Development and testing of Low-NOx Roof Burner SMS RADFlame HY2 for the Steel Industry

Tommaso Bortolussi- Process & Technology, Reheating & Heat Treatment Plants
SMS group S.p.A.

Irene Luzzo- Laboratory Responsible, Lab Combustion Station
RINA Consulting – CSM S.p.A.

Thursday, 31st October 2024

ESTEP
European Steel Technology Platform
20 years together

H2 FOR GREEN STEEL
3rd INTERNATIONAL CONFERENCE
meets
A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine ONE STEP AHEAD.
PRIMETALS TECHNOLOGIES

NOx Emission – EU Action Plan: "Towards Zero Pollution for Air, Water and Soil"

NOx Target Values ?

Actual BAT NOx limits for Reheat furnaces:

≤ 80-200mg/Nm³ @ 3% O_2 new plants

≤ 100-350mg/Nm³ @ 3% O_2 existing plants

Many existing reheat furnaces are emitting **higher values**

Country and plant specific requirements may limit NOx emissions of existing furnaces below **200mg/Nm³ @ 3% O_2**

Abstract from BAT for reheating furnaces*

Parameter	Type of fuel	Specific process	Unit	BAT-AEL (Daily average or average over the sampling period)	Indicative emission level Daily average or average over the sampling period)
NO_x	100 % natural gas	Reheating	mg/Nm³	New plants: 80 –200 Existing plants: 100 –350	No indicative level
		Intermediate heating	mg/Nm³	100 –250	
		Post-heating	mg/Nm³	100 –200	
	Other fuels	Reheating, intermediate heating, post-heating	mg/Nm³	100 –350 (31)	
CO	100 % natural gas	Reheating	mg/Nm³	No BAT-AEL	10 –50
		Intermediate heating	mg/Nm³		10 –100
		Post-heating	mg/Nm³		10 –100
	Other fuels	Reheating, intermediate heating, post-heating	mg/Nm³		10 –50

(*) Commission Implementing Decision (EU) 2022/2110 of 11 October 2022

New SMS RADFlame HY2

Why radiant burners?

Side burner are now the preferred choice thanks to their flexibility and Extra Low NOx emissions BUT **radiant roof burners** are used in many existing reheating furnaces.
New radiant burners designed to:

reduce **NOx emissions** of existing furnaces

reduce **carbon emissions** of existing furnaces thanks to hydrogen ready technologies

New SMS RADFlame HY2

Targets of this development

Targets of the new SMS RADFlame HY2 development:

- guarantee Low NOx emission in any working condition
- the burner could be installed in existing furnaces without modification to the furnace roof, or the combustion system or the automation system (no additional valves, no higher combustion air pressure…)

when no change of throughput or fuel is expected, the burner replacement shall not be considered a substantial modification to the existing furnace -> no need of issuing a new CE certification

