Innovative and Efficient Technologies for Industry

Clotilde Villermaux
GDF - SUEZ (DRI / CRIGEN)

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What priorities for R&D on industrial gas uses today ?

- To remain at a level consistent with high prices and volatility
  - It's the worst time to reduce R&D efforts on industrial energy uses

- To meet the issues of industrials users
  - Compromise between **flexibility and global efficiency** of industrial tools
    - to adjust production level vs. energy prices
    - to allow arbitrages between energies
  - To suppress plant bottlenecks
  - To adapt industrials plants **to environment constraints**
    - in order to match regulation
    - and face opportunities and risks from CO_2 markets

For all these issues the key word is **flexibility**

➔GDF SUEZ has launched R&D projects to develop **energy-efficient solutions** that comply with the **problem of global warming**, directly linked to the energy consumption

INNOVATIVE FLAMELESS REGENERATIVE BURNERS FOR DIRECT FIRED FURNACES ON HOT DIP GALVANIZING LINES

-

UP TO 15% LINES PRODUCTIVITY INCREASE

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What is a continuous galvanizing line ?

WHY IS STEEL GALVANIZED ?

Objective: to protect actively the steel against oxidation

Way & Mean: Many protective forms exist: varnish, paints, organic coatings, … but the most efficient and stable is the deposit of ZINC layer. That is the coating layer which will suffer the oxidation (very low oxidation kinetic towards the Fe oxidation kinetic)

Advantages: the steel pieces are easy to press (specific forms). Aesthetic qualities.

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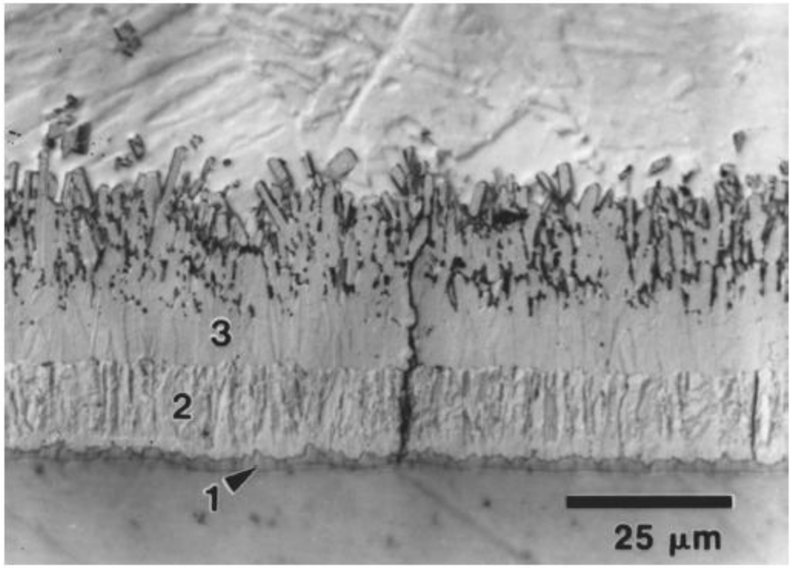

Fig. 8. Microstructure of Zn coating formed after 300 s immersion in a 450°C, 0.00 wt% Al bath on a ULC steel substrate. (1) gamma (Γ) phase, (2) delta (δ) phase (3) zeta (ζ) phase.

PROCESS :

→ Continuous annealing thermal treatment (Strip T ~ 850-950° C)

→ Zinc coating deposit through a liquid zinc bath (Tbath ~ 460° C). An intermetallic appears between the steel (substrate) and coating so that the adherence is ensured. Control of the Coating thickness through the wiping section.

→ Coating solidification & final surface treatment (chromatation, organic coating,…)

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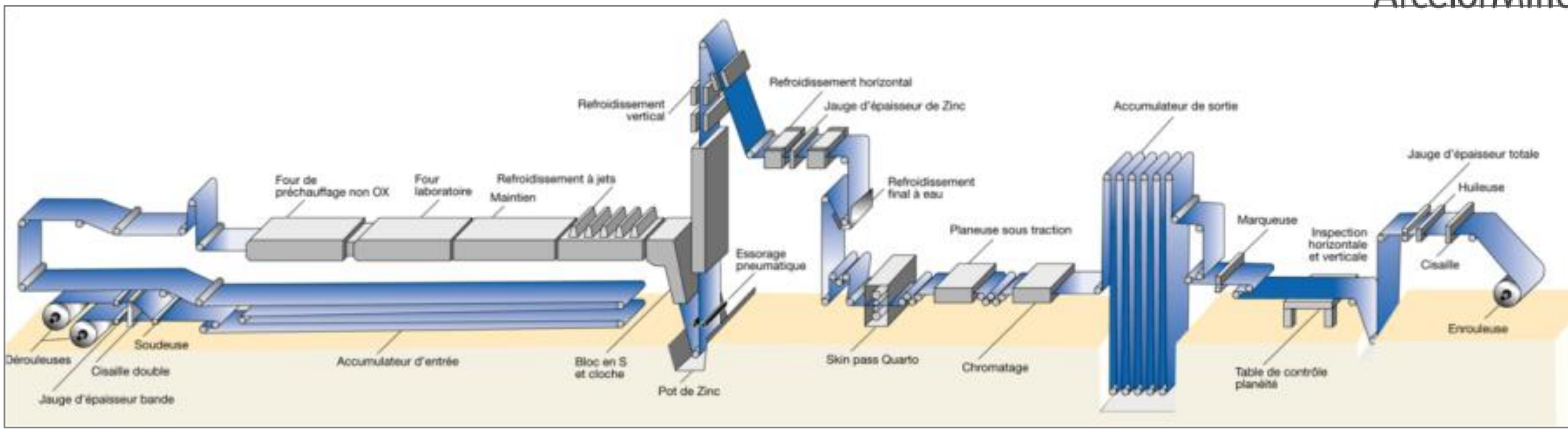

Line entry --→ Line exit

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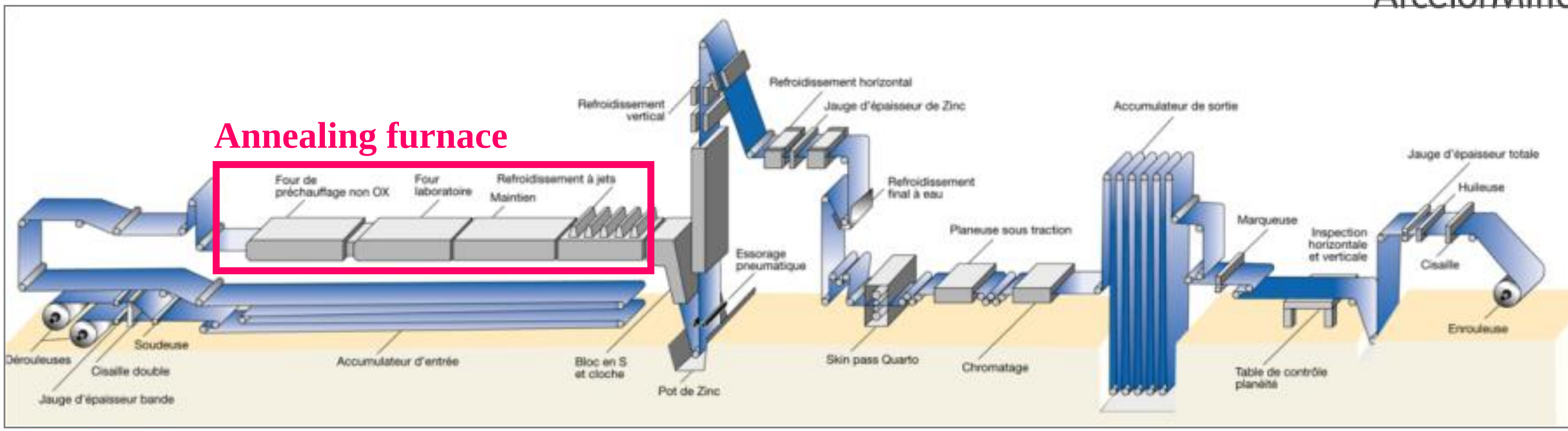

Line entry -► Line exit

Key Process :

The key processes of galvanizing lines are:

→ the **annealing treatment** occurring into the annealing furnace,

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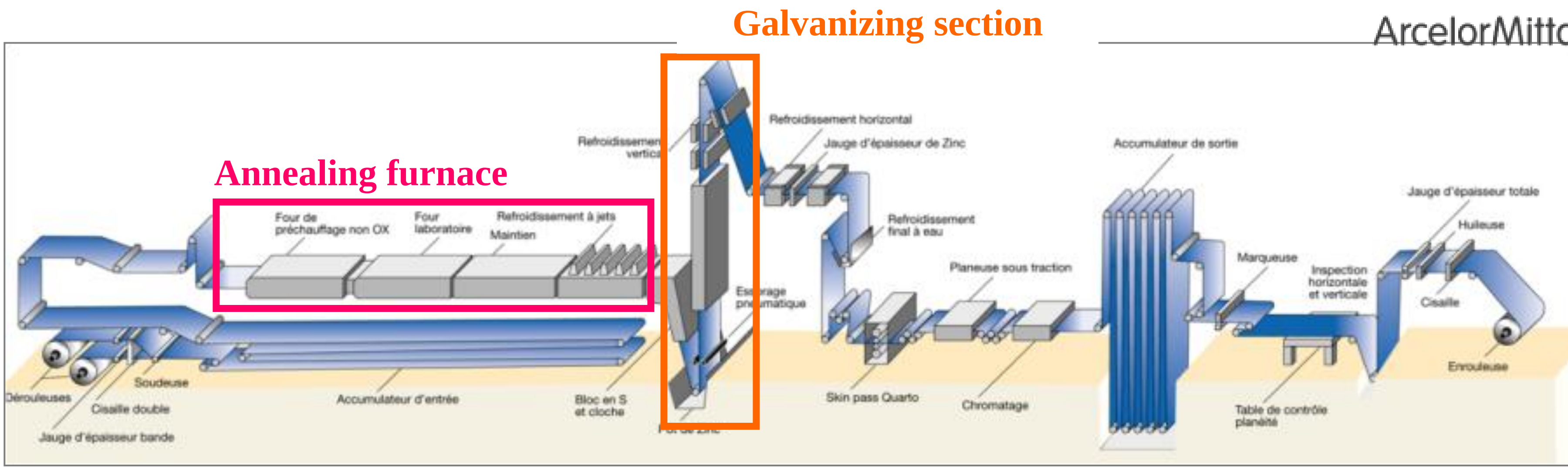

