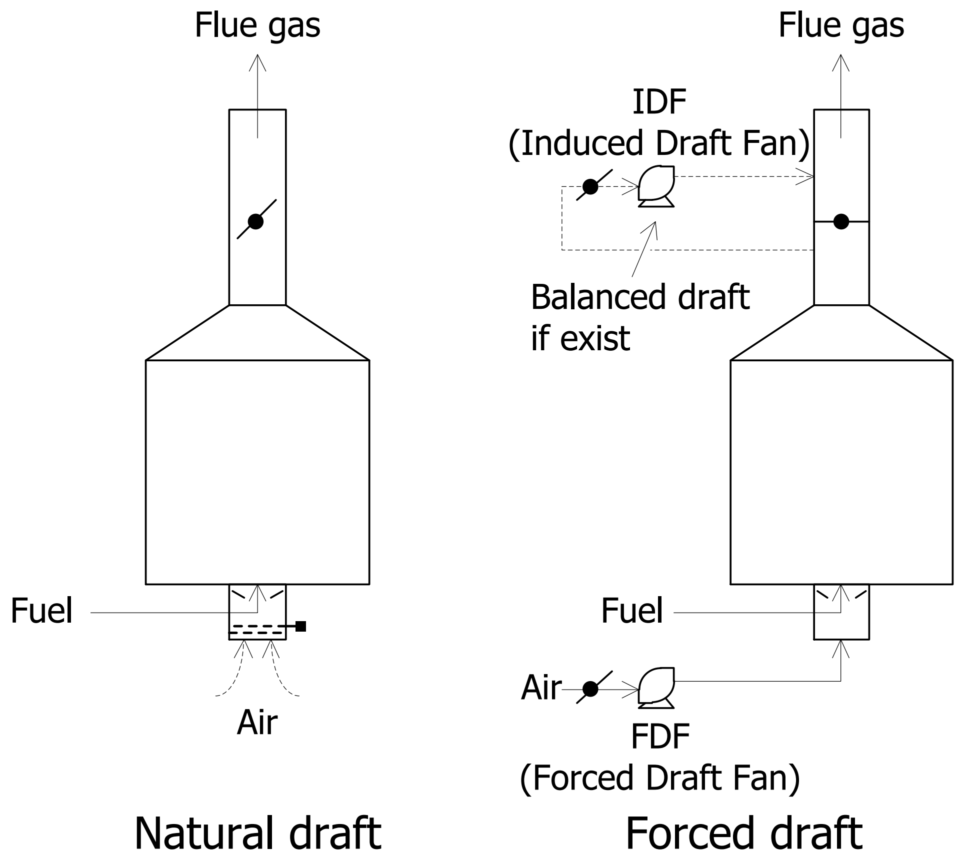
Fired heater

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

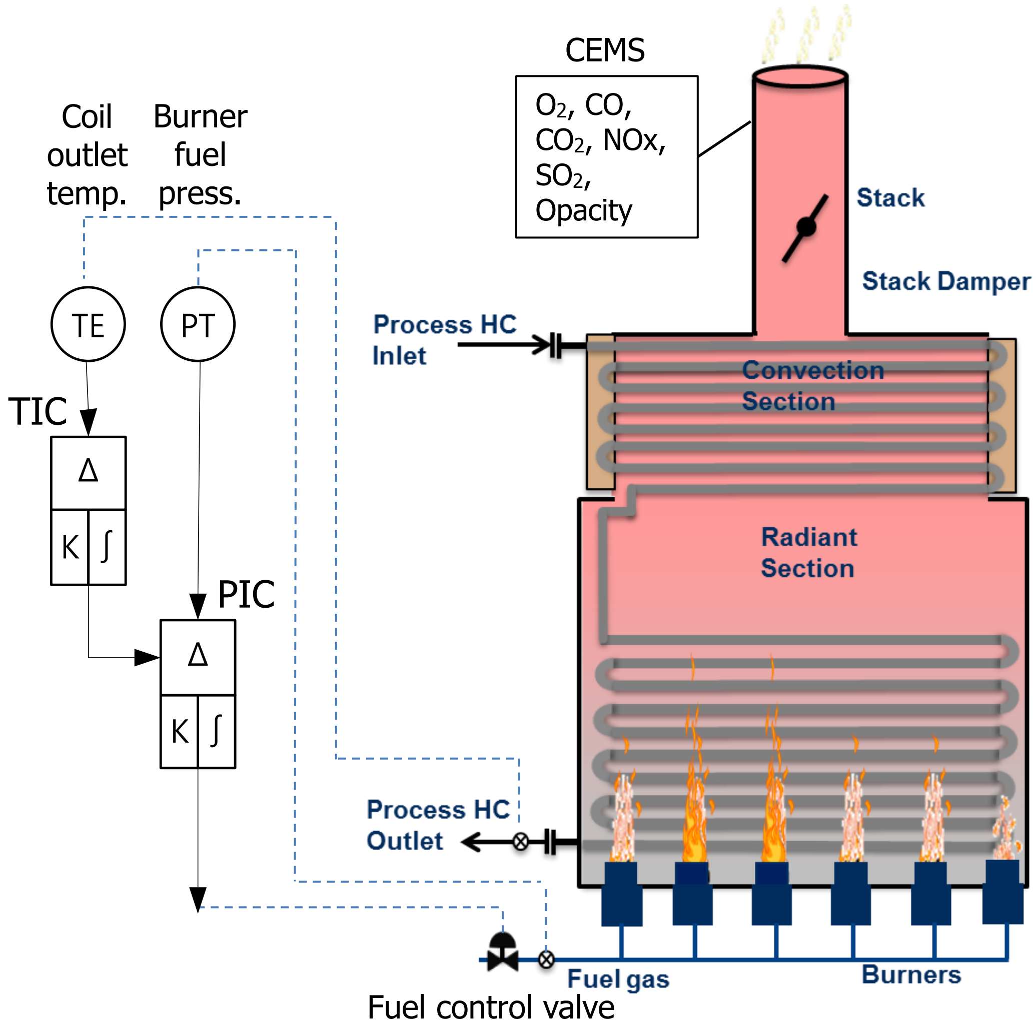
Picture brochure “Fired Heaters” 2013, Foster Wheeler

