SPIRE Sustainable Process Industry through Resource and Energy Efficiency

HORIZON 2020

Sostenibilidad de la Industria de Procesos a través de la Eficiencia Energética y de Recursos

Experiencia del participante en Proyectos SPIRE

Ignacio Martín
Fundación CIRCE

CDTI

3 de Noviembre de 2015

Experiencia CIRCE: Posicionamiento

CIRCE ES MIEMBRO FUNDADOR DE **SPIRE PPP**

- El trabajo desarrollado nos ha permitido estar en puestos de responsabilidad:
  - Miembros del **Board** desde su creación
  - **Líderes** del grupo de trabajo de procesos
- Nos ha dado gran visibilidad entre los socios de SPIRE
- Acceso a una gran variedad de organizaciones participantes
- Posibilidad de participar en elaboración de topics

Resultado: formamos parte de una propuesta de gran calidad gracias a nuestra capacidad de arrastrar a socios relevantes de SPIRE → Proyecto DISIRE (call SPIRE-1-2014)

Experiencia CIRCE: Del 7 PM al H2020

CIRCE COORDINADOR DEL PROYECTO TOP-REF (FP7):

Mejora de la eficiencia de recursos en industria intensiva, mediante el desarrollo de una serie de indicadores, metodologías y herramientas de monitoreo y control.

- 3 sectores involucrados: fertilizantes, químico y refino.
- Contamos con un **Advisory Board** formado por miembros de otros sectores intensivos en consumo de energía
- Objetivo:
  - Potenciar la **replicabilidad** de las soluciones propuestas
  - Alcanzar un mayor **impacto**

Resultado: propuesta muy bien valorada (impacto fundamental en H2020) y se espera una gran proyección de los resultados del proyecto

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TOP REF

OBJECTIVES

TOP-REF aims to develop and validate specific indicators, methodologies and a non-invasive Monitoring and control system (M&CS) devoted to the improvement of resource efficiency in energy intensive industrial sectors.

This methodology will allow the consecution **of TOP-REF final impacts.**

Industrial pilots

1. Chemistry

Tarragona, Spain

Dow Chemical Ibérica, S.L

2. Refining

Sines, Portugal

Petrogal Energía

3. Fertilizer

Utrillas, Spain

Fertinagro

Three large scale industrial pilot plants
driving the change towards sustainability

Sustainable Process Industry through Resource and Energy Efficiency

DISIRE; Distributed In-Situ Sensors integrated into Raw Material and Energy Feedstock

SPIRE-01 2014

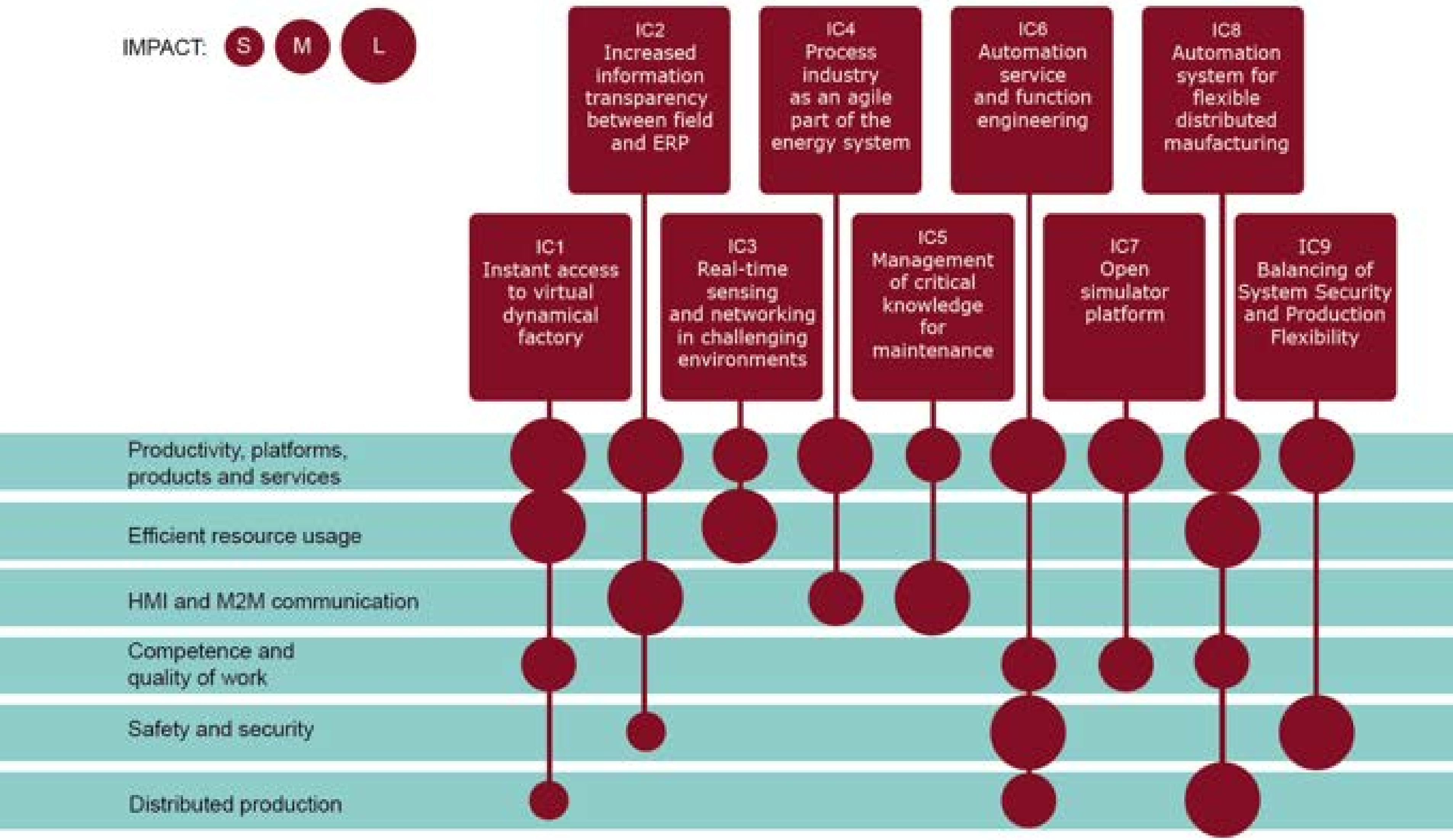
DISIRE Project; In a Nutshell

OBJETIVE; design novel in-situ sensor technologies that will enable the measuring of properties from specific processes and product streams in the ferrous, non-ferrous, chemical and steel industries

ACROSS VALUE CHAINS; tracing of transportations across value chains such as the one between ferrous mining to steel, non-ferrous mining to copper and coal to industrial combustion, etc

ACTIVITIES; direct research and development activities in the areas of industrial process control, electronics and sensor development and data mining

DISIRE Project; Impacts



SPIRE Sustainable Process Industry through Resource and Energy Efficiency

HORIZON 2020

DISIRE

Work Package 8 (WP8) COMBUSTION PROCESSES

CIRCE - DCI

Duration: 5 – 35 months

Status at M9

WP8 – COMBUSTION PROCESSES – OVERVIEW

What is the technical gap?