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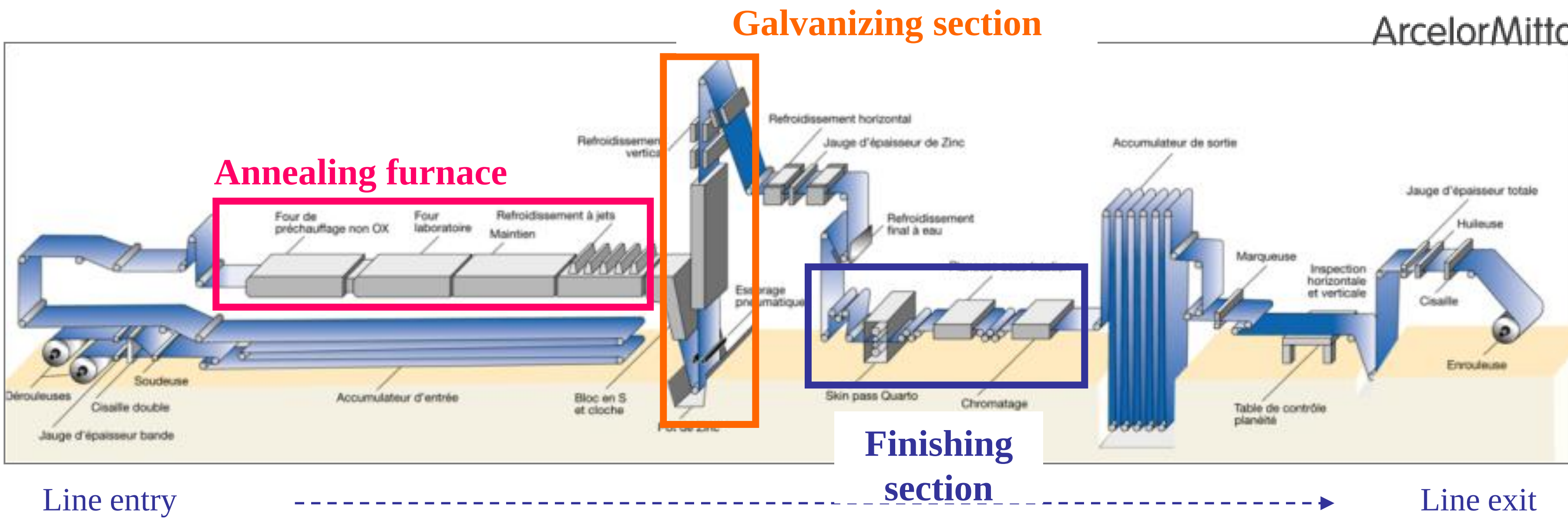

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→ the **finishing section**

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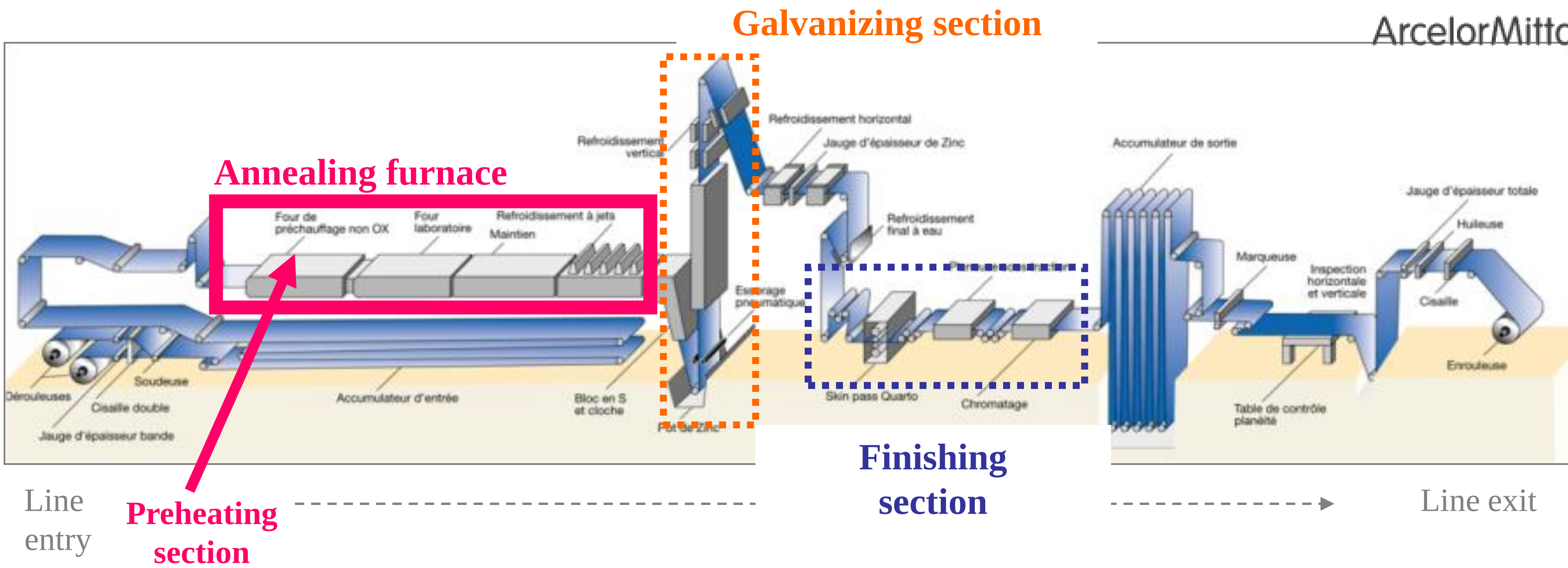

The annealing furnace :

The preheating section, the heating section, the soaking zone and the rapid cooling section make up the annealing furnace. Most of the strip heating occurs into the preheating section.

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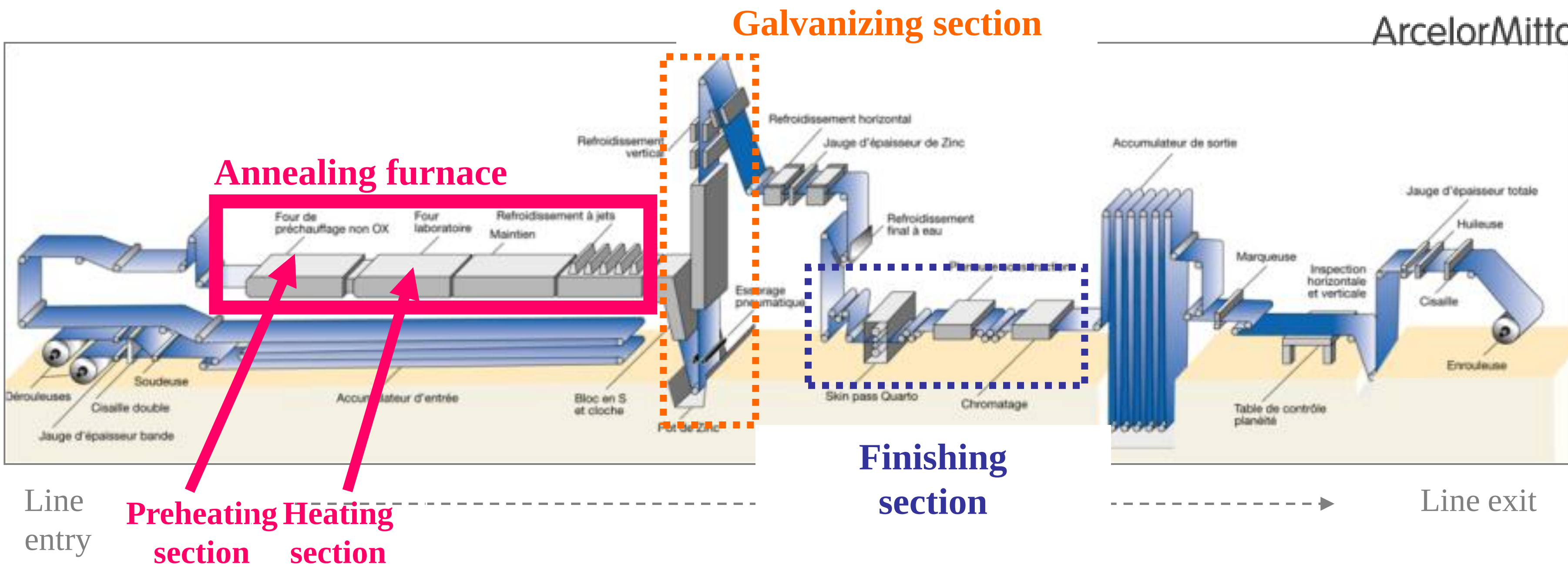