Different types fired heaters

- Fuels
  - Plant off gas (C_1 ~ C_5, H_2, H_2S… composition varies)
  - Natural gas
  - Fuel oil
- Draft system
  - Natural draft
  - Forced draft
  - Balance draft

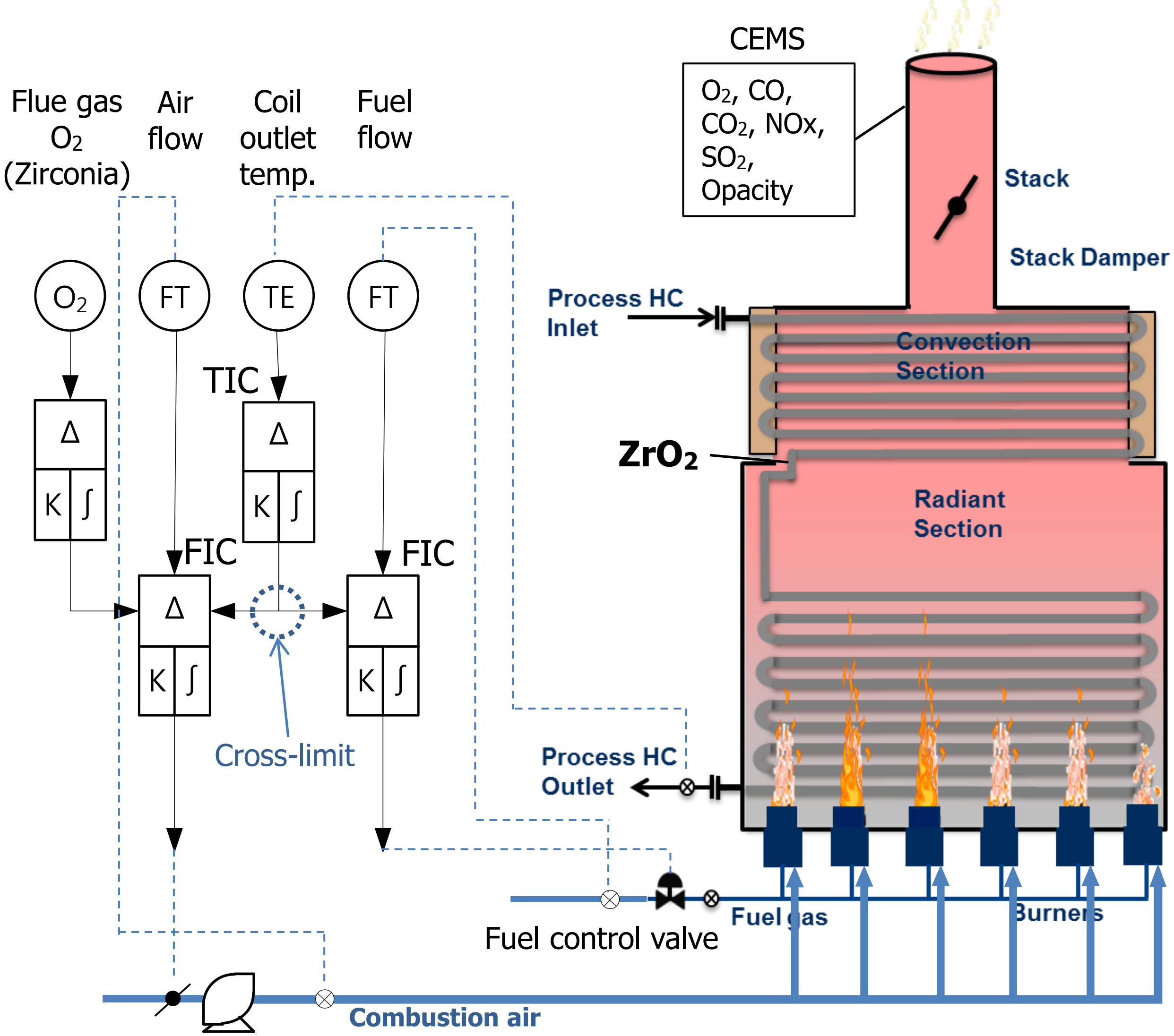


Traditional fired heater control



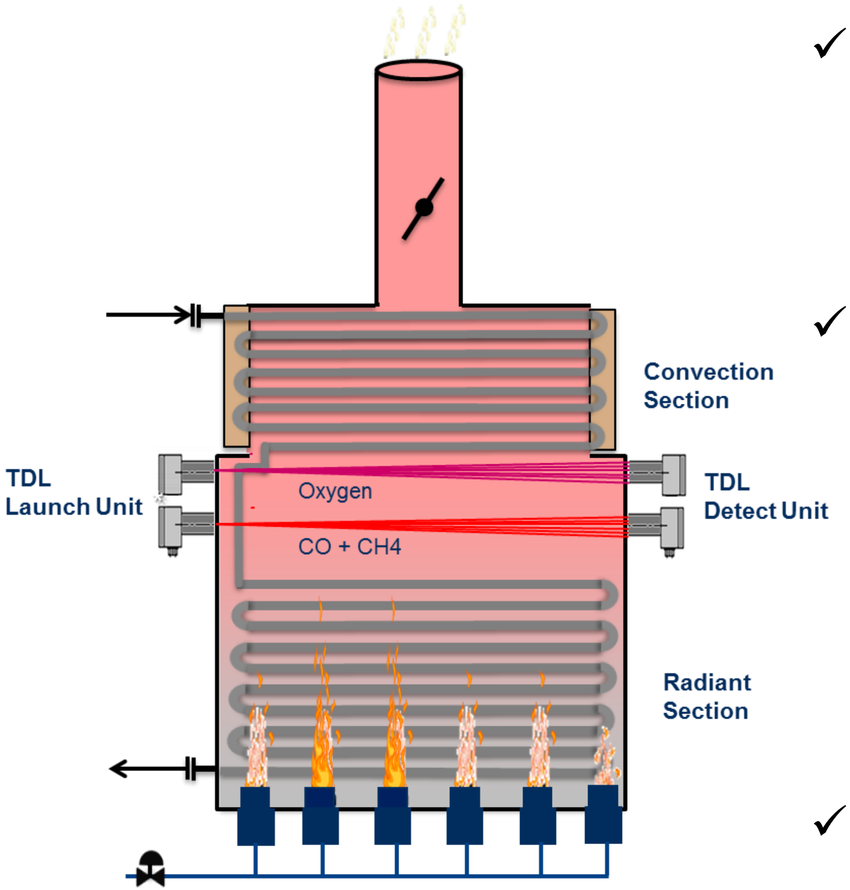
- Coil outlet temperature controlled by burner fuel pressure
- (Natural draft) No air flow measurement & control
- (Forced / Balanced draft) Air flow control but no follow up to fuel amount sometime
- Flue gas measurement for emission monitoring