To improve the efficiency combustion in fired equipment (boilers and ethylene cracking furnaces) by means of an advanced characterization of natural gas flames. The main deficiency in this field is possibly the lack of direct information on the process core: the flame. The methodology involves new concepts of oxygen sensoring on flue gases, computational fluids-dynamics simulations (CFD) of the combustion and Imaging Diagnosis techniques of natural gas flames patterns.

WP8 Final user; Real application and need

WP8 – METHODOLOGY OVERVIEW

- **Task T8.1: Characterization of sensors and boundary production conditions for oxygen measuring in a cracking furnace (CIRCE, DCI, DAPP,ABB) M.5-35**

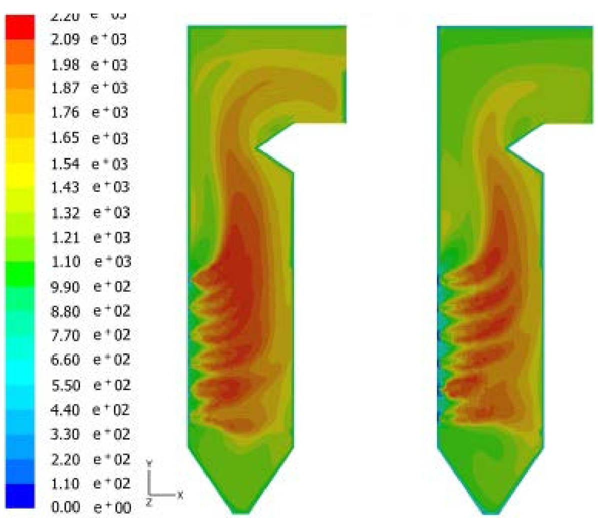
- **Task T8.2: Imaging diagnosis. Lab scale technique development, Design and Engineering (CIRCE, DCI) M. 9-35**

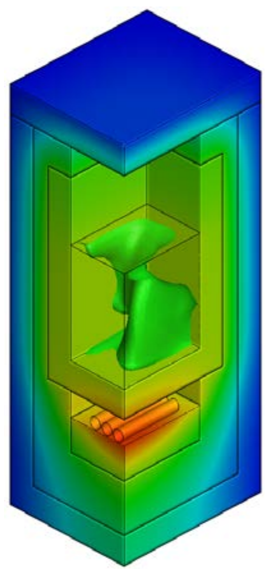
- **Task T8.3: Demonstrator start up (CIRCE and all participating partners) M. 11-35**

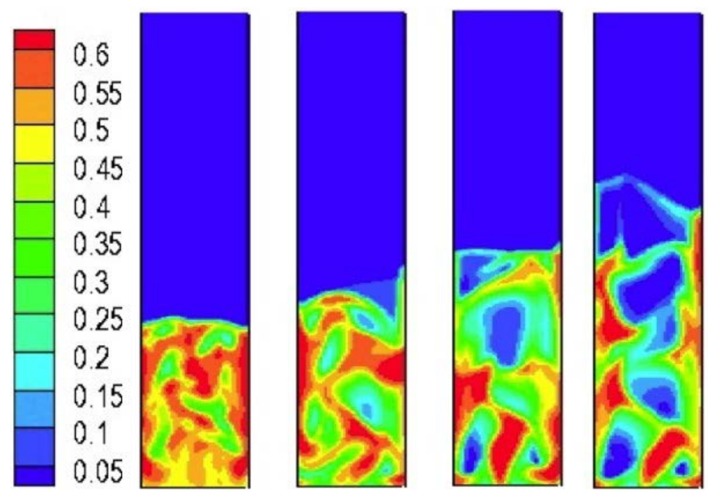
Partner number and short name	WP8 effort
1 - LTU	1.00
4 - ODYS	3.00
6 - IMT LUCCA	1.00
9 - CIRCE	40.00
10 - DOW CHEMICAL IBERICA SL	7.00
11 - ABB AB	1.00
12 - D'APPOLONIA SPA	7.00
Total	60.00

CFD to simulate combustion processes

- Widely used in industry in all steps of design process
- Important economic saving in prototypes
- Scale-Up of pilot plants
- Detailed information of critical points in processes and equipment