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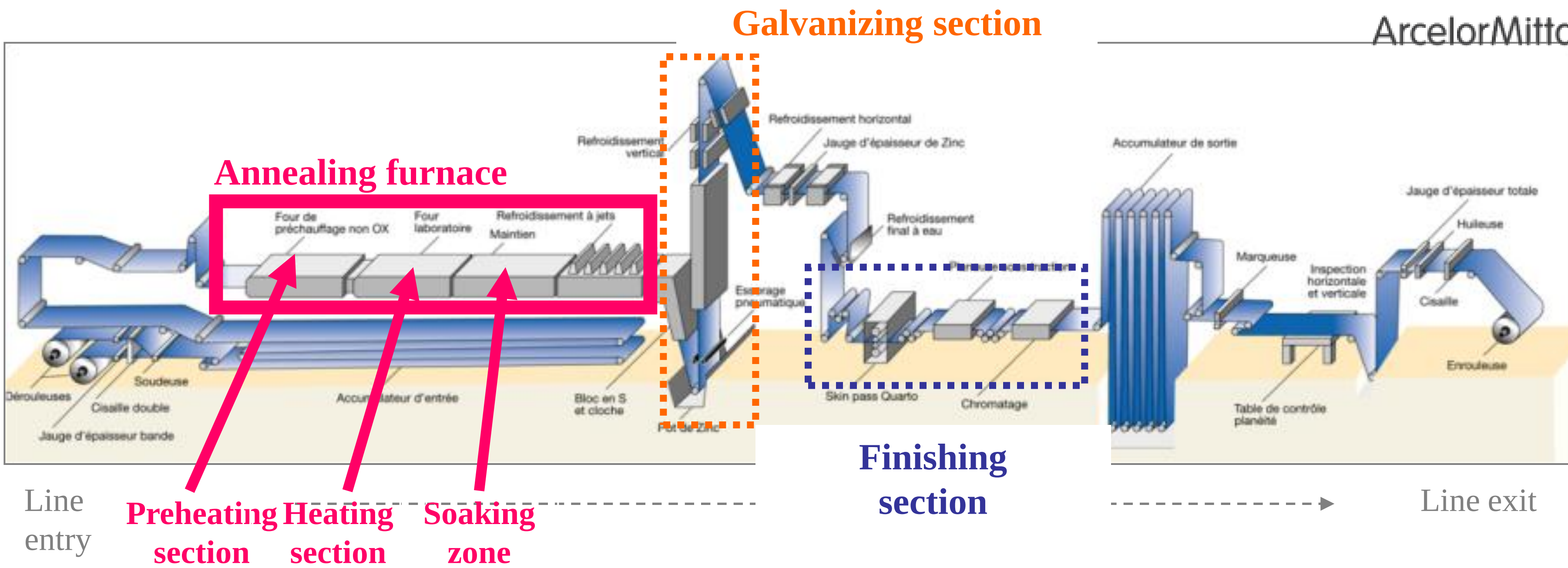

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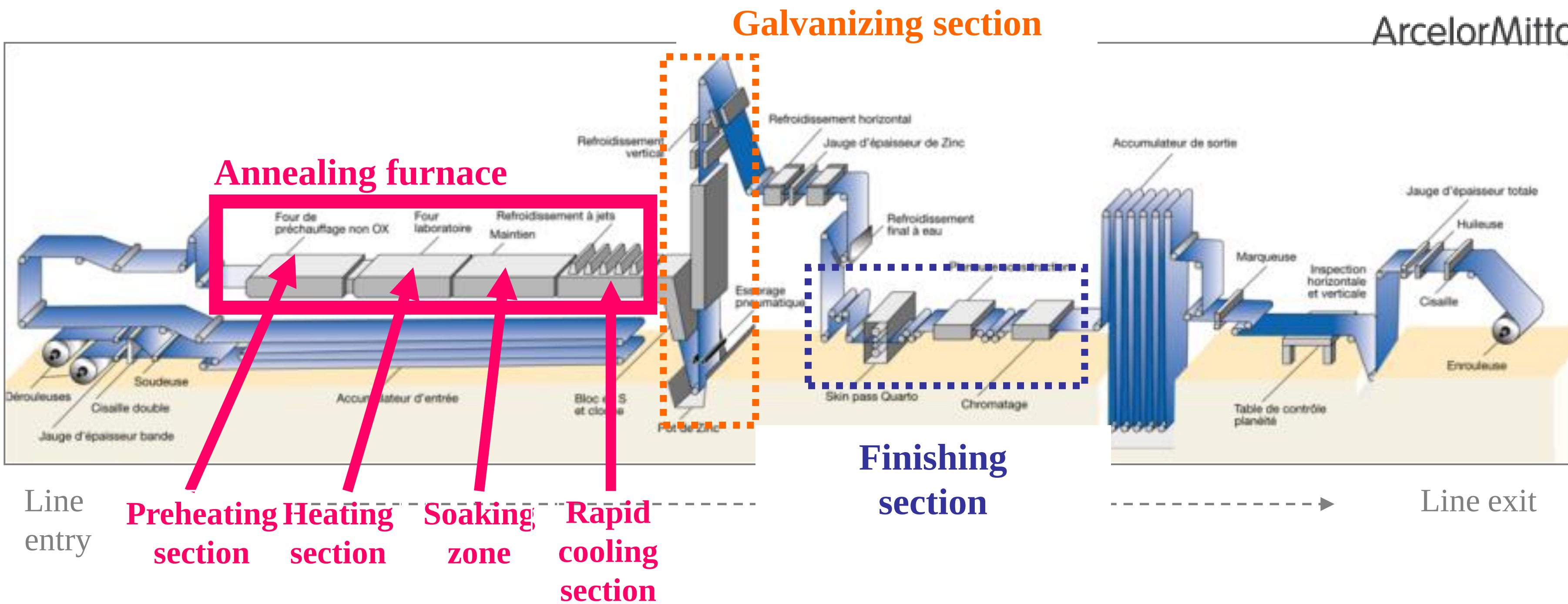

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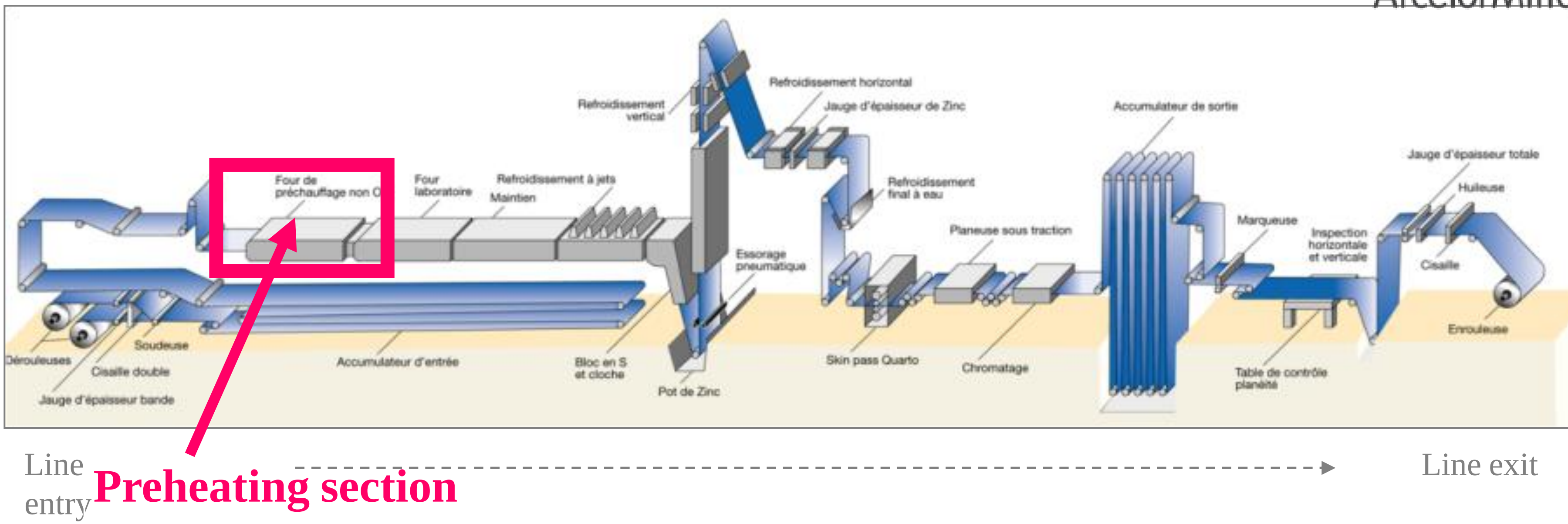