Typical fired heater control with flue gas O_2 control



- Coil outlet temperature control by <u>fuel flow</u>
- Burner fuel pressure control by limiting fuel control valve opening
- Coil outlet temperature controller sends <u>set point to both air and fuel flow</u>
- Air/fuel cross-limit may be configured
- Flue gas measurement for emission monitoring
- <u>ZrO_2 sensor</u> is installed for flue gas O_2 control

Fired heater optimization by TDLS for O_2, CO/CH_4



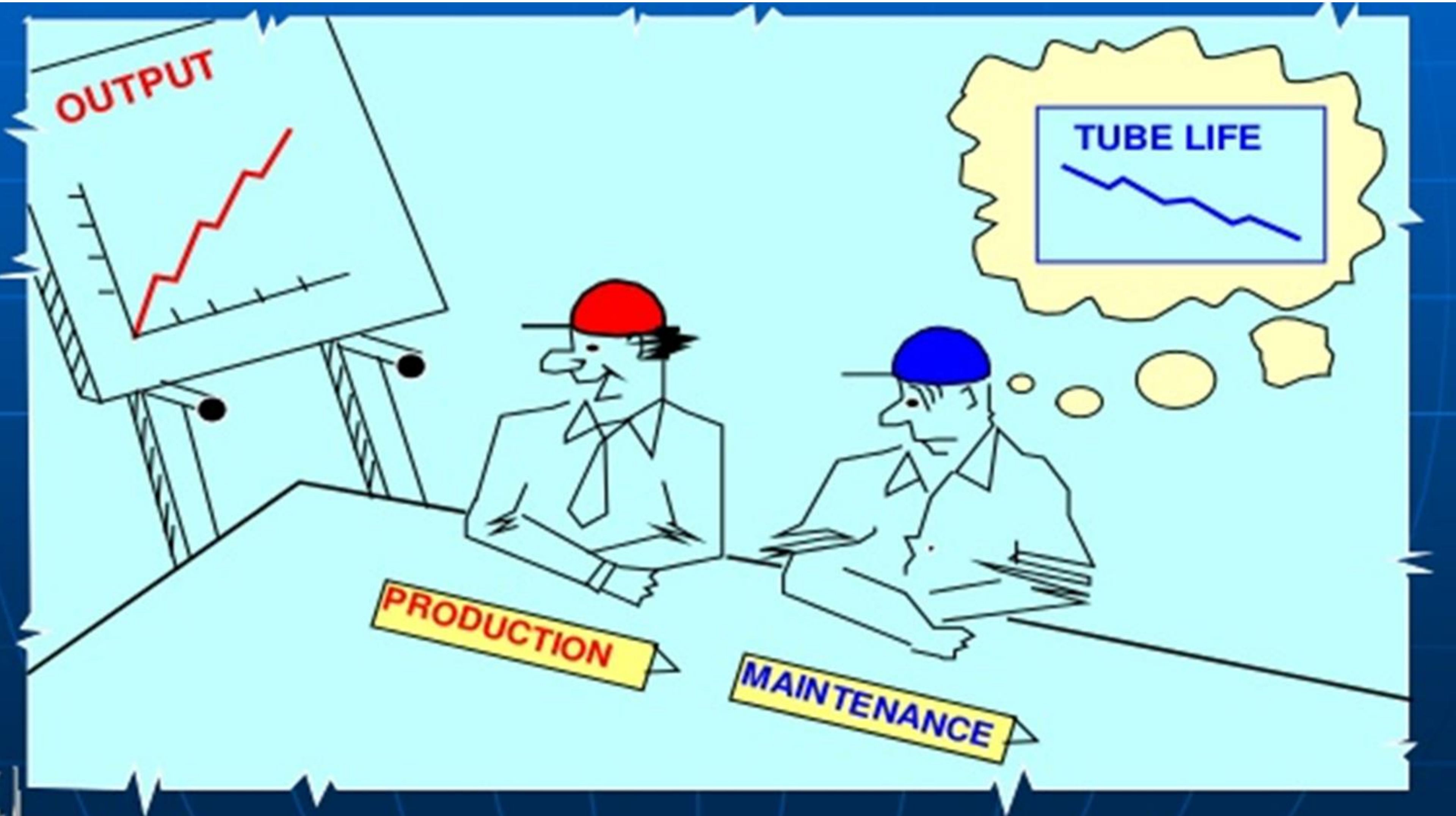
TDLS enables:

✓ Measurement near combustion zone
- Before CO is diluted by tramp air and afterburning
- Up to 1500 degC

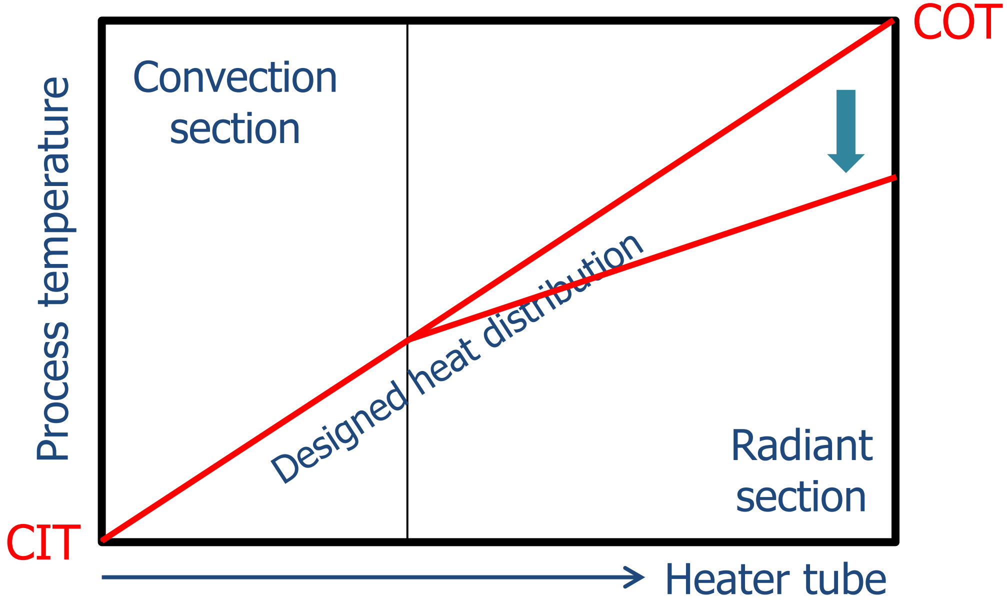
✓ Measurement with cross firebox coverage
- Improve accuracy against uneven combustion of the burners
- Detect malfunction of burner by CH_4
- Breakthrough of CO
- Fast response: 2 seconds or less
- High sensitivity for CO: less than 10 ppm