- capability of running with Natural gas and Hydrogen blend up to 75% Hydrogen

1 Introduction: why Radiant burners?

2 Design and CFD analysis

3 Experimental trials

4 Conclusions

Design and CFD analysis

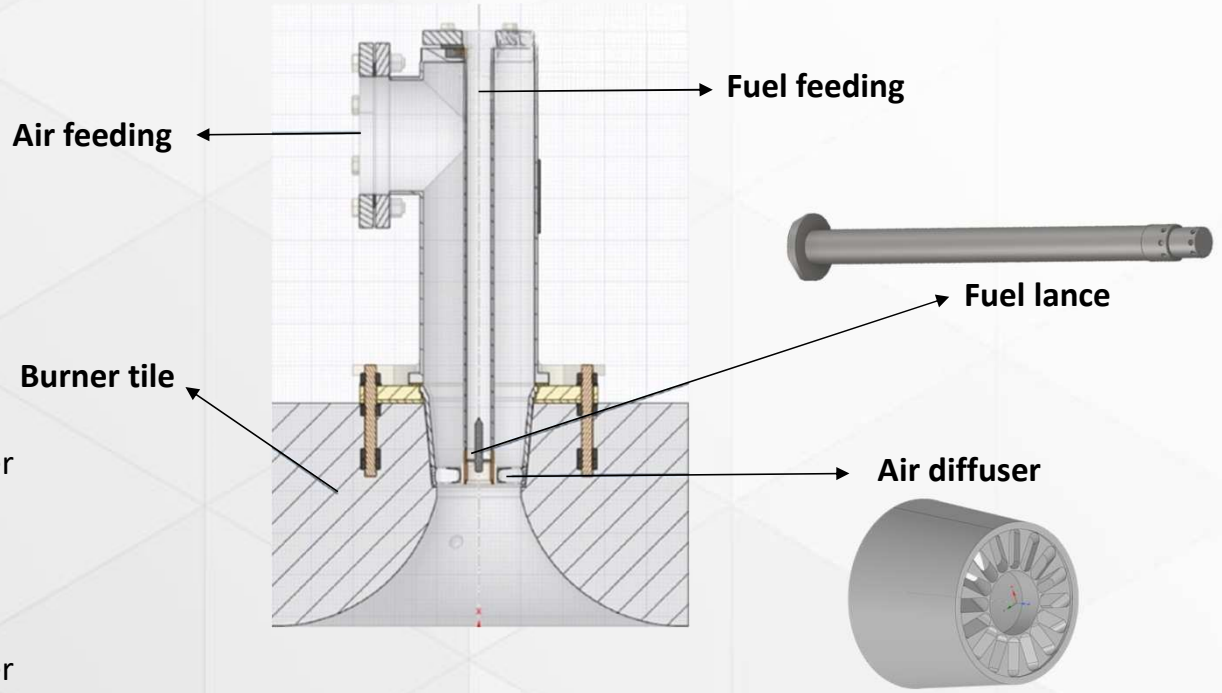
Variables and configurations

Target of CFD:

Predict the flame thermal and chemical behavior

Select the most promising geometries

Reduce the number of prototypes to be built



Key aspects for SMS RADFlame HY2 development:

1) Comburent air diffuser:

   optimize the air-fuel mixing in the furnace chamber

   minimise the air pressure drop

2) Fuel lance geometry:

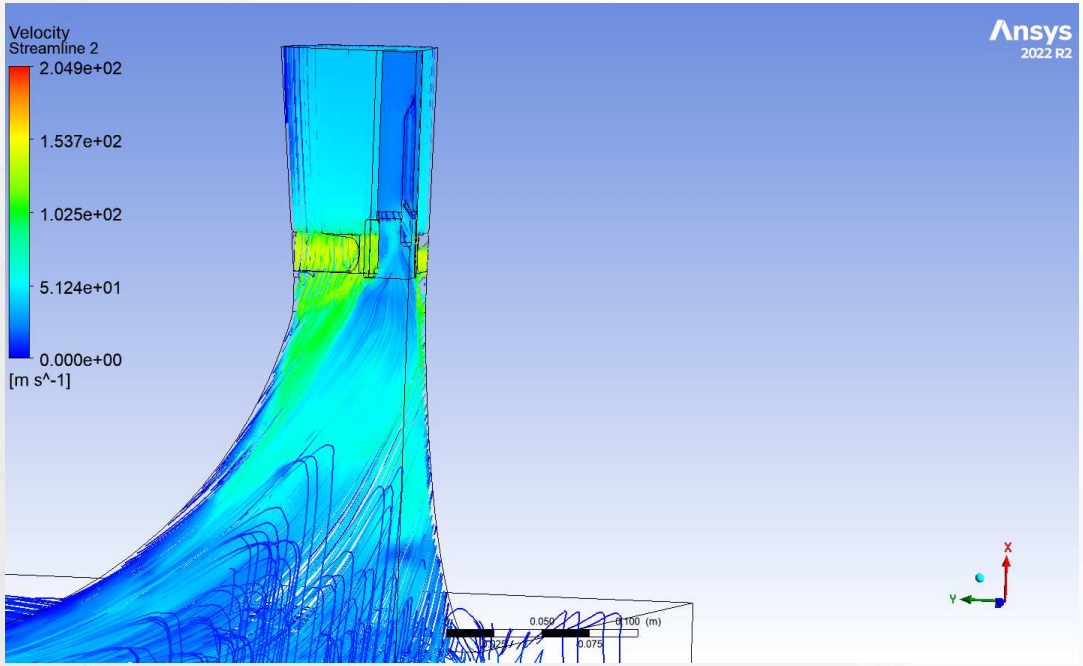
   optimize the air-fuel mixing in the furnace chamber