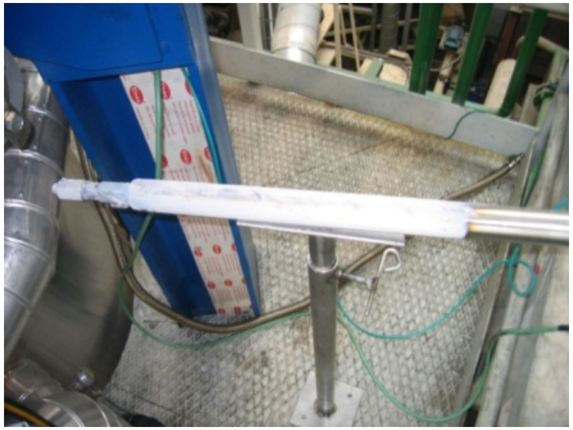






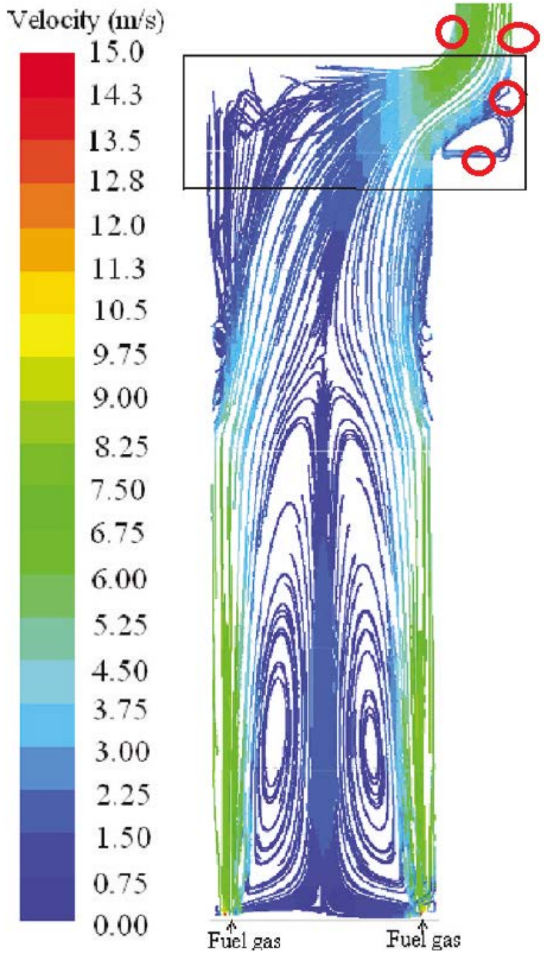
CFD to simulate combustion processes

- Development of an Imaging Diagnosis tool based in Charge-Coupled Device (CCD) Cameras :
  - On-line
  - Non-invasive technique
  - Low investment cost
  - Compatible with high temperature and the harsh environment
- Experimental facility - 50 kWt burner, CCD cameras, measurements probes



CFD to simulate combustion processes

- **Specific DISIRE applications:**
  - Find the exact locations to O_2 sensors



Hu et al. Ind. Eng. Chem. Res. 2011, 50, 13672

CFD to simulate combustion processes

- **Specific DISIRE applications:**
  - Find the exact locations to O_2 sensors
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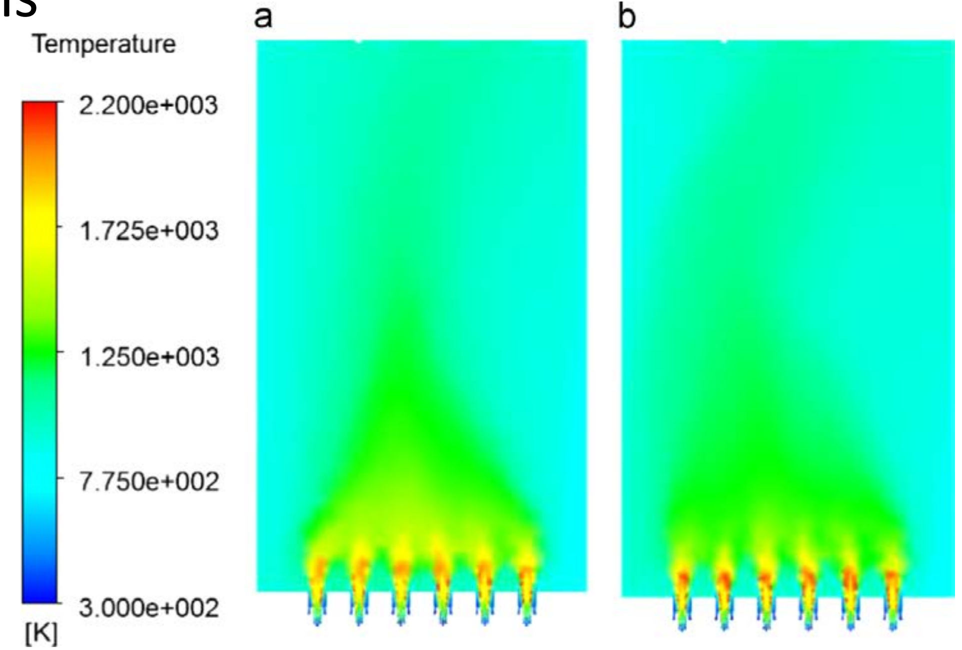
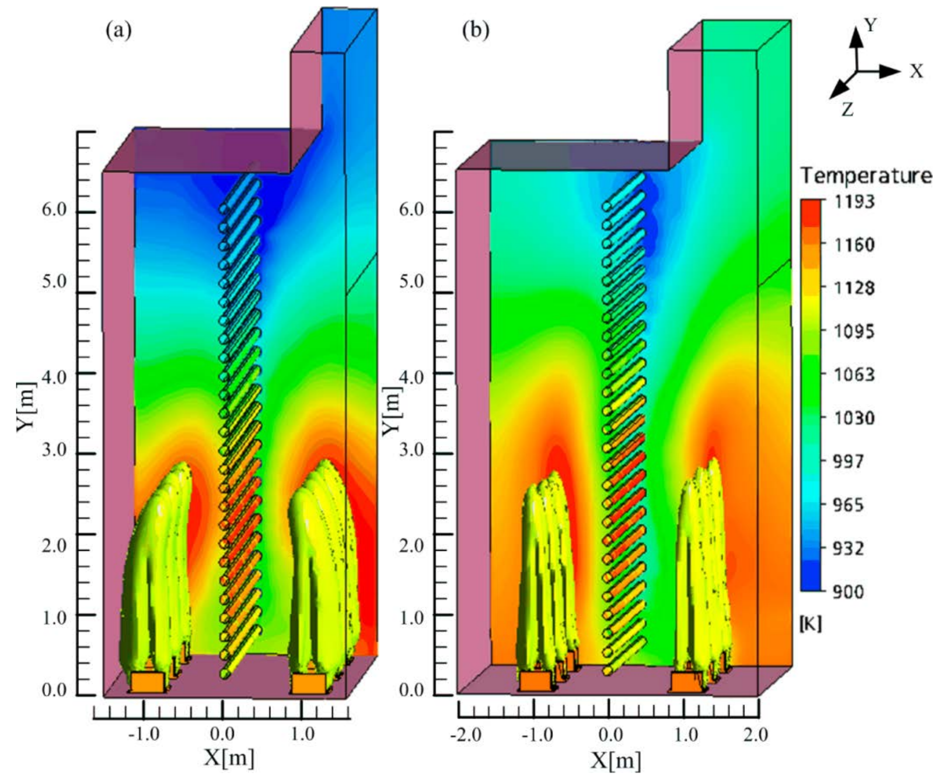


X. Li et al. Chemical Engineering Science 123 (2015) 70

CFD to simulate combustion processes

- **Specific DISIRE applications:**
  - Find the exact locations to O_2 sensors
  - Improve operational conditions
  - Propose modifications in design

