Innovative Technologies for Greener Copper Smelting and Refining Processes

IWCC Technical Seminar 2024

Joachim von Schéele, William J. Mahoney, and Brenno Ferreira

Milan, Italy

February 2024

IWCC Legal Disclaimer

The purpose of this presentation is to guide programs benefiting the copper industry and to provide attendees with information to make independent business decisions.

Linde Technology

- → Linde provides leading, value-adding technologies to:
  - → Improve energy efficiency, reduce CO_2
  - → Deliver environmental benefits, reduced NOx
  - → Improve productivity, reduced CAPEX
- → Dedicated global team of specialists and R&D experts:

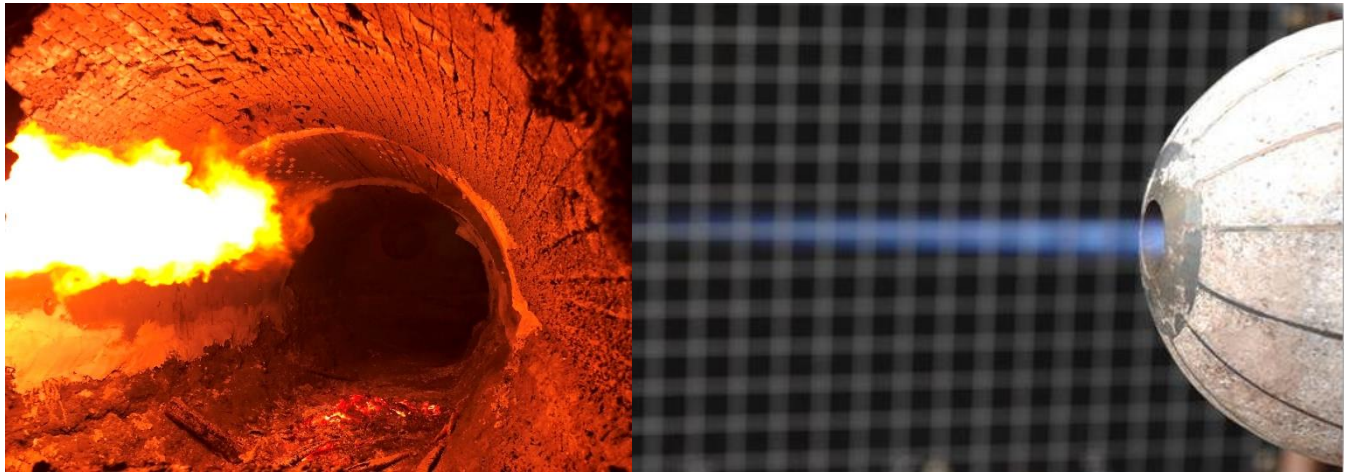
- → Applications Equipment and Support:
  - → We design, build, supply, start up, optimize and support all our technologies
- → Capabilities
  - → Experimental Indoor High Temperature furnaces
  - → Outdoor bays and pilot scale testing
  - → CFD modeling