→ right compromise between **flame stability** and **low NOx emissions**

CFD simulations of the prototype

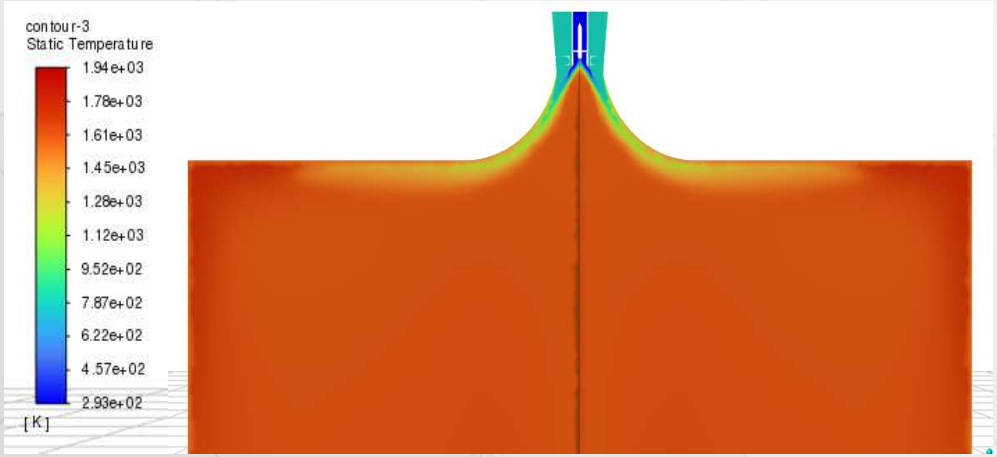
Development process of the prototype

Optimised degree of **air-fuel mixing** thanks to air diffuser and fuel lance **geometry**

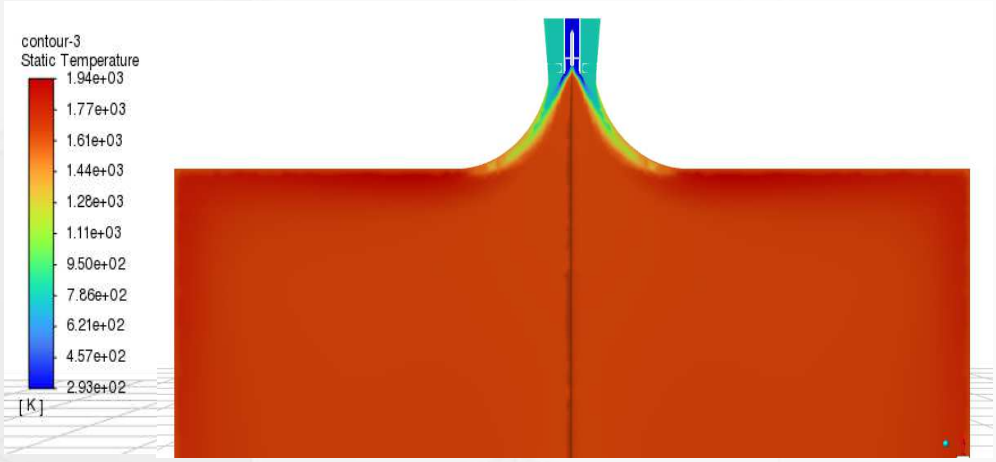


Design and CFD analysis

Temperature distributions



100%vol. NG



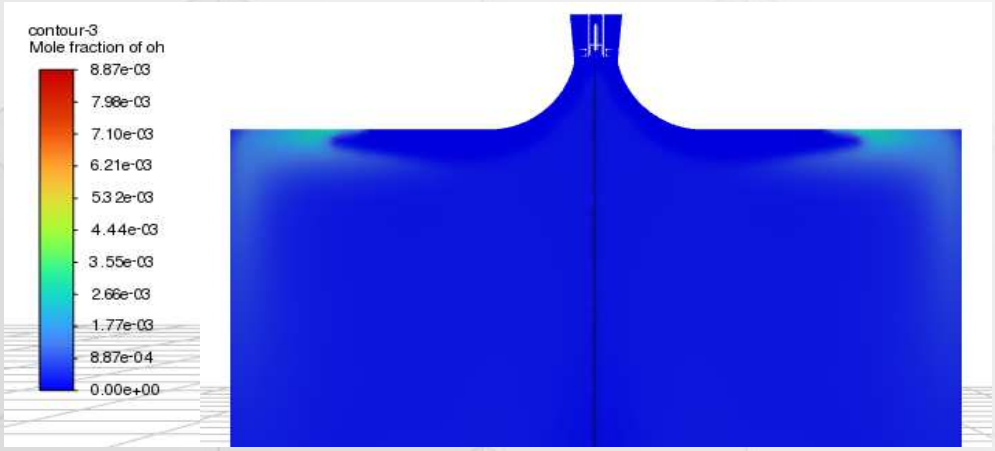
50%vol. NG, 50%vol. H_2

CFD shows a **temperature increase** with increasing **H_2** content in the **NG-H_2** fuel blend