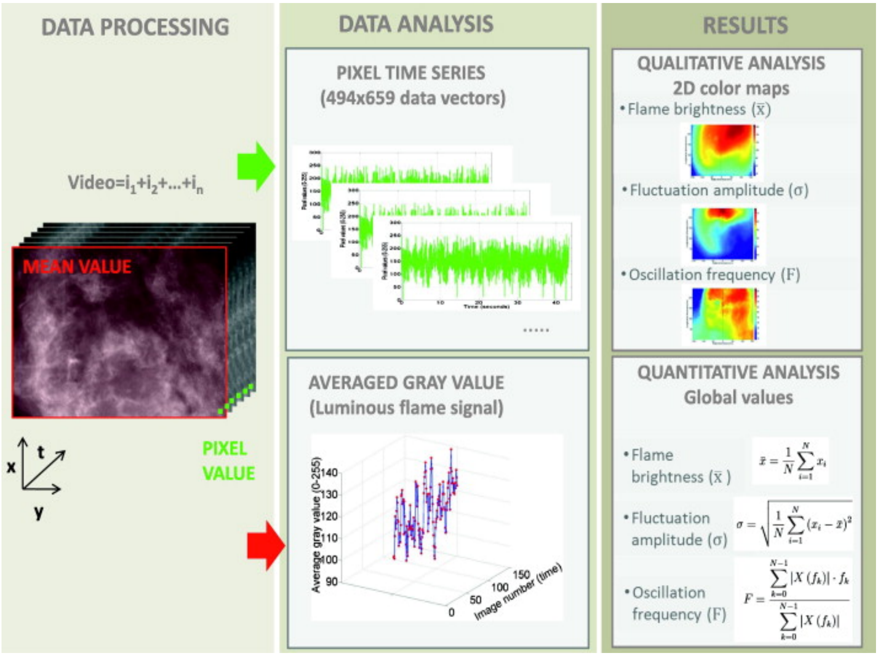


Yang et al. Ind. Eng. Chem. Res. 2012, 51, 15440

From CFD tool to new CCD camera

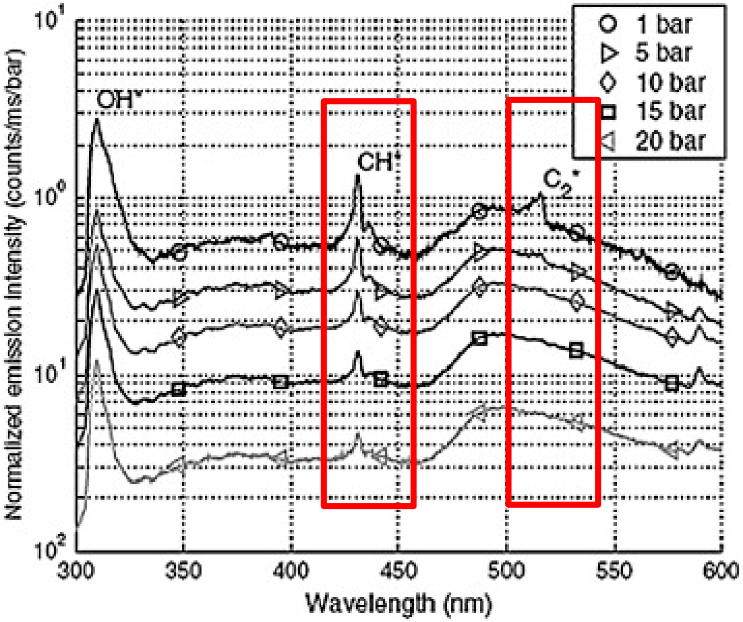
Develop algorithm to correlate statistical and spectral flame characteristics with emissions and operational parameters

CIRCE Current state – Coal flame



Gonzalez et al. (2013) Fuel, 113, 798

Methane flame spectra

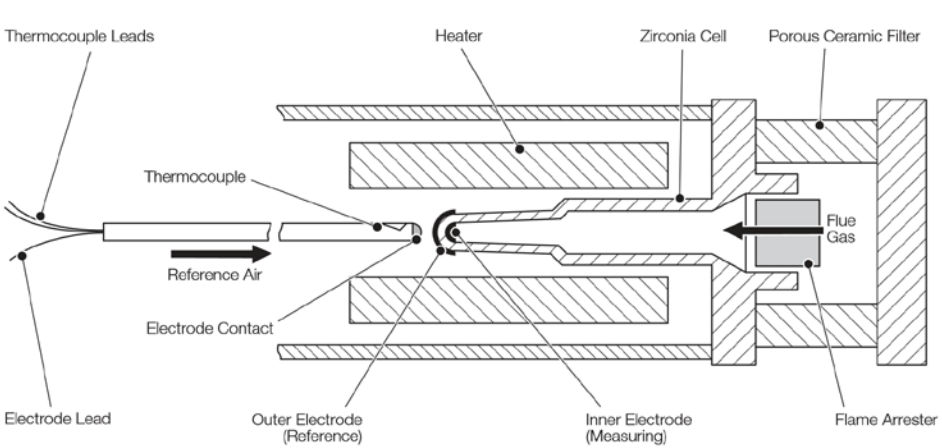


Docquier et al. (2002) Proc. Comb. Ins. 29 I,139

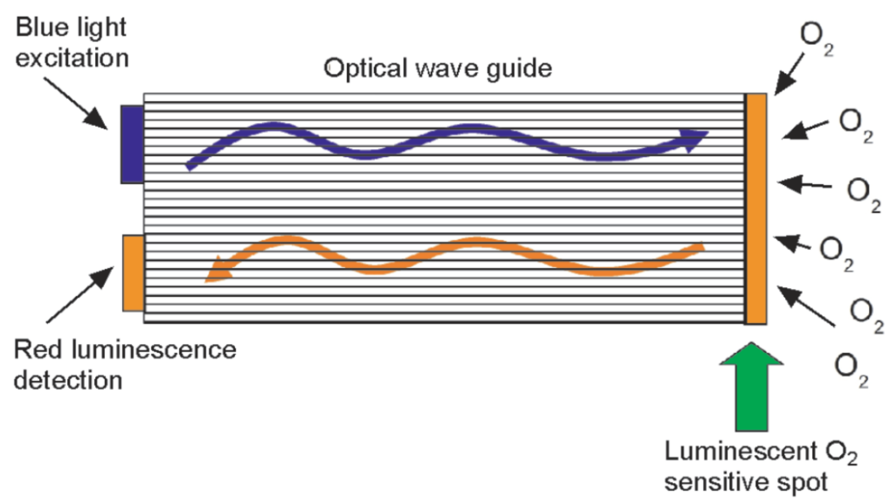
T8.1: SENSORS SELECTION

- **Characterization of oxygen sensors**
- **Selection of sensor**
- **Location of sensor based in CFD simulations**