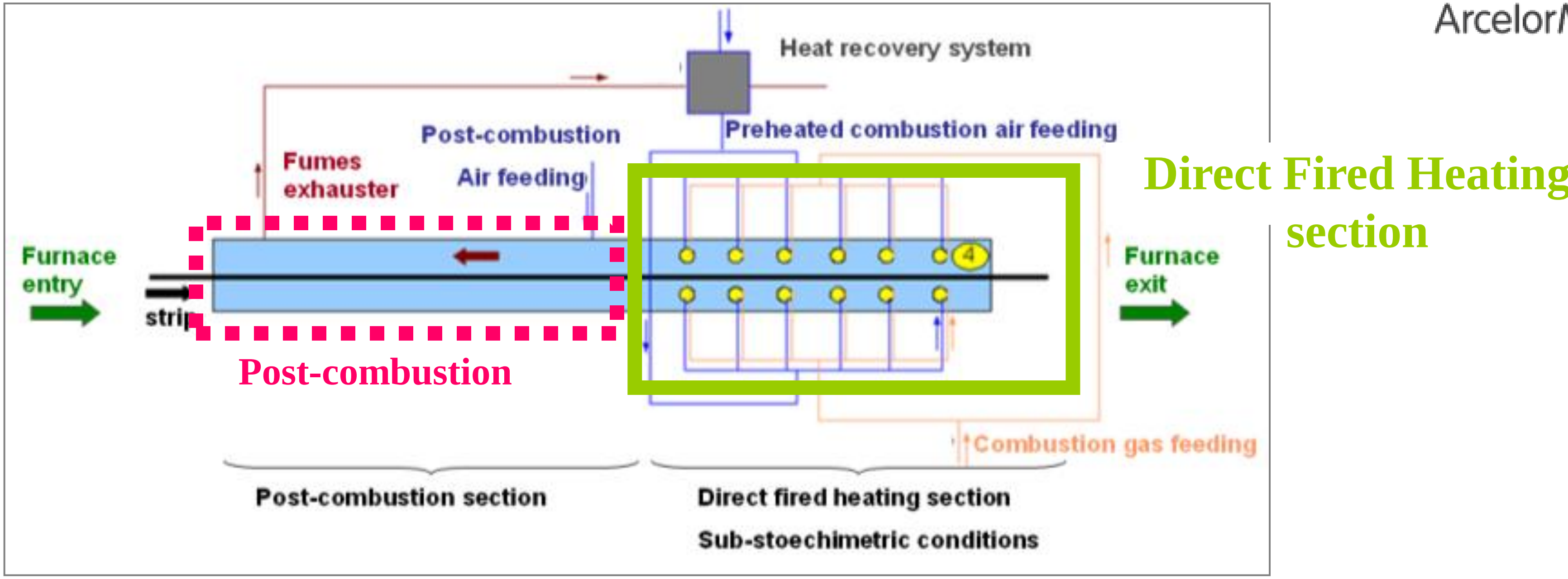
The direct flame furnace (DFF) :

Hot dip galvanizing lines are equipped with preheating sections (Tstrip: 25° C to 750° C). 2 kinds of preheating sections:

→ **Direct Fired Furnace** – the heating burners are direct flame burners

→ Radiant Tube Furnace - the burners are introduced into radiant tubes. The strip is heated through the tubes radiation.

What is a direct flame furnace ?



The direct fired furnace (DFF) :

The direct fired section is divided in 2 zones:

→ a **post-combustion section** (for residual gas power recovery to start the preheating of the strip)

→ a **heating zone** equipped with **direct fired burners** managed with **sub-stoechiometric gas combustion conditions**

Most of the time, for energy efficiency issues, there is a heat recovery of fumes for air preheating (up to 450° C)

Why innovative burners for the DFF section?

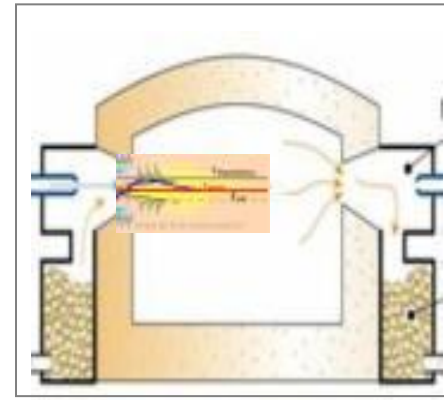
Industrial needs :

→ **Strong demand on the markets** for **high added value steel grades** like the hot stamping "Usibor" grade (automotive & industry applications)

→ **Respect** of **strip surface oxidation kinetics** and **oxide nature**

→ Identified lines require corresponding **productivity increase**

→ **Direct fired furnace preheating section encountered bottlenecks issues** to increase their productivity thanks classical heating power boosting (initial nominal condition design)



Technological solution:

→ **Regenerative burners** adapted to the **sub-stoechiometric combustion** conditions

→ existing heating power kept identical (few additional fumes for existing exhauster and heat recovery system)

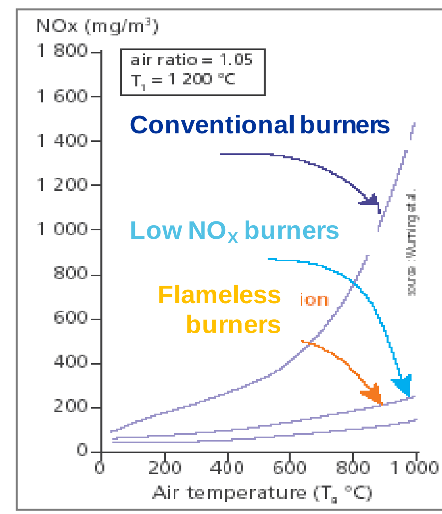
→ **strong heat efficiency** thanks high preheated combustion air (~1000° C vs ~450° C for classical solutions)

→ **energy savings** & production costs reduction (in case of identical productivity ratio)

→ **productivity increase** (in case of identical energy consumption)

→ **Flameless combustion for homogeneous heating**

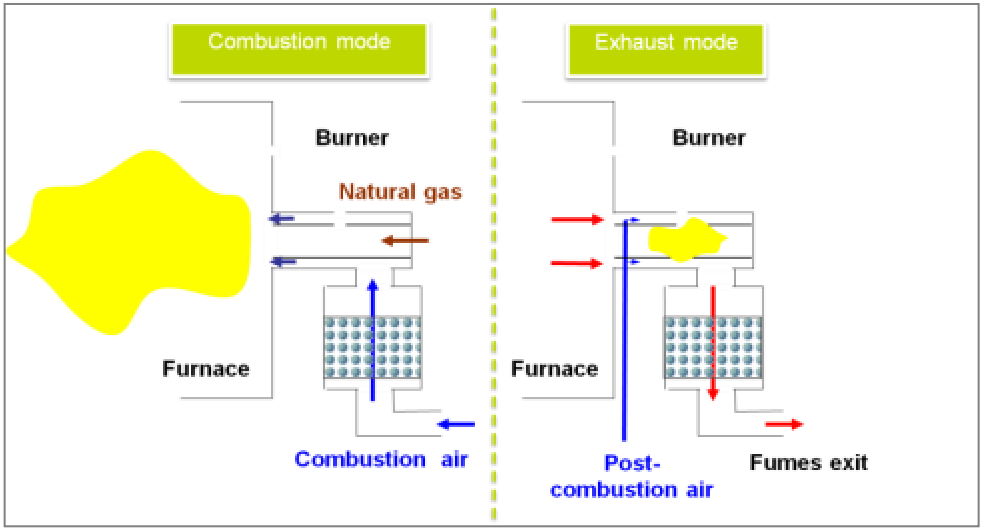
→ **Pollutants emission mastered** (NOx)



Flameless regenerative burners adapted to direct fired furnaces

- The **innovative burning technology** dedicated to non-oxidizing heating atmospheres consists on a combination of :
  - a **regenerative system** and
  - a **flameless combustion technology**.
  - **an integrated post-combustion system**

  → **Fumes in the DFF section are products of sub-stoechiometric gas combustion, with residual gas power**



Schematic working principle of regenerative burners

- The **association of those three principles** should allow meeting the following requirements
  - to guarantee a **complete combustion** at the furnace exit
  - to lead to **high energy efficiency** (all residual gas power recuperated within the burner → maximum temperature air preheating)
  - to achieve **a cleaner process** (NOx & CO emissions)
  - to obtain an **homogeneous heating temperature**

Three complementary work axes to prepare a demonstration operation on a ArcelorMittal plant

- To answer these questions, the project was set-up following **three work axes**:
  - **Experimental characterization of the combustion efficiency and the gas atmosphere** generated within an semi-industrial scale furnace, optimization of operating conditions;

Burner test
-**Atmosphere characterisation**
-**Operating condition optimisation**

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Laboratory facilities
Steel quality qualification

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  - Based on previous results, **impact of the generated gas atmosphere to the steel surface**
  - **Evaluation of the energy savings**, the **environmental impact** and **costs savings** for specific ArcelorMittal hot dip galvanizing lines with dedicated numerical tools

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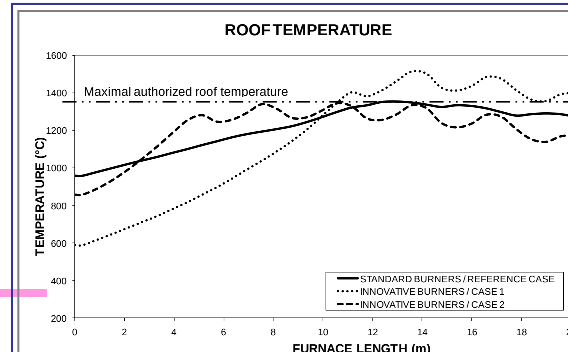


Full scale numerical tool

-Best implementation of the technology

-Expected gains / baseline

Innovative burner's design and optimization of high efficient regenerative solution

- **Reference case : Hot Dip Galvinizing line A of ArcelorMittal**

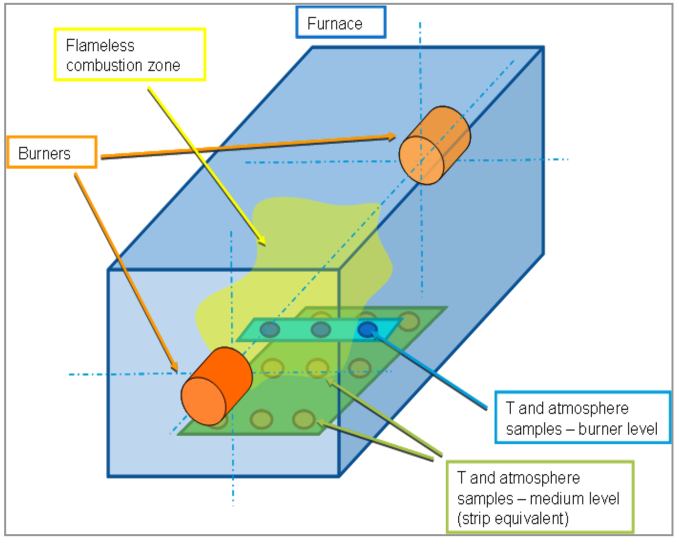
- **Parametric study in the semi-industrial furnace of GDF SUEZ**
  - **Prototype burner** gas power input (from 100 to **400 kW**),
  - Furnace temperature (up to **1300°C**),
  - Air gas ratio in the furnace (from **0.85 to 0.95**),
  - Oxygen content in fumes after regenerator (from 0.5% to few %),
  - Regenerative burner cycling time (from **1 to 2 min**),
  - Extraction rate of fumes inside the regenerator (from 50 to **90%).**