✓ O_2/CO measurement "matching"
- Same location, same condition

Output increase vs lifetime assets

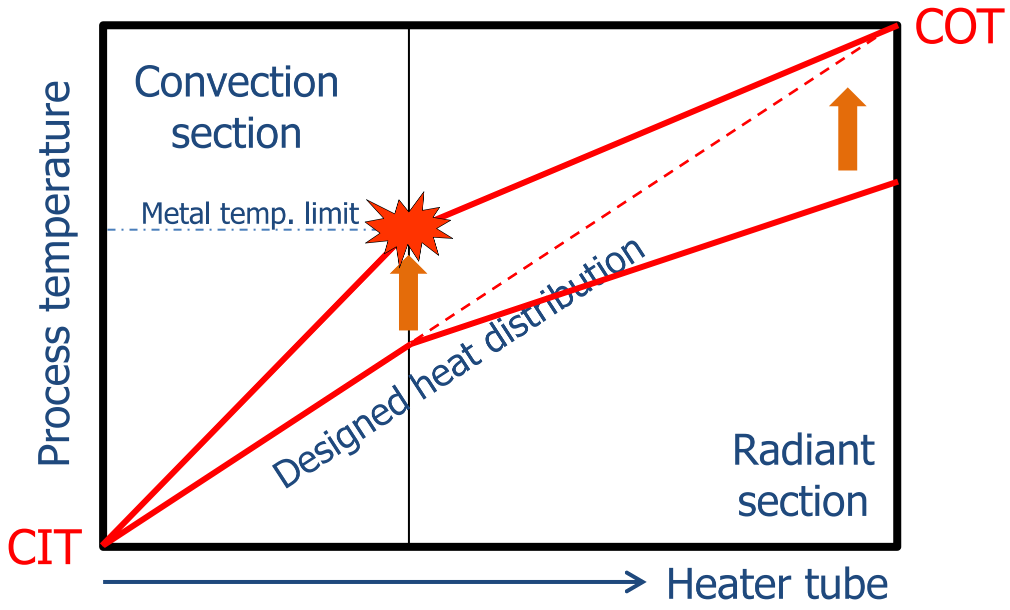


Impact of high excess air on heater lifecycle



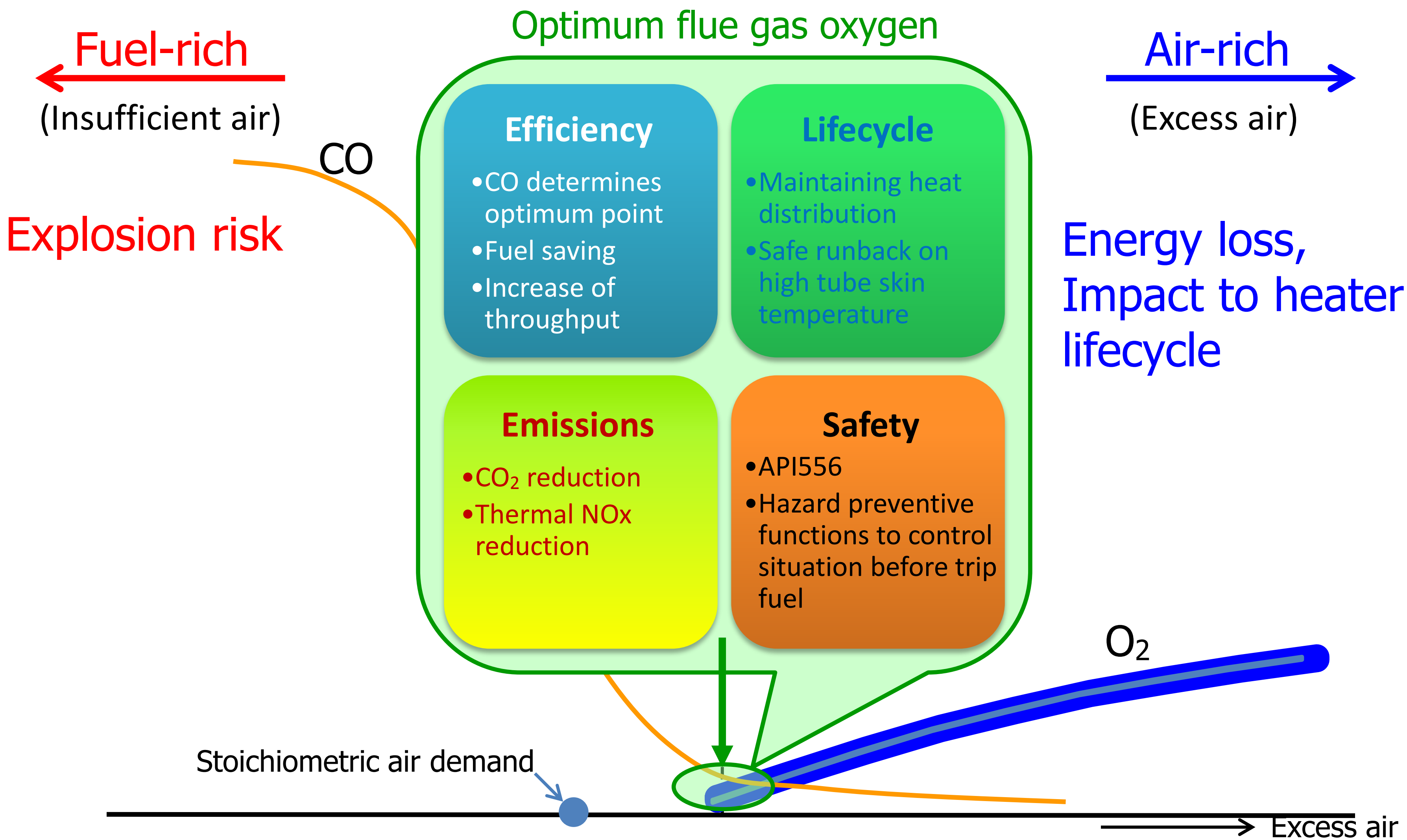
- Efficiency of heat transfer depends on flue gas composition
- O2 and N2 have poor emissivity
- CO2 and H2O have better emissivity
- High excess air dilute CO2 and H2O: heat efficiency decreases