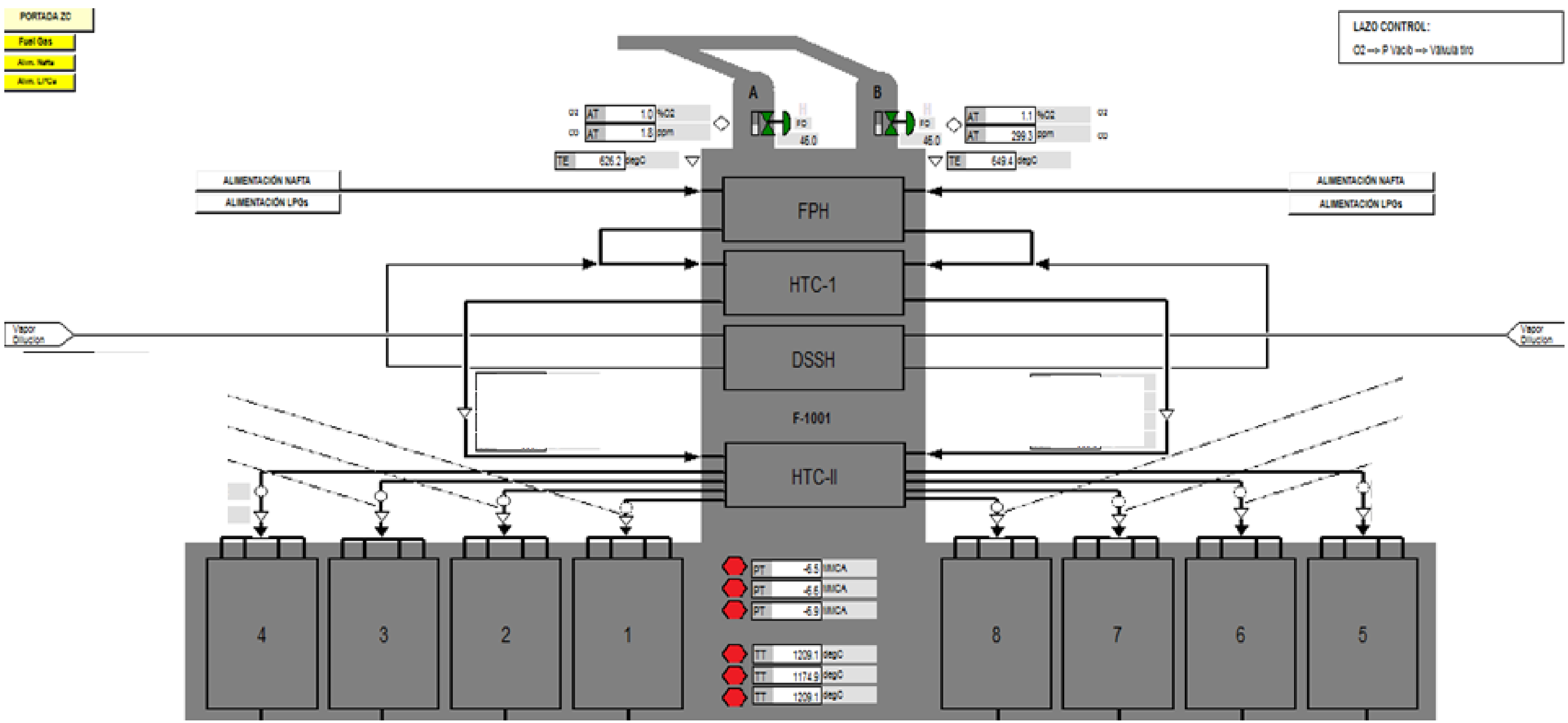
ELECTROCHEMICAL (e.g. ABB)



OPTICAL (e.g. Hach)



DATA GATHERING



GAS SIDE SENSORS

T (gas, coils), P (Draft), Fuel (flow & composition), O_2 and CO concentration

T8.1: DATA GATHERING(II)

DATA GATHERING

Fuel Gas			
Tag	Units	Description	Value
EB_AC_0084	kg/h	F-1001 Caudal de FG corregido FT-0101 - kg/h	3483,921
L_16_AE8401_H2	%_Vol	AE8401 COMP-LPGAS HIDRÓGENO	25,86911
L_16_AE8401_MET	%_Vol	AE8401 COMP-LPGAS METANO	71,43438
L_16_AE8401_O2	%_Vol	AE8401 COMP-LPGAS OXÍGENO	0,03
L_16_AE8401_ACET	%_Vol	AE8401 COMP-LPGAS ACETILENO	0
L_16_AE8401_CICLOP	%_Vol	AE8401 COMP-LPGAS CICLOPROPANO	0,005
L_16_AE8401_PROPI	%_Vol	AE8401 COMP-LPGAS PROPILENO	0,031543
L_16_AE8401_PD	%_Vol	AE8401 COMP-LPGAS PROPADIENO	0,005005
L_16_AE8401_MA	%_Vol	AE8401 COMP-LPGAS METILACETILENO	0,005
L_16_AE8401_Ibuta	%_Vol	AE8401 COMP-LPGAS isoBUTANO	0,01179
L_16_AE8401_nbuta	%_Vol	AE8401 COMP-LPGAS n-BUTANO	0,020274
L_16_AE8401_1BUTE	%_Vol	AE8401 COMP-LPGAS 1-BUTENO	0,033361
L_16_AE8401_CICLOB	%_Vol	AE8401 COMP-LPGAS CICLOBUTANO	0,005
L_16_AE8401_IBUTE	%_Vol	AE8401 COMP-LPGAS isoBUTENO	0,049937
L_16_AE8401_T2BUTE	%_Vol	AE8401 COMP-LPGAS trans-2-BUTENO	0,020423
L_16_AE8401_C2BUTE	%_Vol	AE8401 COMP-LPGAS cis-2-BUTENO	0,01009
L_16_AE8401_13BUTA	%_Vol	AE8401 COMP-LPGAS 1,3-BUTADIENO	0,009242
L_16_AE8401_12BUTA	%_Vol	AE8401 COMP-LPGAS 1,2-BUTADIENO	0,005
L_16_AE8401_IPENTA	%_Vol	AE8401 COMP-LPGAS isoPENTANO	0,005
L_16_AE8401_NPENTA	%_Vol	AE8401 COMP-LPGAS n-PENTANO	0,005
L_16_AE8401_C5	%_Vol	AE8401 COMP-LPGAS C5 INSATURADOS Y SUPERIORES	0,005
L_16_AE8401_H2S	ppm_Vol	AE8401 COMP-LPGAS ÁCIDO SULFHÍDRICO	0,01
L_16_AE8401_OCS	ppm_Vol	AE8401 COMP-LPGAS SULFURO DE CARBONILO	0,01
L_16_AE8401_CH4S	ppm_Vol	AE8401 COMP-LPGAS METIL MERCAPTANO	0,01
L_16_AE8401_C2H5SH	ppm_Vol	AE8401 COMP-LPGAS ETIL MERCAPTANO	0,01
L_16_AE8401_CO	%_Vol	AE8401 COMP-LPGAS MONÓXIDO DE CARBONO	0,274365
L_16_AE8401_CO2	ppm_Vol	AE8401 COMP-LPGAS DIÓXIDO DE CARBONO	6,332053
L_16_AE8401_ETA	%_Vol	AE8401 COMP-LPGAS ETANO	1,261055
L_16_AE8401_ETI	%_Vol	AE8401 COMP-LPGAS ETILENO	0,797947
L_16_AE8401_N2	%_Vol	AE8401 COMP-LPGAS NITRÓGENO	0,131825
L_16_AE8401_PROP	%_Vol	AE8401 COMP-LPGAS PROPANO	0,105978
L_16_AE8401_CC	kcal/kg	AE8401 CALC-LPGAS Calor de Combustión	12504,03