- **Criteria for the technology evaluation and operating parameter optimisation**
  - **Burner stability**, for ignition and nominal use of the technology
  - **Energy efficiency** of the technology
  - **NOx and CO emissions**
  - **Impact on the strip quality**

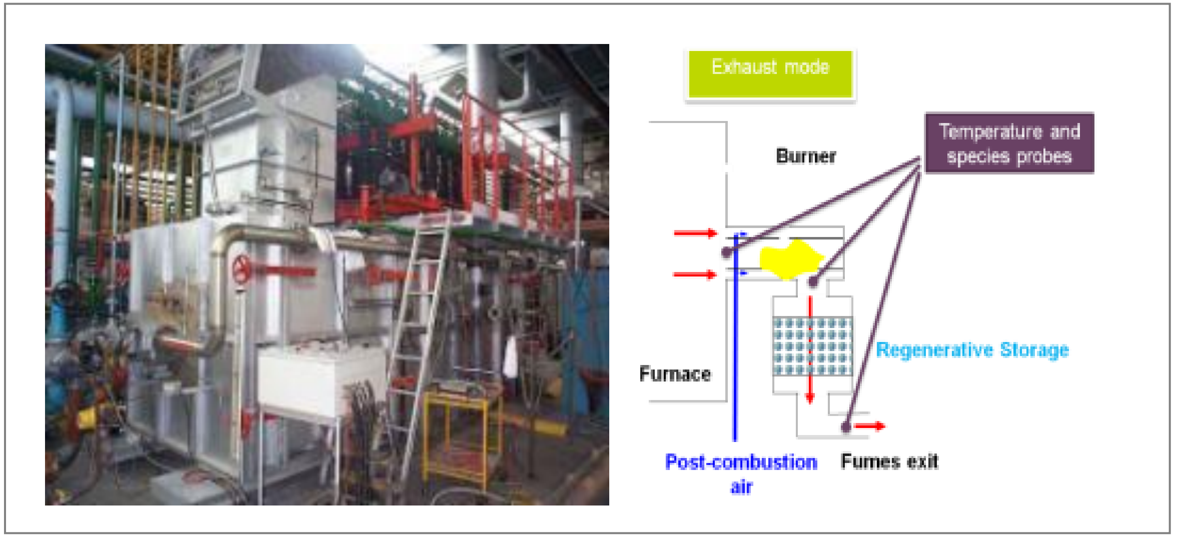
Semi-industrial scaled pilot facility to optimize the combustion parameters

A **500 kW furnace** has been designed and set up at GDF SUEZ Research Centre

- **representative of metallurgy processes** (up to 1350°C)
- One specific parameter varies while keeping constant the other operating conditions
- **Every relevant parameter such as combustive temperature, input power, air ratio can be separately controlled**



Schematic view of the species characterization into the semi-industrial cell



Schematic of the species contents and T measurements

These experimental data have been used

- to characterize the **energy and environmental performances** of the burner
- for the **validation of the numerical tools**

Encouraging and suitable results for industrial use

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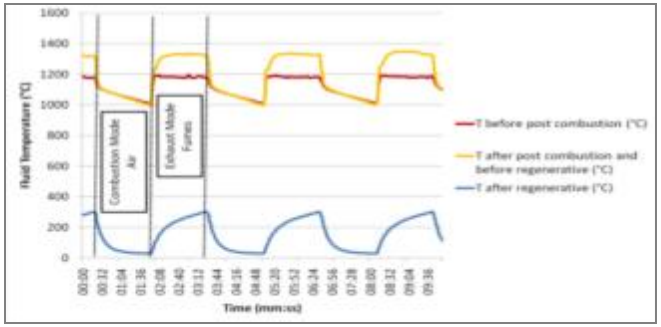
  - 1000°C preheated air, exhaust fumes temperature at around 250°C. increase by more than 150°C because of the post-combustion heat.



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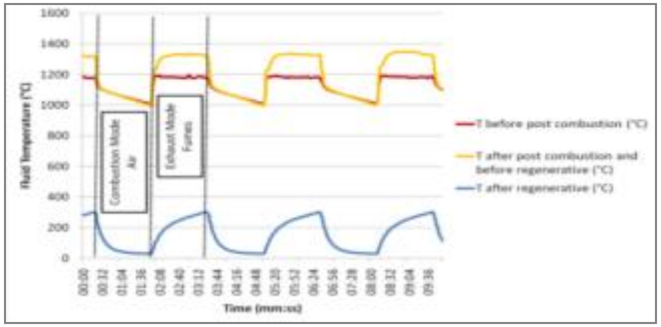

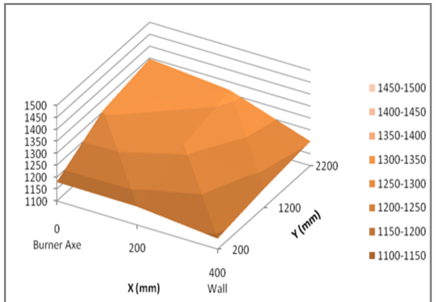

temperature field close to the strip

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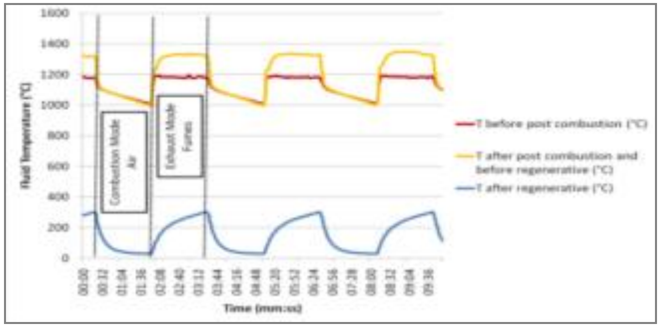
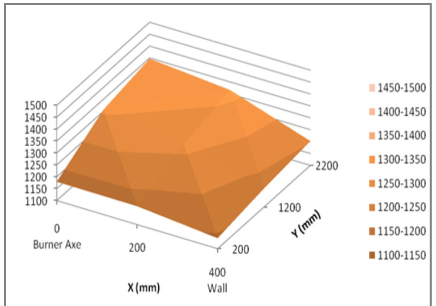
- **High energy efficiency of the technology with homogeneous temperature field near the strip**
  - 1000°C preheated air, exhaust fumes temperature at around 250°C. increase by more than 150°C because of the post-combustion heat. Vault temperature can achieve 1300°C instead of1200°C with the same energy feeding
  - a better control of the strip quality and more specifically to the strip flatness are expected.
- **Performances in terms of NO_x and CO emissions need a set of optimised values of the operating parameters but already satisfactory levels for an industrial use**
  - NOx contents measured are under the today's regulation requirements with an appropriate set of operating parameter, (around 200 mg/Nm^3 @3%O_2 inside the furnace)
  - A complete combustion (minimum CO level) and all sucked elements (CO, H_2) can be burnt
- **The contents of H2, CO2, CO, H2O is quite equivalent in both conditions.**
  - The main difference is the O2 content detected ,especially the O2 peaks observed during the switch time of the regenerative burners





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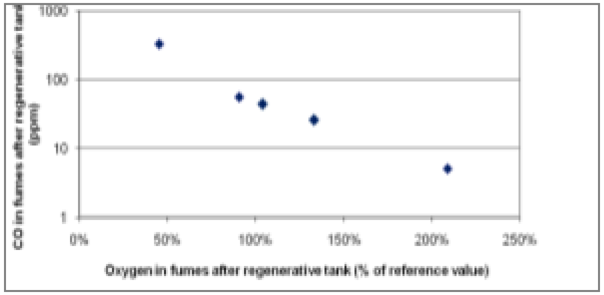
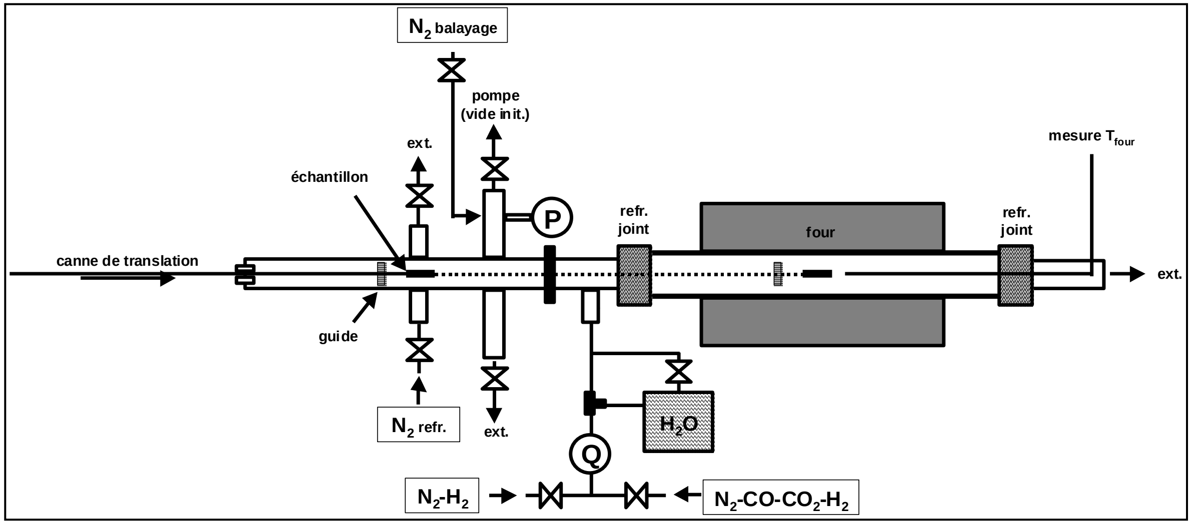