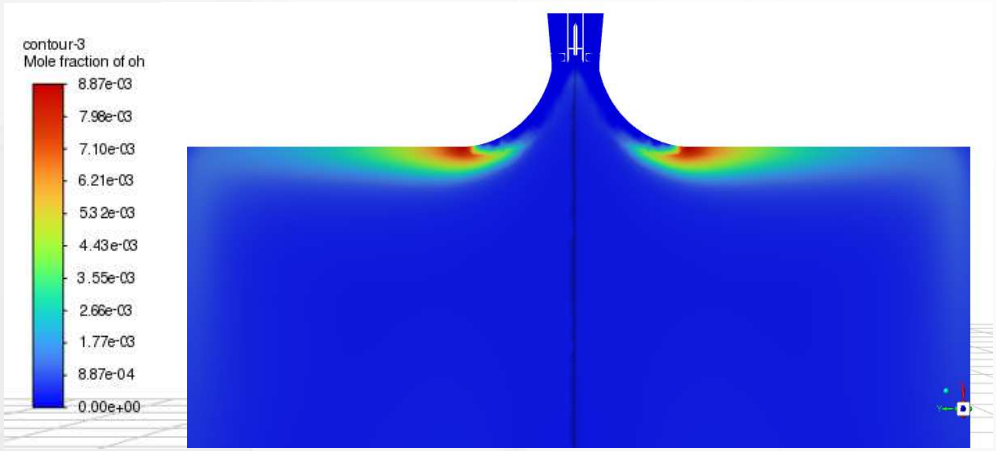
The calculations are **not coherent** with the experimental results

Design and CFD analysis

OH radical distributions



100%vol. NG



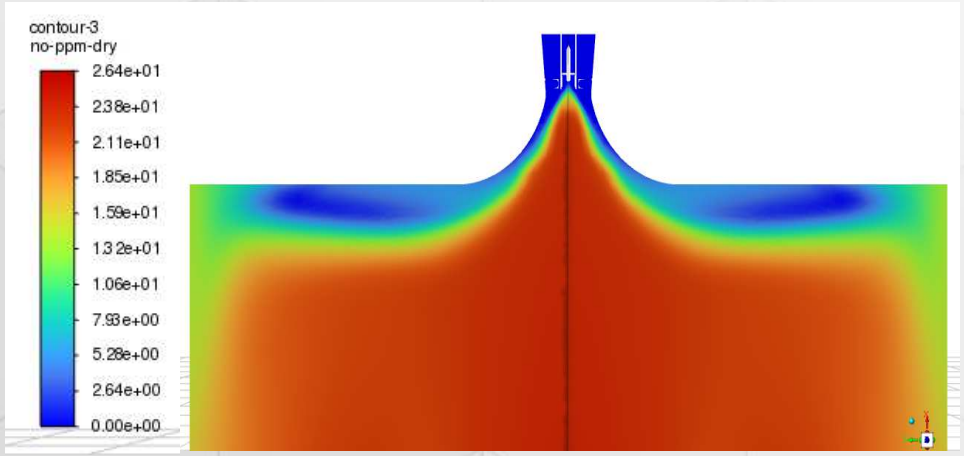
50%vol. NG, 50%vol. H_2

CFD shows a flame shortening with increasing H_2 content in the NG-H_2 fuel blend

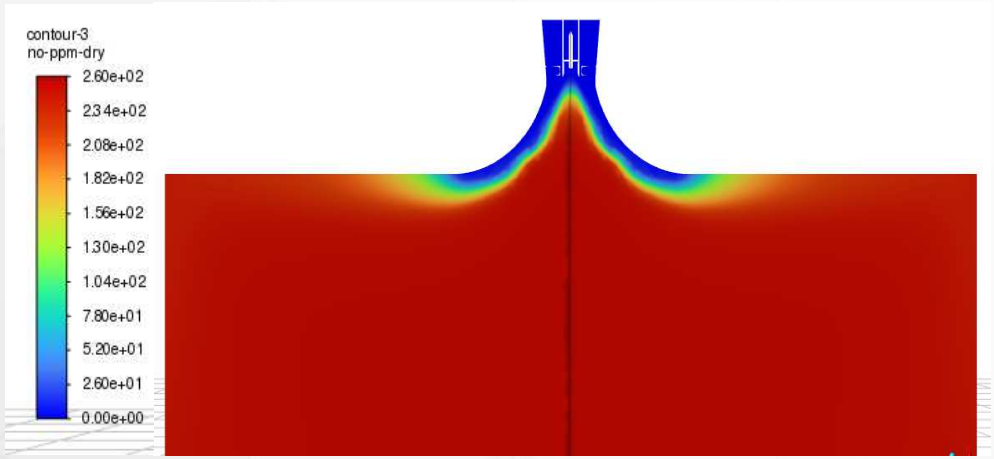
The calculations are **not coherent** with the experimental results

Design and CFD analysis

NOx distributions



100%vol. NG



50%vol. NG, 50%vol. H_2

CFD shows a NOx increase of approx. 10 times with NG/H2 blend (50%-50%) compared to full NG