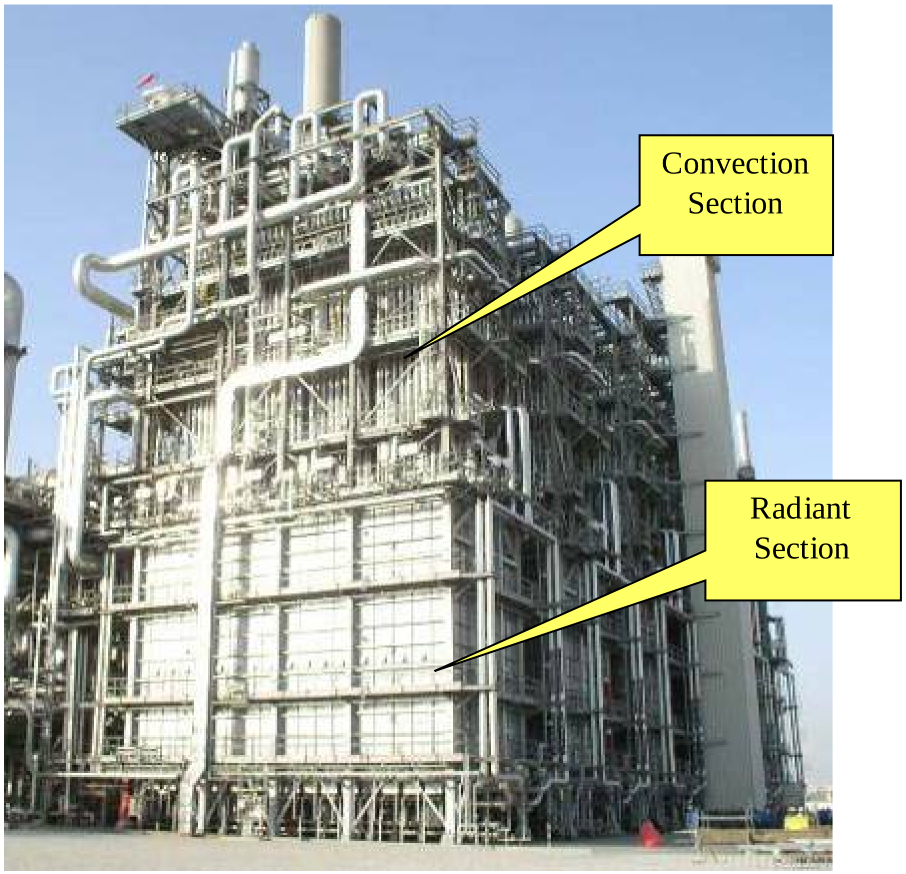
Analizador general de humos (Hornos + Caldera)			
Tag	Units	Description	Value
EA_AC_2863	MG/NM3	SO2 en mg/Nm3 [mg/Nm3]	14,0432
EA_AC_2869	MG/NM3	NOX en mg/Nm3 [mg/Nm3]	102,3077
EA_AC_2875	MG/NM3	CO en mg/Nm3 [mg/Nm3]	25,45803
EA_AC_2834	%	Oxigeno seco en % [%]	7,593279
EA_AC_2835	%	Oxigeno humedo en % [%]	6,699944

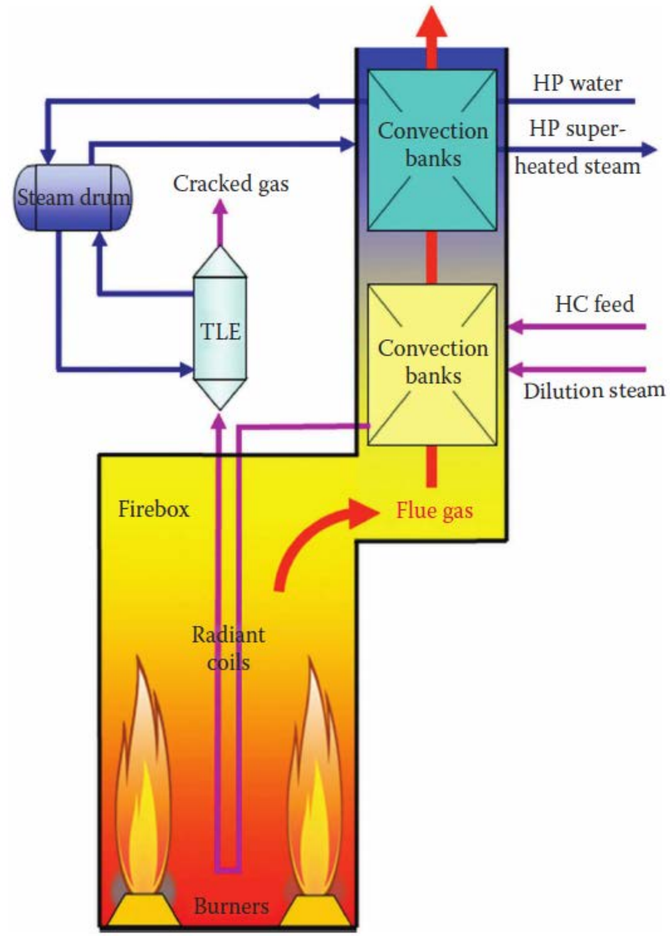
- Instrumentation complete
- Detailed fuel composition and flow
- Full available data for simulation

CHALLENGES

- Data reconciliation (CO/O_2)
- Losses estimation (E&M balances)
- Pseudo-stationary process (scenarios)

Cracking Furnace Overview





Typical cracking furnace firebox layout.