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



Example from the field

Installation examples

Furnace Radiant Section

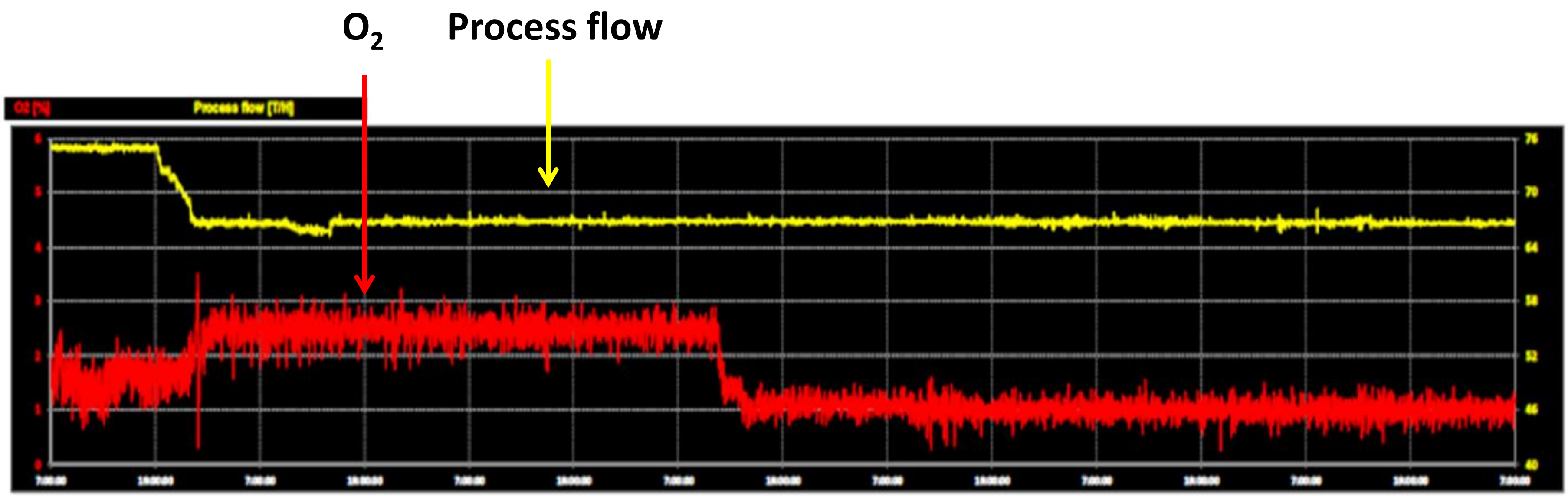
Analyzer Installation Launch and Detect

Launch

Detect

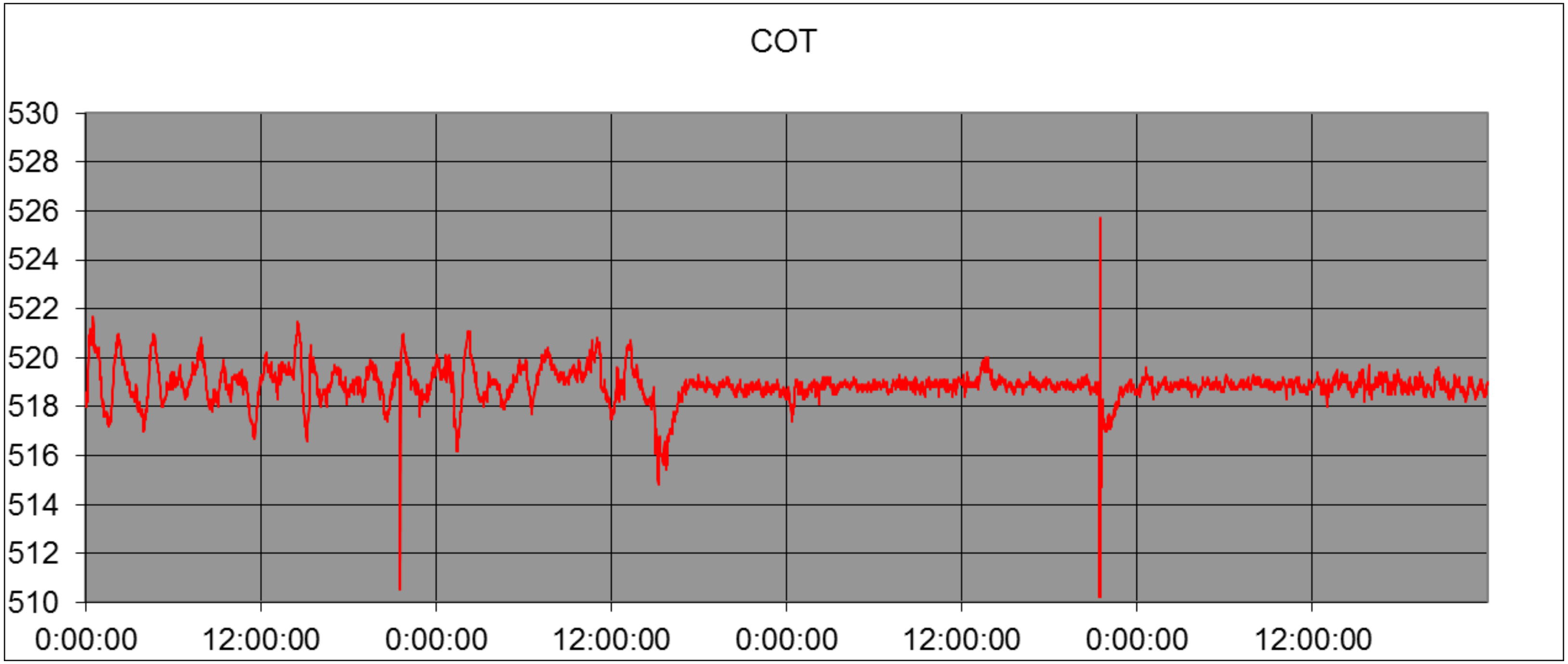
Results from first application performance test

- Stable process
- Reduction of excess air: energy saving



And more results…

- More stable process parameters: COT(*)



(*) Coil Outlet Temperature

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)	0.708	0.290
Fluctuation (±3σ,99.7%)	4.25 °C	1.74 °C

The results:

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

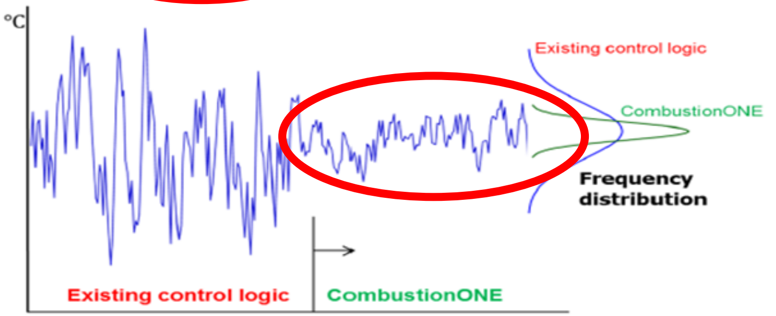


*Image diagram

$aving$

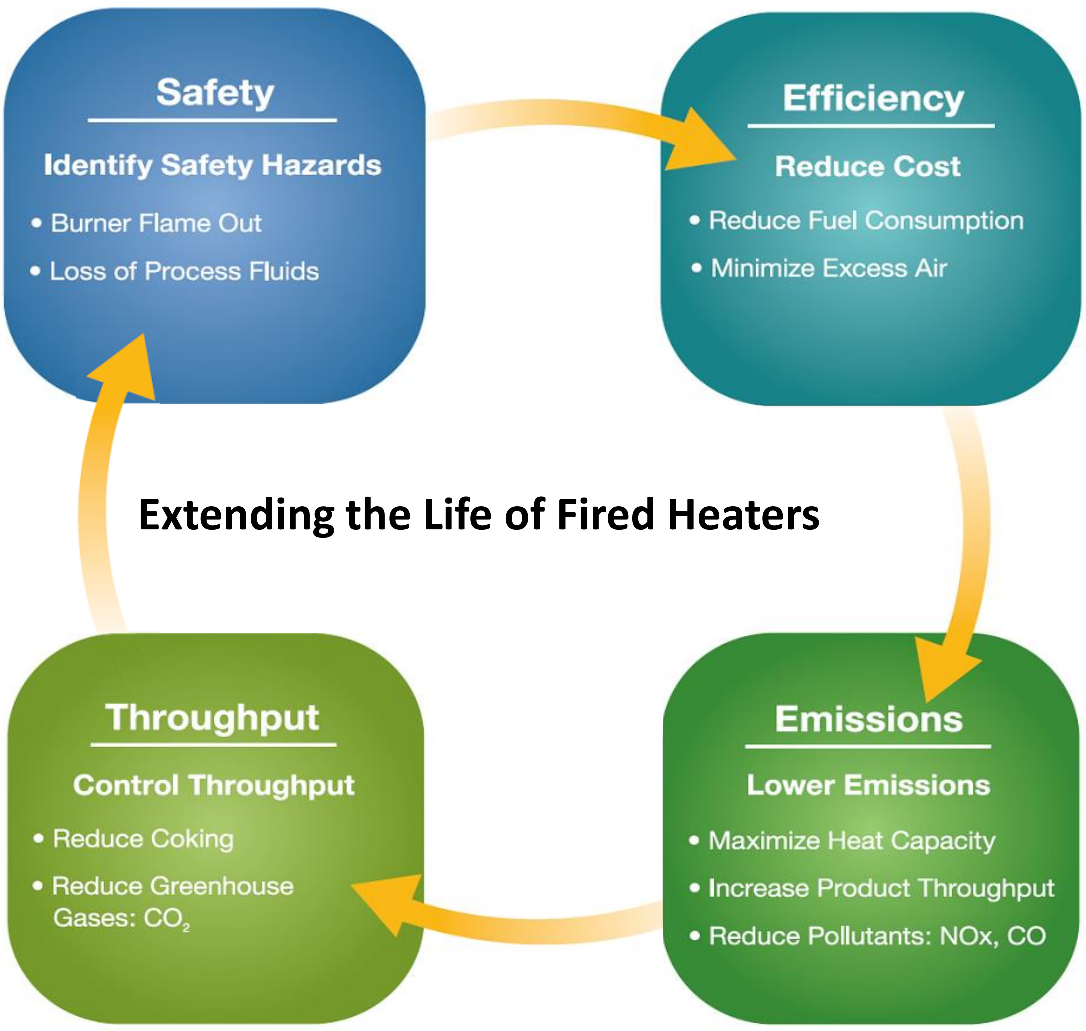
Excess air / Oxygen level decreased from 3,5% to 1 %

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

SAVINGS

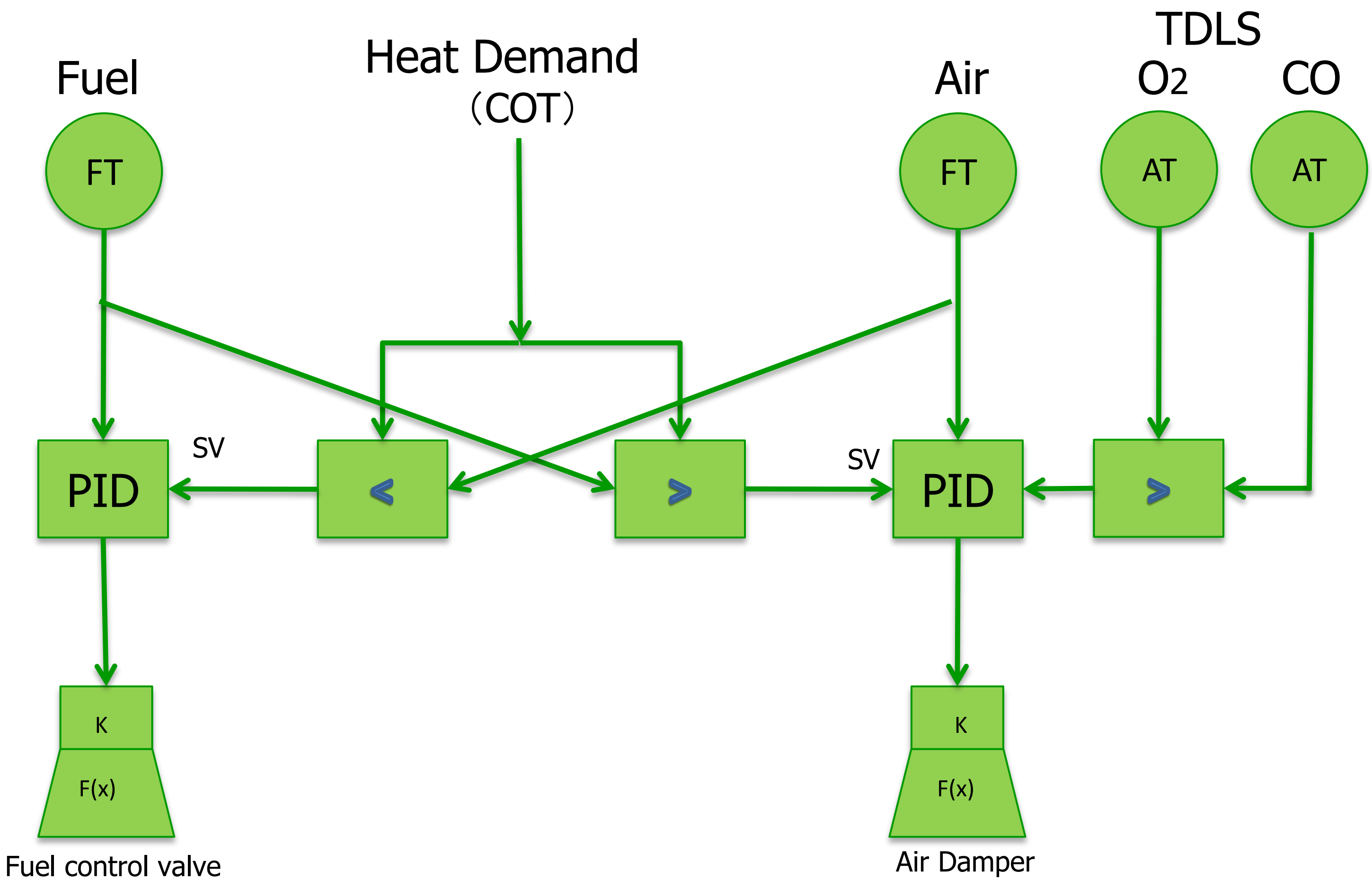
Performance test periode results					
	Consumption				**Calculations**
	48 hours test periode		48 hours test periode		
	High O2 (4%)		**Low O2 (1%)**		
	From 26th July 11:00	**To 28th July 11:00**	**From 29th July 11:00**	**To 31st July 11:00**	
Used fuelgas [KG]		**67 836**		**64 506**	5,7%
Used heat 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**