Laboratory scale preheating pilot to investigate the impact on product quality

The preheating simulator of ArcelorMittal is made of a furnace equipped with SiC resistances:



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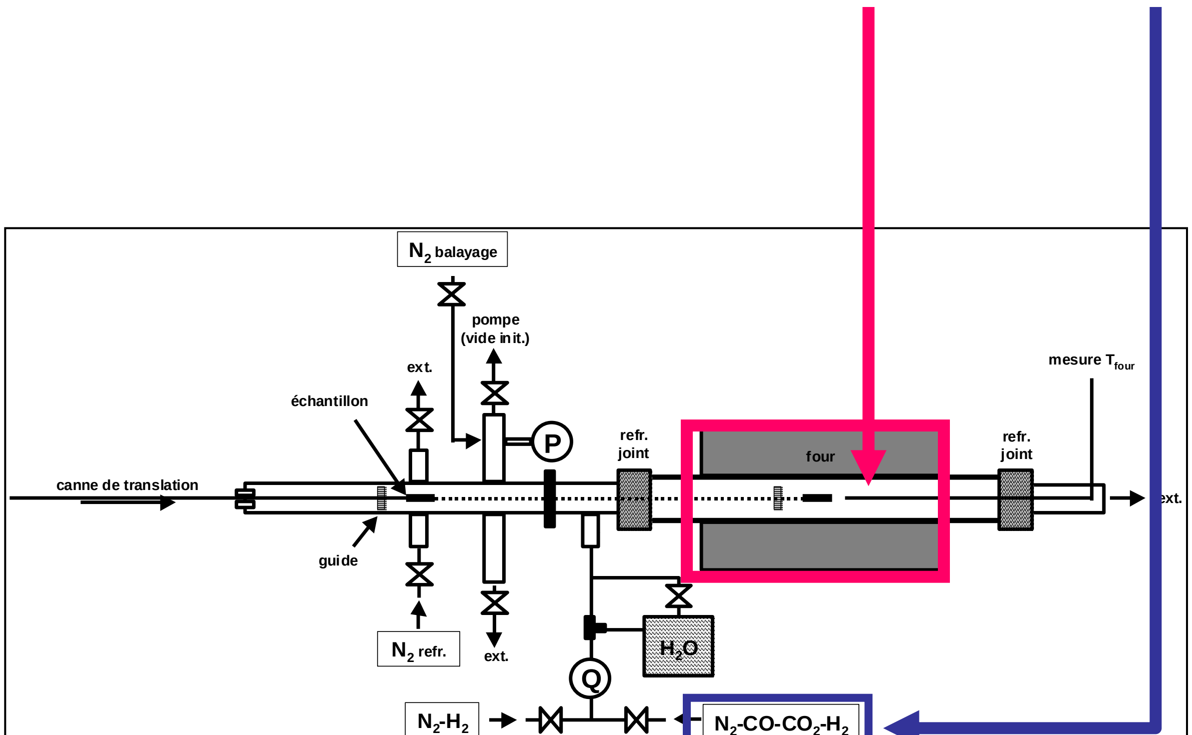

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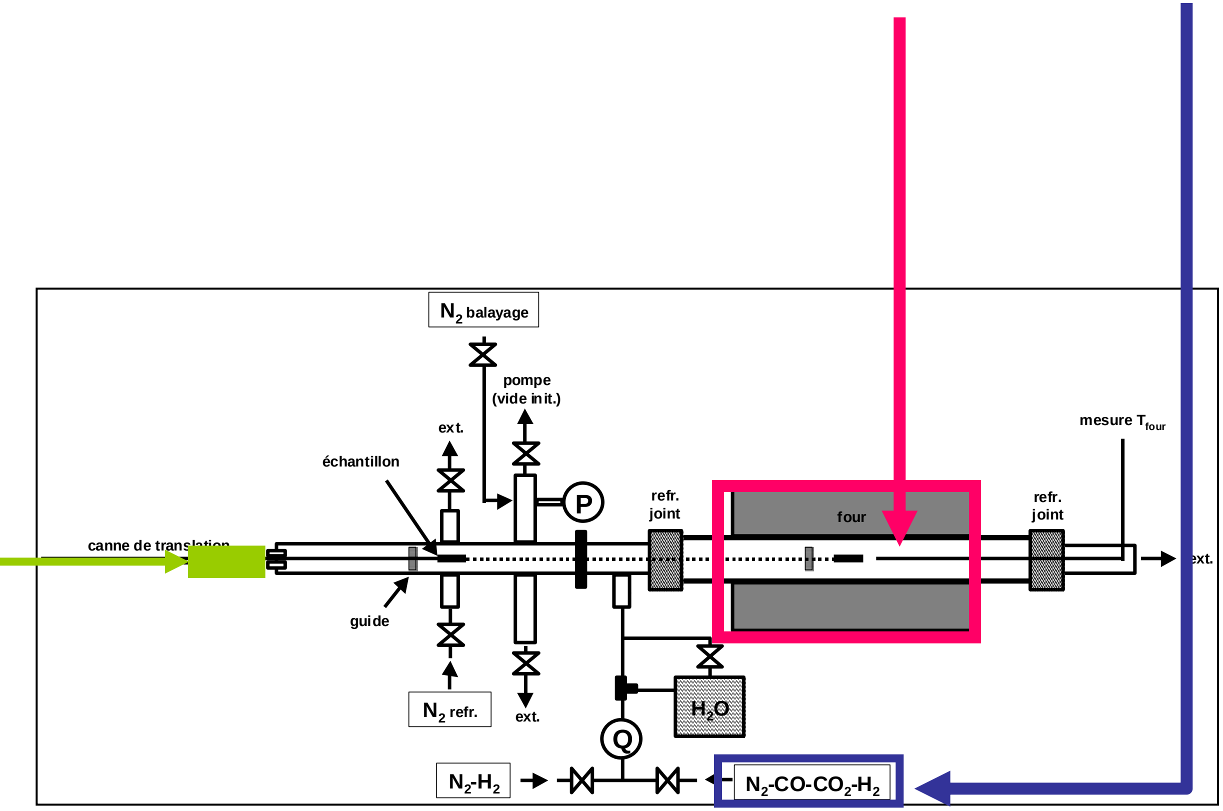

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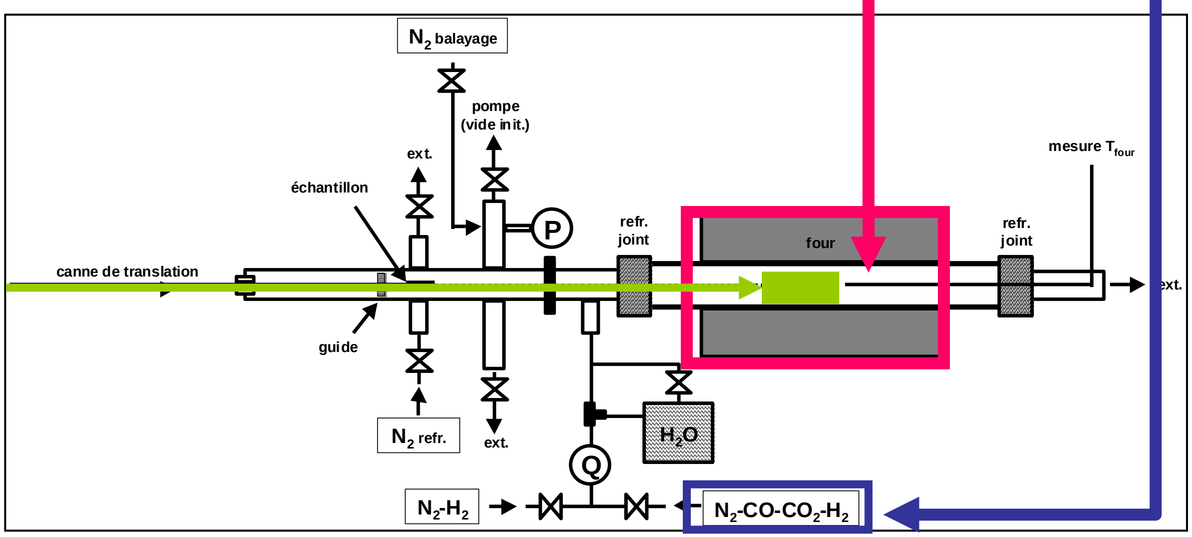