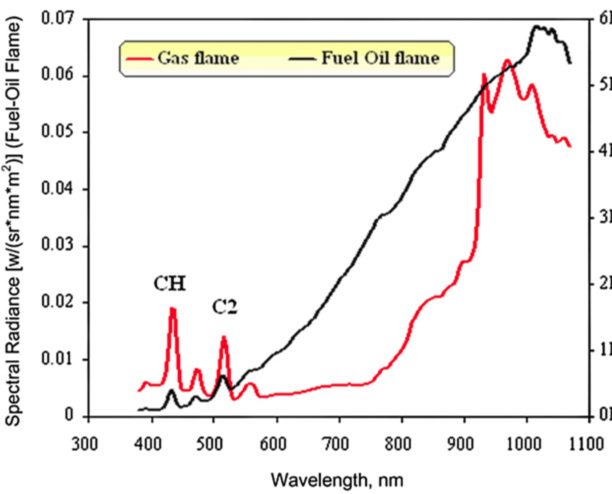
FURNACE CFD SIMULATIONS

Simulation Plan

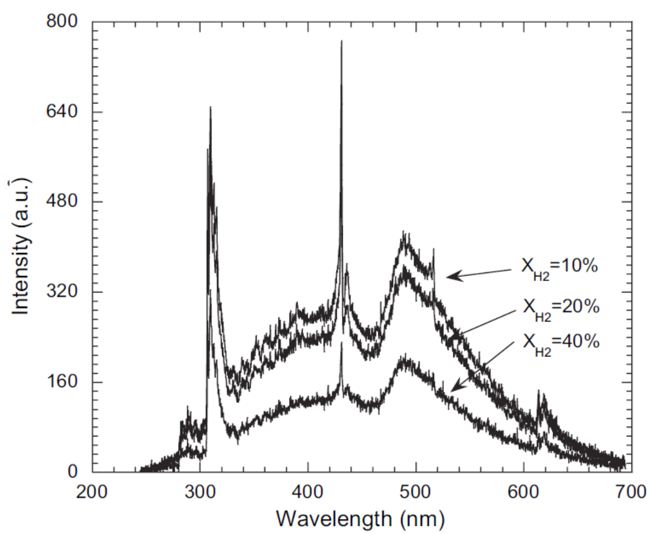
- **FURNACE – F-1001-09 - RETROFITTING POTENTIAL**
- **3 TIME AVERAGED SCENARIOS**
  - 3 days after decoking
  - 3 central cycle days
  - 3 days before decoking
- **TWO DIFFERENT PROCESS SIDE FEEDSTOCK**
  - Naphta
  - Propane