The calculations are **not coherent** with the experimental results

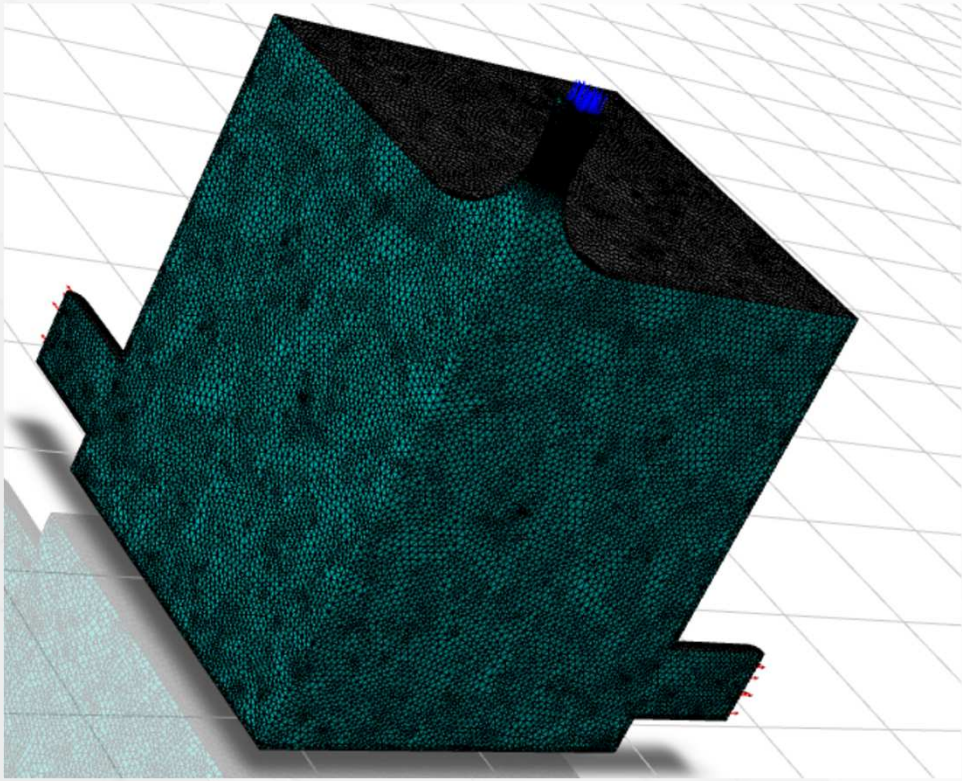
Main outcomes of CFD analysis

CFD analysis was used to study the behavior of **SMS RADFlame HY2** prototype, comparing the cases of **50%vol. H_2-50% vol. NG** with **100%vol. NG**

Higher furnace chamber temperature

Flame shortening

Approx. 10 times increase of NOx emissions



1 Introduction: why Radiant burners?

2 Design and CFD analysis

3 Experimental trials

4 Conclusions

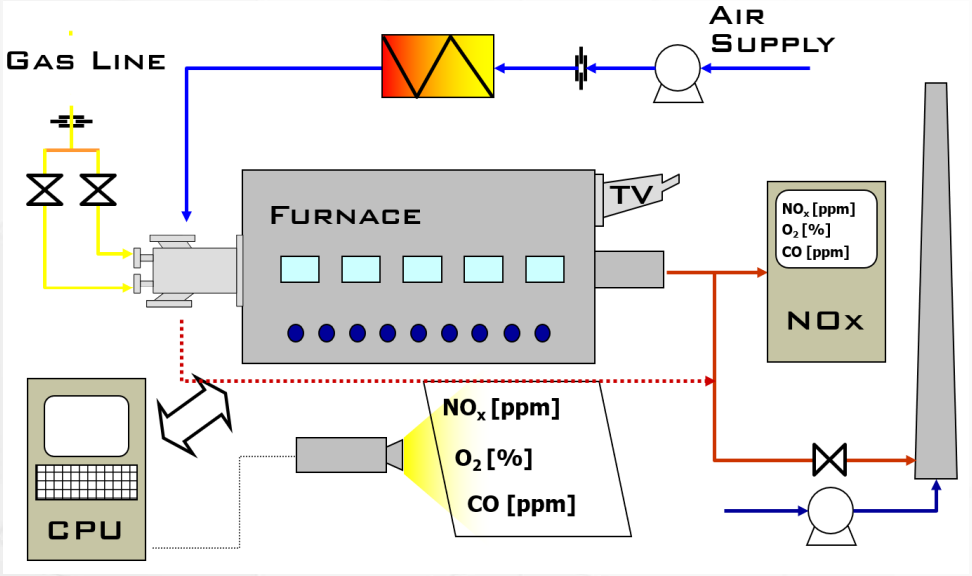
Experimental activities

RINA-CSM Experimental Station for Combustion Studies, Dalmine (BG), Italy

MEASURMENTS AND SENSORS

1. Fuel: NG and SYNGAS (any composition)
2. Max fuel flow rate:
   - 300 Nm^3/h of NG,
   - 2000 Nm^3/h SYNGAS
3. Max air flow rate: 3000 Nm^3/h
4. Air preheater: max temperature 550 °C
5. Pollutants monitoring and recording: O_2, CO, CO_2 and NOx
6. Control system of furnace
7. Flow rate, pressure and temperature monitoring and recording
8. Continuous video monitoring