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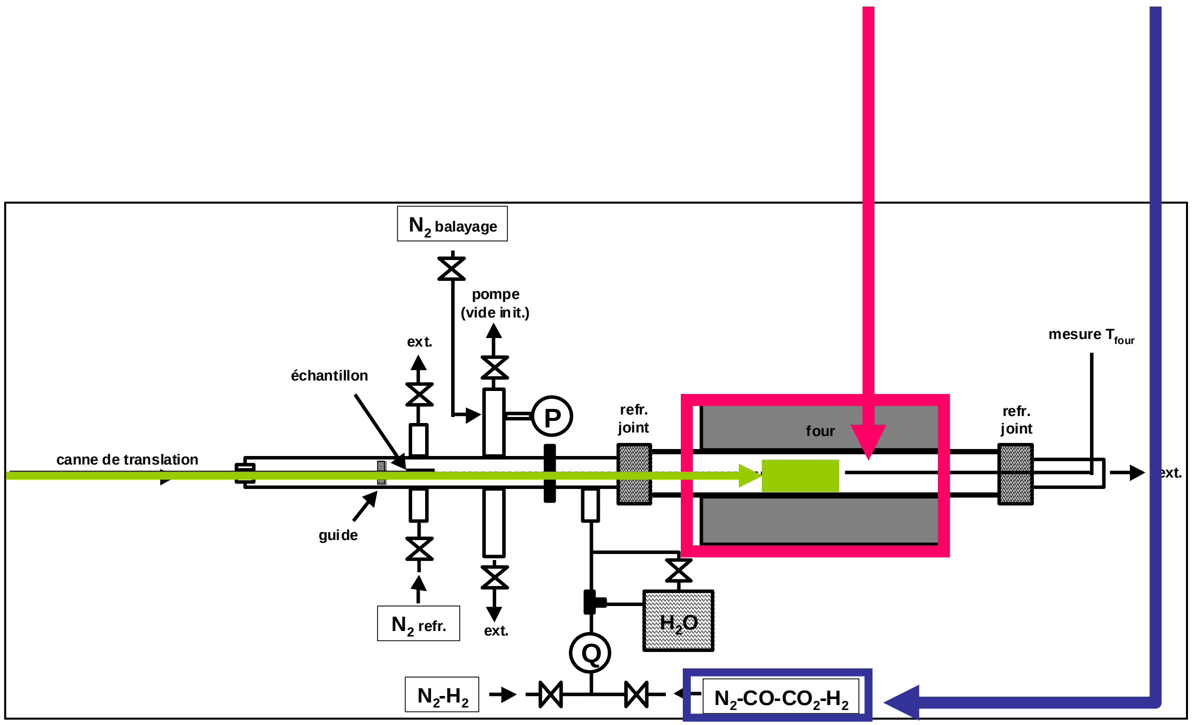

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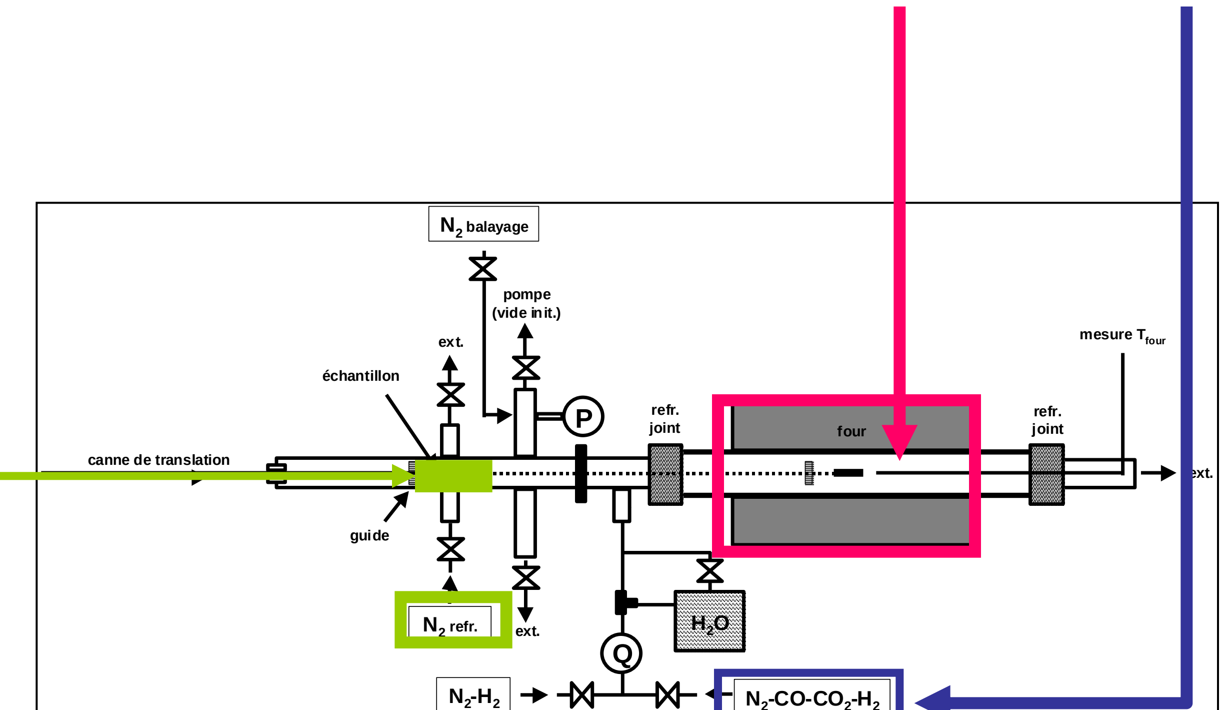

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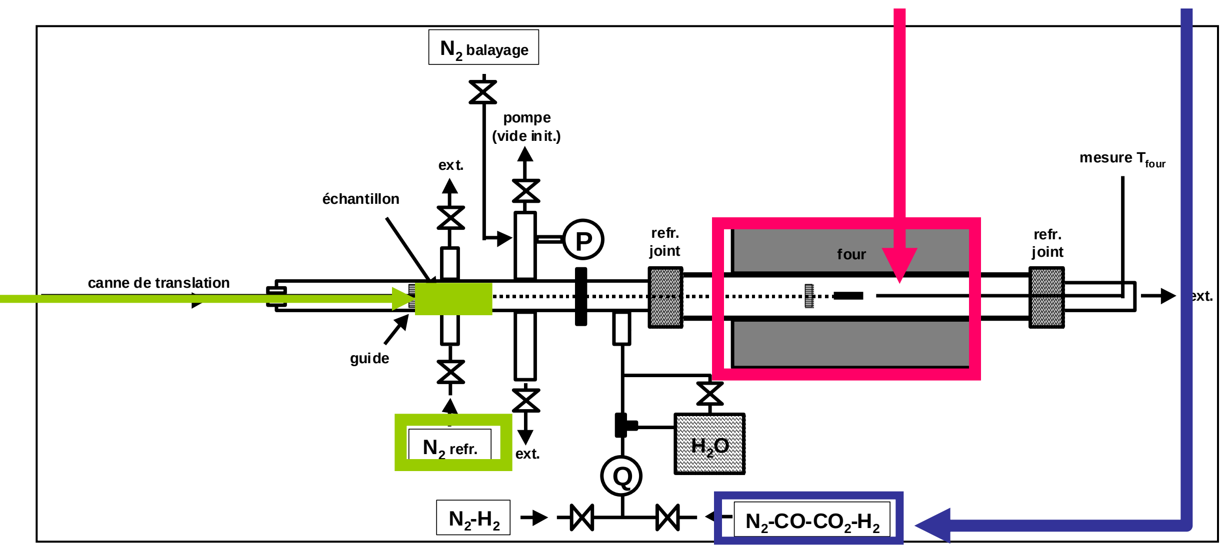
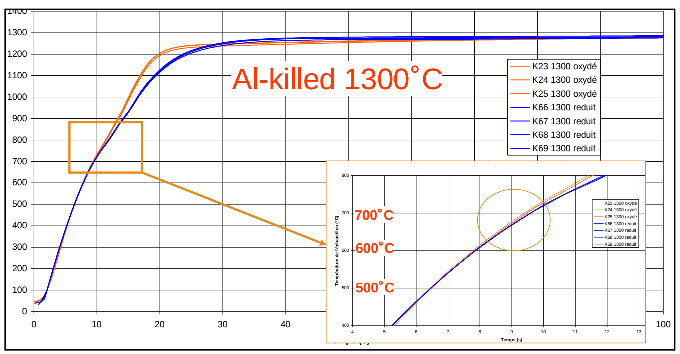
- Traditional surfaces observations (Glow Discharge Optical Emission Spectroscopy or GDOES) to **characterize the effect of the furnace atmosphere and temperature on the product quality**



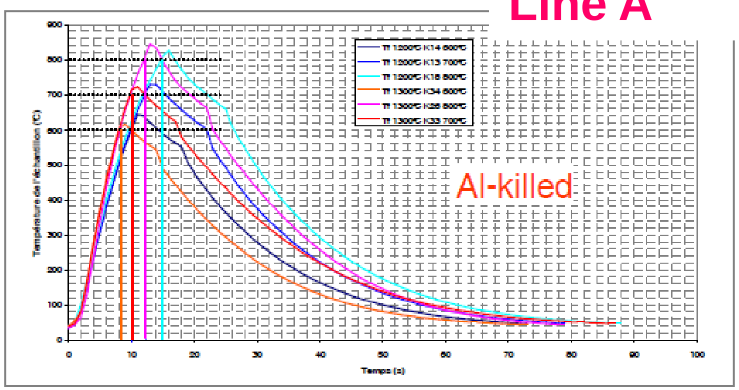
Surface oxidation & heating kinetics confirm the good product quality

- **Based on the line A order book, two sensitive steel grades (AlK and IF) and their critical formats have been selected to conduct the tests.**
  - Three sample temperature studied : 600, 700 and 800°C. (line A , strip temperature around 700°C)
  - The industrial reference of line A is 1200°C - the vault temperature measured on the experimental cell equipped with the regenerative burners is 1300°c due to the high efficiency of the burners

- **The thickness effect**:
  - Surface oxidation and sample heating are coupled : heating kinetics is accelerated above ~700°C (as standard burners)
  - The heating kinetic of thin samples is quicker than the heating kinetic of the thick samples so that the oxidation occurred earlier.