GAS COMBUSTION IS CHARACTERIZED BY A SPECTRUM THAT DEPENDS ON FUEL, AIR/FUEL RATIO AND GEOMETRY

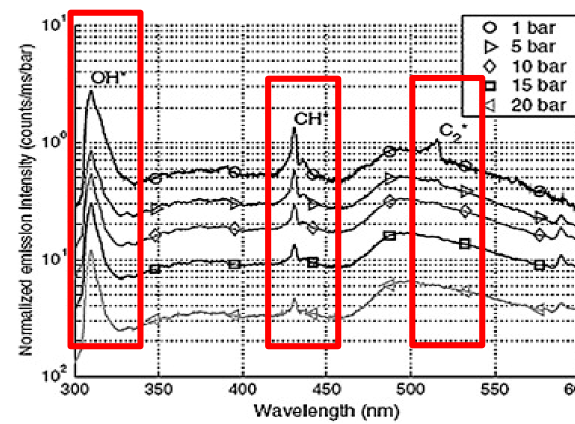
Methane vs fuel oil



Methane / Hydrogen



Methane



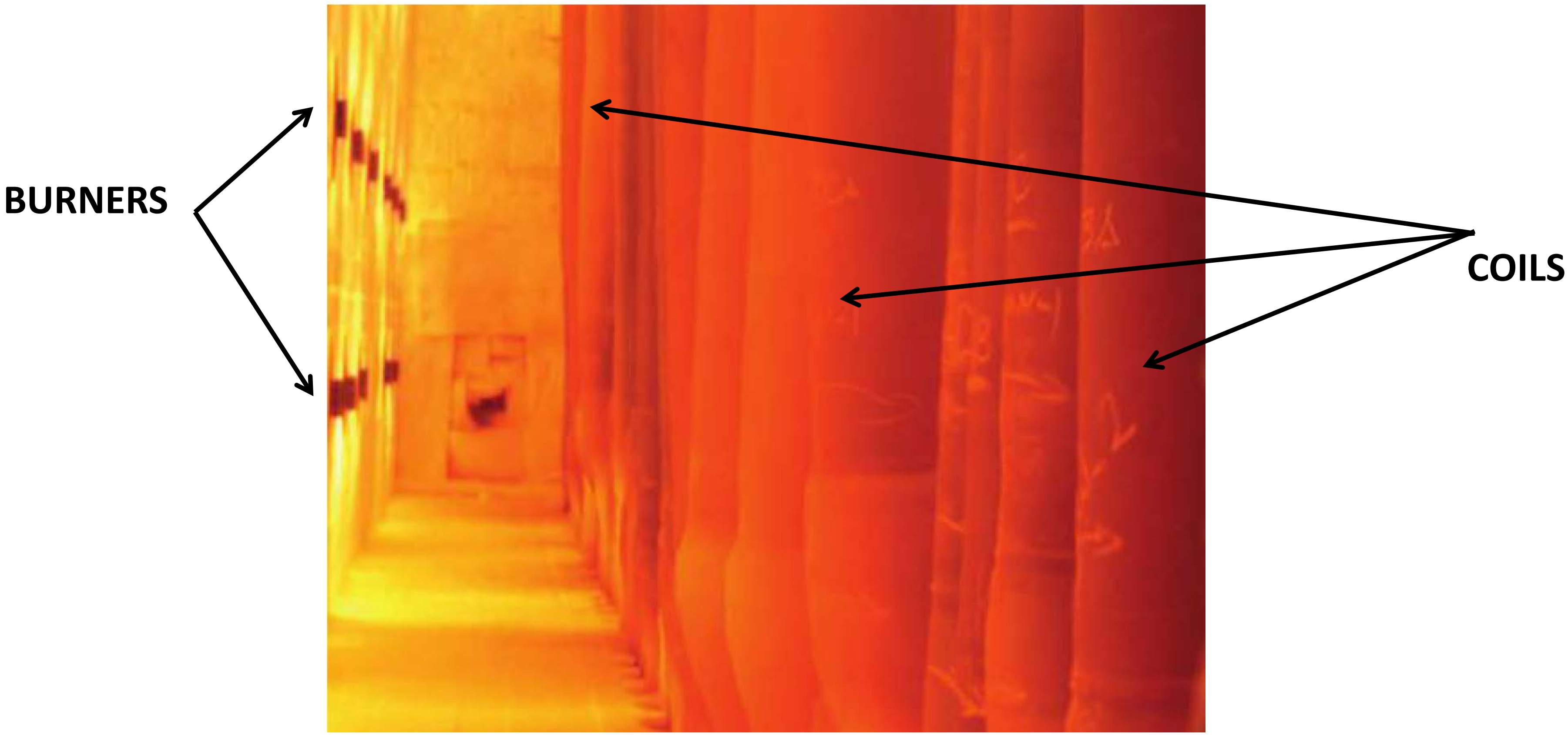
COMBUSTION QUALITY → RADICALS OH*, CH*, C2*, …

REVEALED AT DIFFERENT WAVELENGHT 200 to 850nm

Ballester and García-Armingol Prog. En. Comb. Sci. 2010,36,375

Docquier et al. (2002) Proc. Comb. Ins. 29 I,139

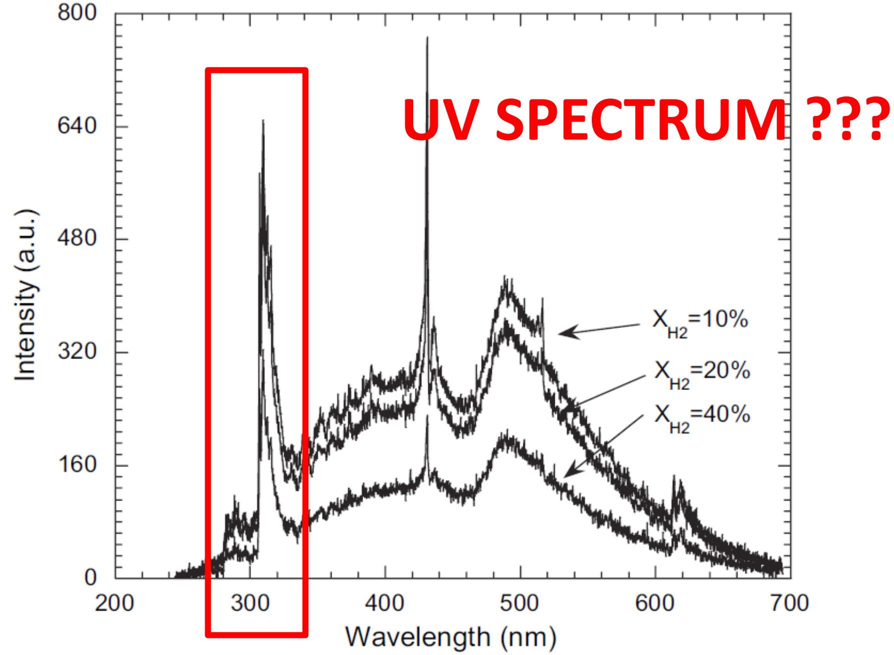
CRACKING FURNACE OPERATION

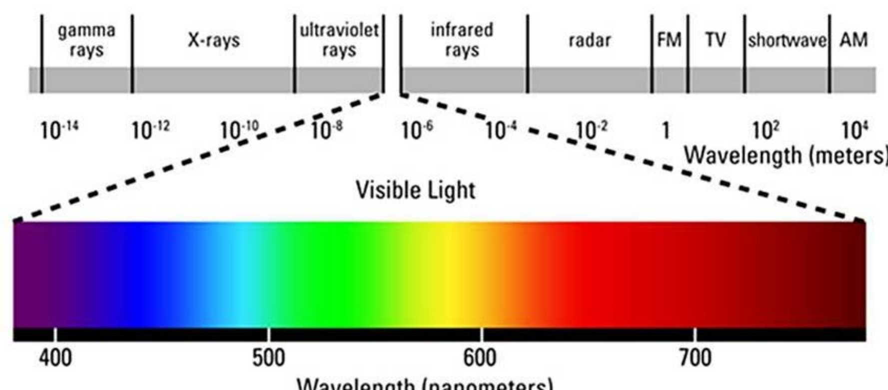


Platvoet et al."Refining and Petrochemical Industries" The John Zink Hamworthy Combustion Handbook, 2012

WHERE IS THE FLAME???

T8.2: IMAGING DIAGNOSIS





CHALLENGES

- Flame characterization
- Participative gases filter
- Wall radiation filter

DIAGNOSIS TECHNIQUE DEPENDS ON SPECTRUM

Ocean Optics Flame-S-UV-VIS-ES

Relevant impacts of DISIRE Project

- Most of the **deliverables are public**, in the spirit of facilitating theire replicability within and among sectors.
- Cross-sectorial approach and multifuntional solutions tested

- In DCI, expected targets range between 2% - 5% of energy efficiency improvement**…..NOT MUCH????!!!!**

Expected efficiency gains in DCI

1500 TOE/year
(tonnes of oil equivalent)

3200 tones/year CO_2 (GHG) emissions reduction per one cracking furnace

Impact on the DOW's Tarragona facility will be 10 times the above-mentioned figures accounting for up to 2 million EUR savings per year (based on Dow Chemical case study)