Length (internal)	[m]	3 – 7.5
Cross Section	[mm] x [mm]	2000 x 2000
Maximum Burner Capacity	[$MW_{gas\ based}$]	3
Maximum NG Flow Rate	[Nm^3/h]	300
Maximum Syngas Flow rate	[kg/h]	2000
Maximum Air Flow Rate	[Nm^3/h]	3500
Maximum Working Temperature	[°C]	1250
Thermocouples for measuring longitudinal temperature profile along burner axis;		
Pollutants Monitoring system for O_2, CO & NOx;		
Computer Controlled System		
Continuous Video Monitoring		



All the steps of the experimental activity on the SMS RADFlame HY2 were performed at the RINA-CSM Combustion Lab in Dalmine (BG), Italy

Experimental trials

Test rig and Design of Experiments

Conditions of experimental trials (<u>targets</u>):

Different % of H_2 in the NG-H_2 fuel blend (up to 75%vol.)

Different pre-heated air conditions

Different turn-down ratios

Different furnace chamber temperatures

O_2 excess in furnace chamber (1, 2 and 3%)

<u>Object of this work:</u> T_furnace= 1150 °C, T_pre h. air= 450 °C, full rating, 1%vol. O_2 excess in the flue gases

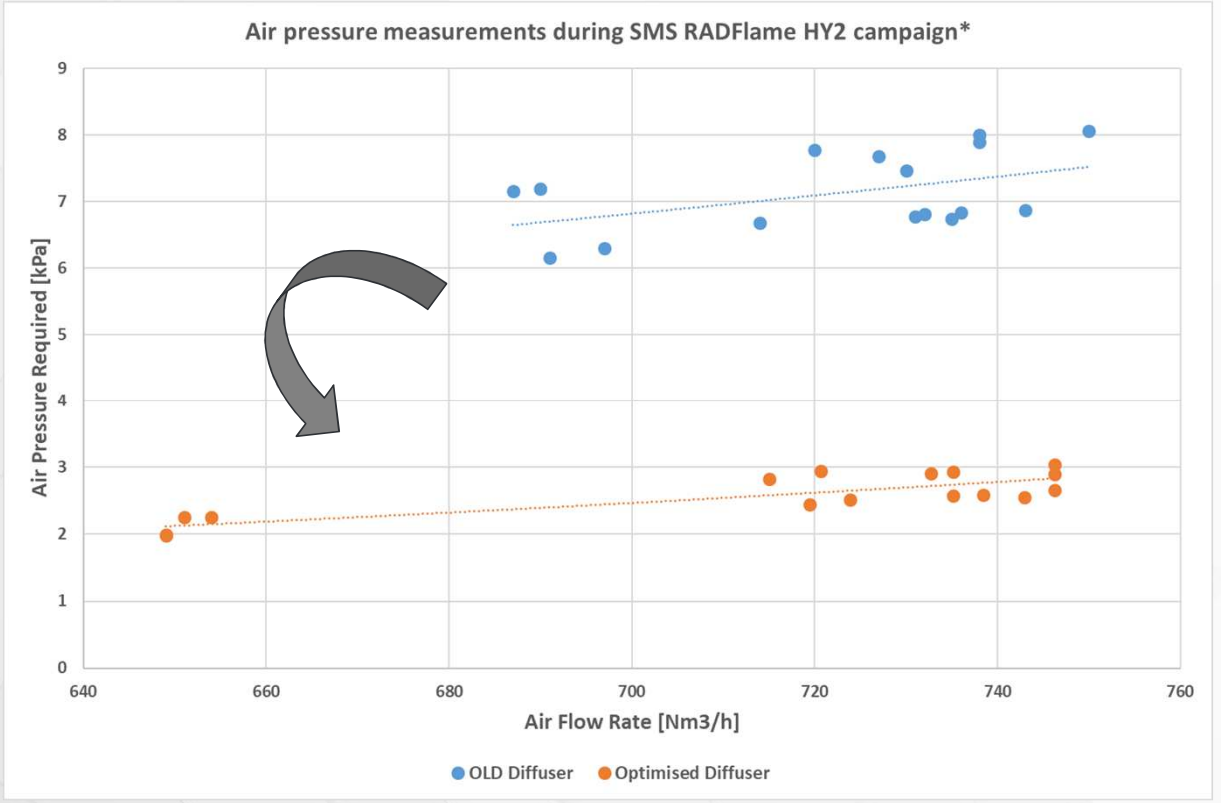
Measurements:

- emissions: NOx, CO
- air and fuel supply pressure, temperature and flow rates
- furnace temperature

RINA-CSM Experimental Station for Combustion Studies, Dalmine (BG), Italy

Experimental campaign of the SMS RADFlame HY2

Combustion air pressure drop

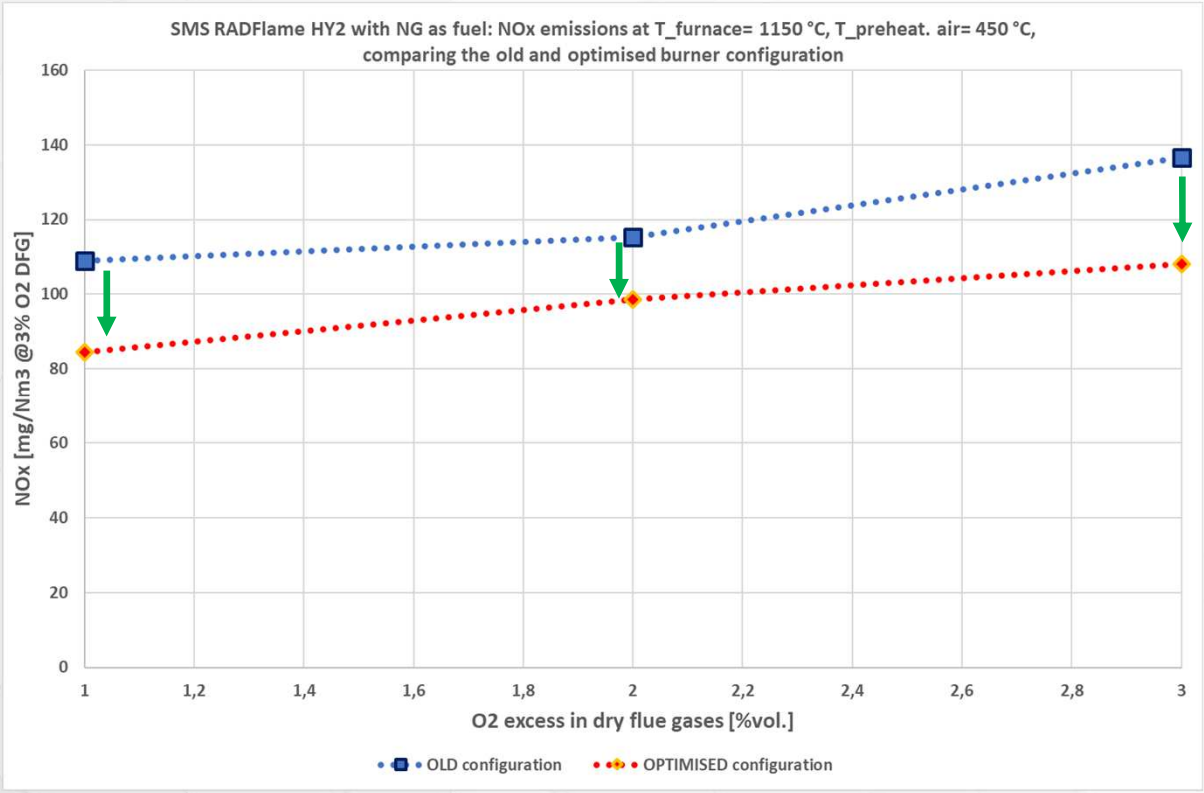


Combustion air pressure consistent with the majority of existing furnaces, and reduced variability with the working conditions of the furnace

* normalized @ 3% O2 DFG with T_furnace= 1150 °C, T_preheat. air= 450 °C, full rating, NG-H2 fuel blend with H2 content up to 75%vol.