Complete packed solution: CombustionOne



[Control] of the Fired heaters Solution

Fuel/Air Cross Limit with O_2 Trim and CO Override Control

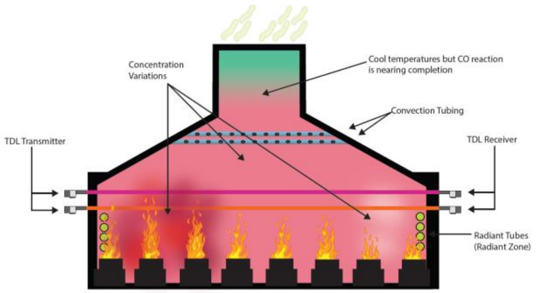


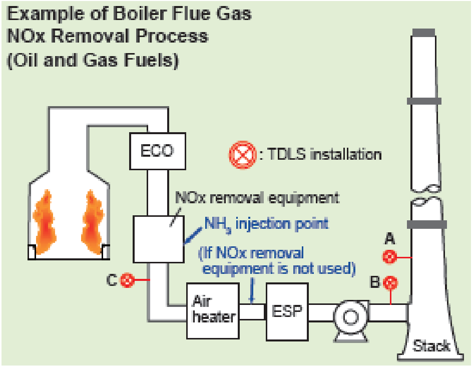
Conclusion on Combustion benefits

- TDLS measurements can provide combustion diagnostics:
  - CO measurement with cross firebox coverage
  - Average O_2 value from one analyzer
  - O_2/CO Matching for control
  - CH_4 and gas temperature measurements at high speed and across the firebox

Solutions provided by Yokogawa

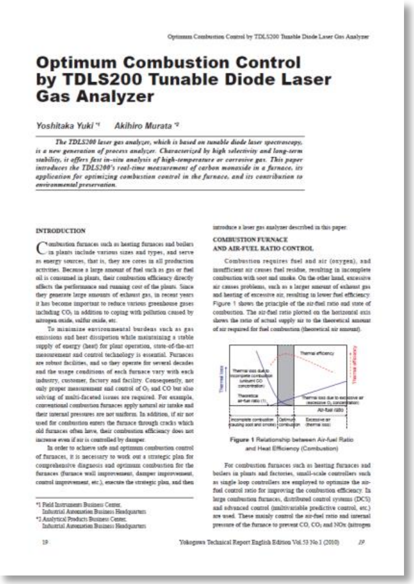
- Fired heaters
  - Safety
  - Combustion optimization
  - Asset management
- Limited Oxygen Concentration
  - Safety
- Process Oxygen
- Ammonia slip
  - Emission
- Moisture
  - Process



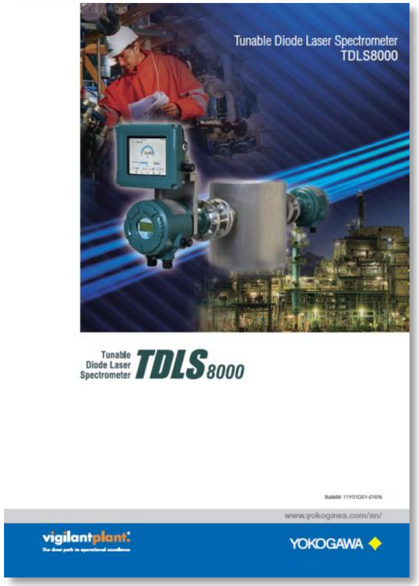


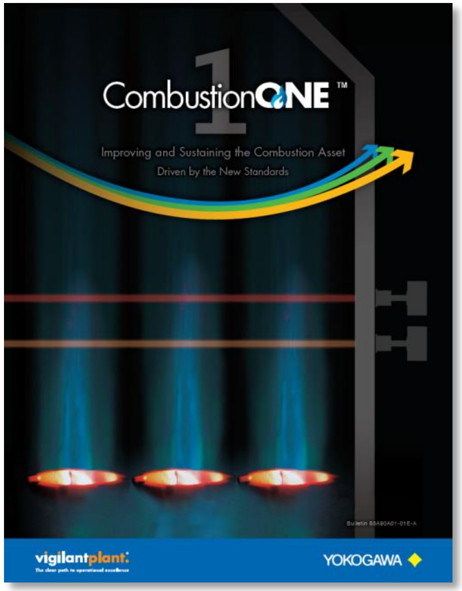
Publications

- 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

Yoshitaka Yuki *1 Akihiro Murata *2





Q&A