Line A



- **Effect of the vault temperature from 1200°C to 1300°C:** a reduction of the required time to heat the sample at the desired final temperature. The potential gain on the heating kinetic observed on laboratory conditions and for this sample can reach 20%

- **Minor effect of higher O2 content**: the classical reaction between the steel and the gas is lightly modified but does not induce significant damages on the sample surface)

Representative numerical tool to dimension industrial furnaces

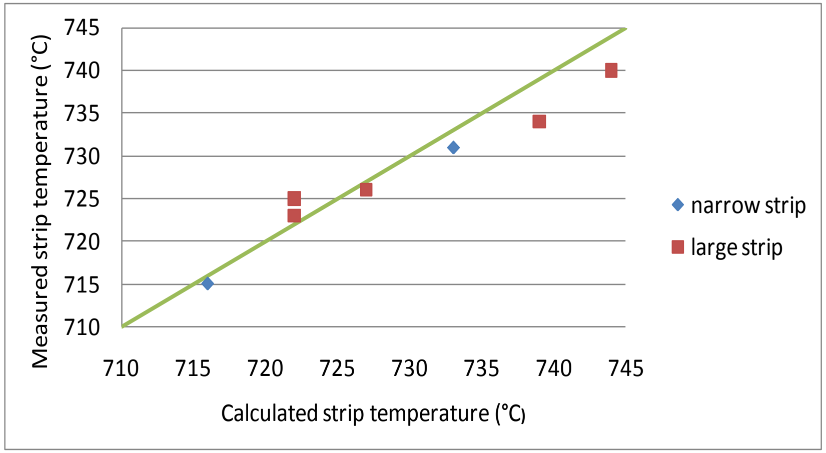
GDF SUEZ

ArcelorMittal

• The industrial lines are interested to implement regenerative burners within their preheating sections equipped with direct fired section.

It requires pre-dimensioning investigations to evaluate the new furnace design (burner's location, power…) and to estimate the expected energy savings and productivity stakes

• Baseline configuration of two ArcelorMittal lines for validation

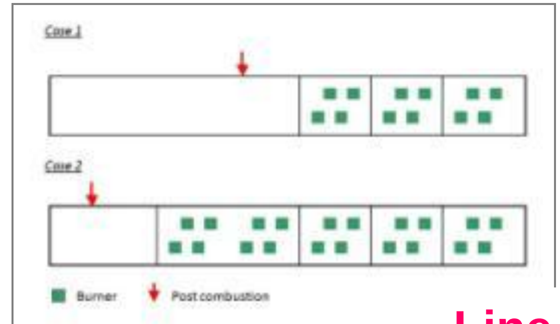


• Specific subroutines for regenerative system (including post combustion within the burner) have been carefully qualified, based on experimental data measured within these particular burners on GDF SUEZ semi-industrial scale furnace

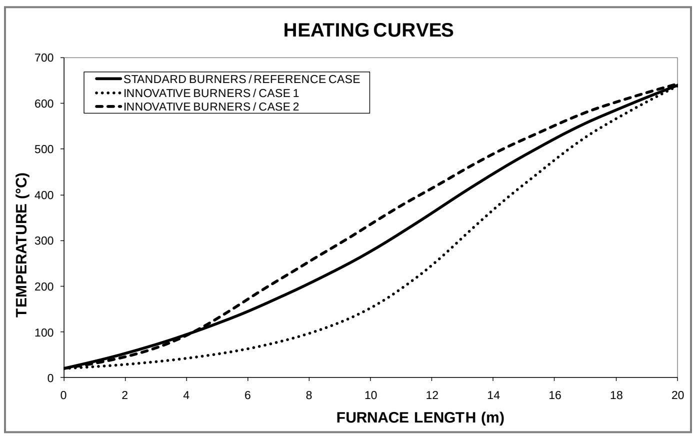
Flameless regenerative burners

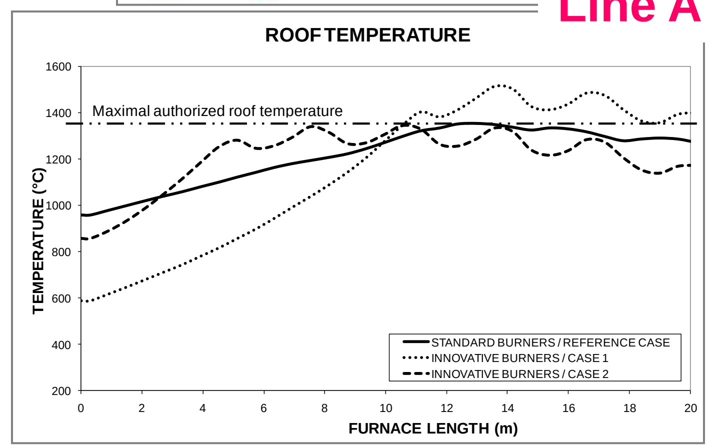
Significant improvements provided an adapted implement

- **Energy savings stakes for line A:**
  for that case, a full conversion from standard burners to the innovative burners has been analysed.



Line A





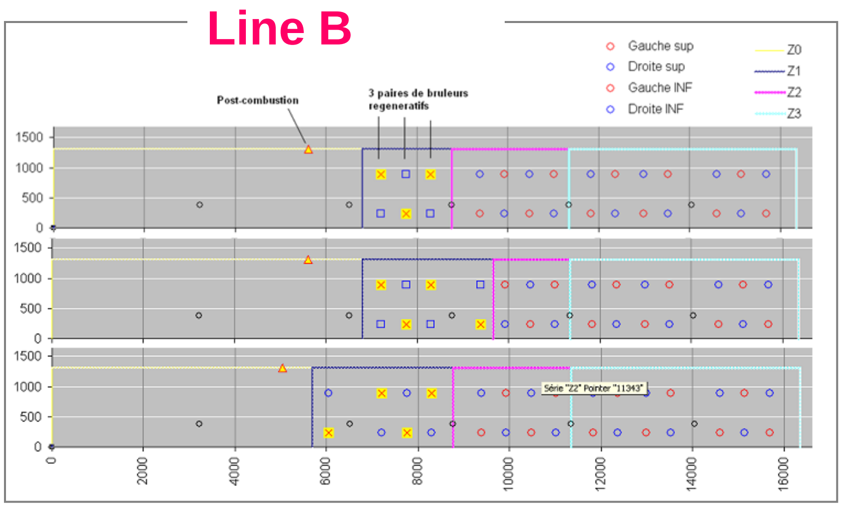
- **Provided the innovative burners are located at an optimised place** on the line, not simply replaced at the location of the existing burners, we can then have
  - significant energy savings (**up to 14% for thick strip**)
  - while respecting the constraints of the furnace such as the maximum temperature of the roof.

Flameless regenerative burners

Productivity increase at lower investment costs

- **A productivity increase issue for line B:**
  For that case, a retrofit of one combustion zone has been studied.
  Power limitation due to recuperator design implies a bottleneck in term of production.
  No existing technology meets the issue except the full retrofit of the recovery system.

- The computations performed show
  - a maximum **productivity increase of 15 %** for the considered product order book and **specific gas consumption reduction can reach 5%**
  - The **strip thermal profile** and **target temperature at the exit of the preheating furnace** are respected as well the acceptable **roof temperature and fumes temperature at the exhauster**.



Schematic view of 3 industrial configurations equipped with regenerative burners.

For each, gains gave been computed thanks the numerical tools

•In that second industrial case

the regenerative burners is the optimal candidate to solve the furnace bottleneck in order to increase productivity at lower investment's costs.

Flameless regenerative burners already suitable for industrial use on HDG lines

- **GDF-Suez and ArcelorMittal identified the potential interest to apply flameless regenerative burners to the specific conditions of preheating section on HDG lines**.

- They joined their complementary competencies within a collaboration to test and to characterize in semi-industrial conditions the performances of this innovative solution, and finally **to prepare the first industrialisation**

- Resulting from characterization campaigns, **the performances of the tested burners are very encouraging and already suitable for industrial use**:
  - **No operating problem has been detected**.
  - Performances in terms of NO_x and CO emissions need a set of optimised values of the operating parameters, but have already **satisfactory levels for an industrial use.**
  - Combustion efficiency of this innovative technology is very high and **promises to reach a more energy efficient furnace compared to current technology.**
  - Temperature field within the furnace, and particularly in the strip neighbourhood, is quite homogeneous, **leading to a better heating quality.**
  - There is **no impact of the generated atmosphere on the quality of the surface of the strip**

Next step : flameless regenerative burners implemented on HDG lines

- **Expected energy savings, pollutant emissions and productivity gains in the case of an industrial implementation**:
  - A saving up to 15% on gas consumption and associated CO_2 emission,
  - A decrease of 10% on CO emission
  - A low level of NOx emission: 200 mg/Nm3 @ 3% O_2
  - No impact on product quality

- These encouraging results allow us **to predict a productivity increase up to 15% on the studied bottlenecks of HDG lines, especially dedicated to high added value steel grades**.

- Complementary measurements and tests will be conducted in real production conditions **on the industrial line** where the first implementation of developed flameless regenerative solution will be done **to assess the performances measured in the semi-industrial conditions and the estimated associated gains**

THANK YOU FOR YOUR ATTENTION

INTERNATIONAL GAS UNION RESEARCH CONFERENCE 2011

Innovative flameless burners for galvanizing lines

Clotilde Villermaux, Karen Beaujard, Nicolas Richard, Armand Danda