Experimental campaign of the SMS RADFlame HY2

Results- 100% NG

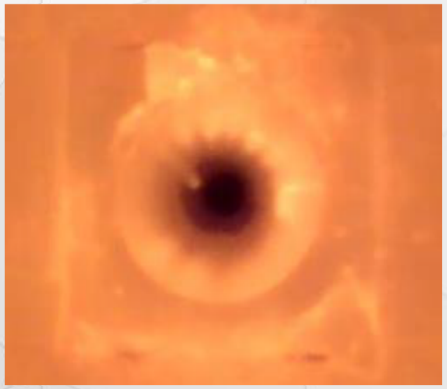


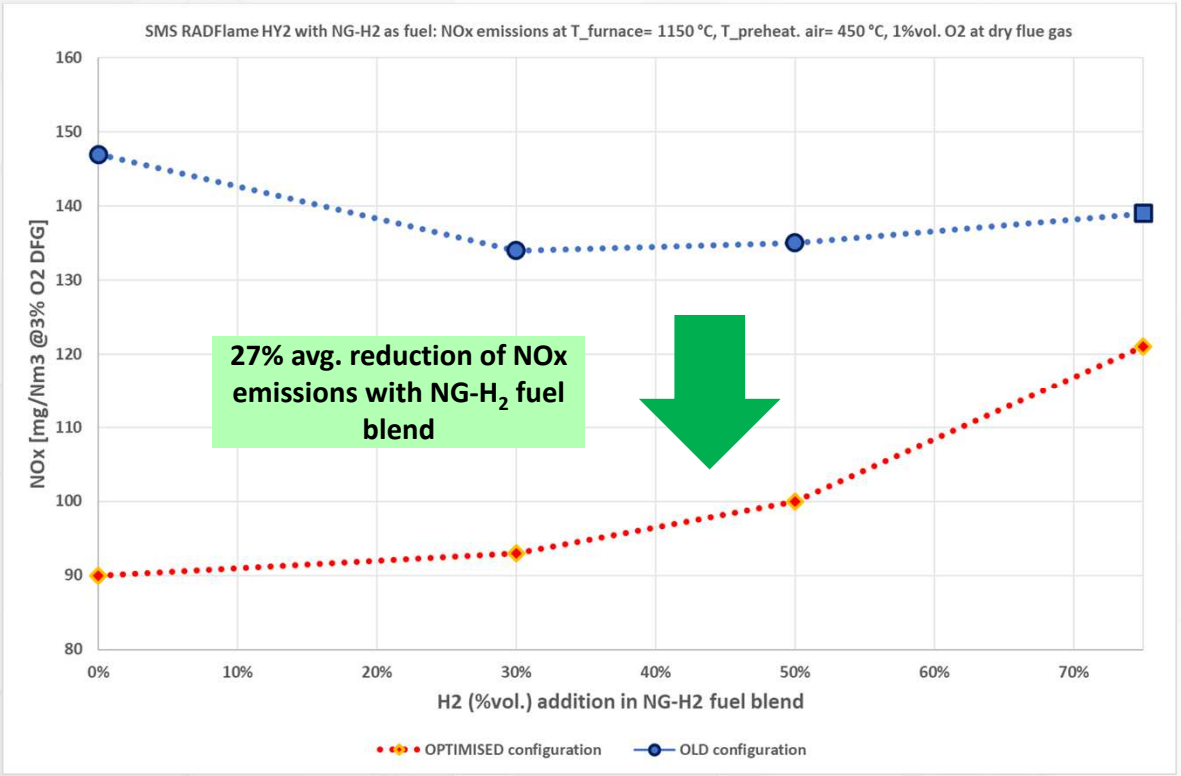
25% av. reduction of NOx emissions with NG, with 90 mg/Nm3* at 1% O_2 DFG

(*) normalized @ 3% O2 DFG with T_furnace= 1150 °C, T_preheat. air= 450 °C, full rating, 100%vol. NG

Experimental campaign of the SMS RADFlame HY2

Results- NG/H_2 blends





NOx emissions below 120 mg/Nm³ * for any NG/H_2 blend up to 75%vol. H_2

(*) normalized @ 3% O2 DFG with T_furnace= 1150 °C, T_preheat. air= 450 °C, 1% O2 @ DFG, full rating, NG-H2 fuel blend with H2 content up to 75%vol.

1 Introduction: why Radiant burners?

2 Design and CFD analysis

3 Experimental trials

4 Conclusions

Outcomes of the SMS RADFlame HY2 development process

SMS RADFlame HY2 can be easily installed in **existing furnaces**:
- burner tile can be **customized**
- **no need of additional valves and automation adjustment**
- **no need of increased air pressure**

SMS RADFlame HY2 with full NG can guarantee a low NOx emission of **90 mg/Nm^3** *

Emissions slightly increase at lower rating and higher furnace chamber temperature

Emissions slightly increase with the hydrogen content but are **below 120 mg/Nm^3 with 75%vol. H_2** *

CFD allowed to develop a **strong and reliable** tool for burner development, while the predictions regarding combustion were more valuable for identifying **trends**, rather than detailed values

(*) normalized @ 3% O2 DFG with T_furnace= 1150 °C, T_preheat. air= 450 °C, 1% O2 @ DFG, full rating

Thank you

Tommaso Bortolussi

Process & Technology, SMS group S.p.A.

Reheating Furnaces and Heat Treatment Plants

Tommaso.Bortolussi@sms-group.com

Irene Luzzo

Laboratory Responsible, RINA Consulting – CSM S.p.A.

Lab Combustion Station

Irene.Luzzo@rina.org