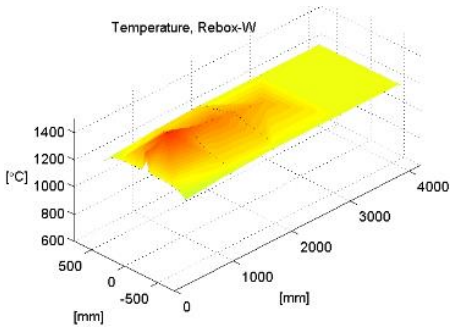
CUSTOMIZED SOLUTIONS

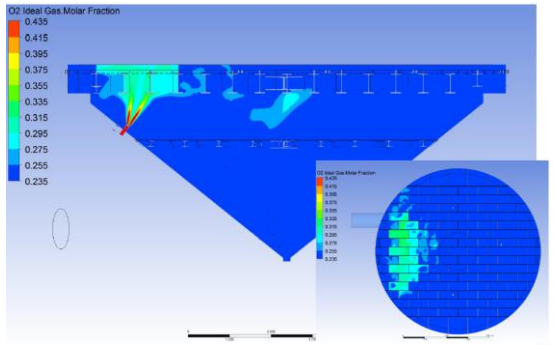
Linde Technology

Technologies Supporting Greener Steel, Metals, and Glass Production

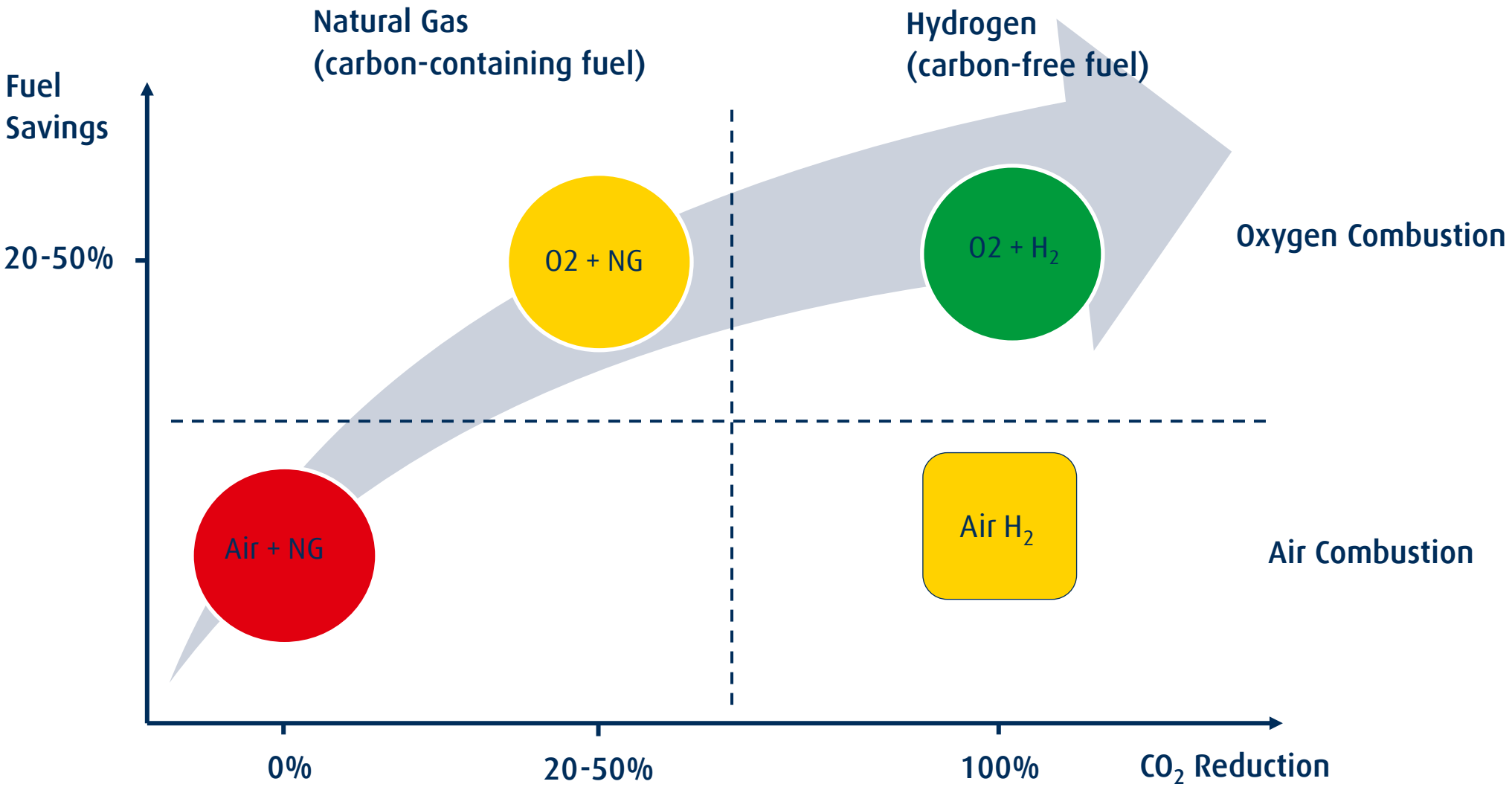
- → LTOF® 50+ installations in Aluminium Melting
- → Lead 100+ furnaces (Rotary, TRF, QSL, and reverb)
- → Copper Different projects for Primary and Secondary producers
- → AOD 75% of world stainless steel production
- → CoJet® 170+ installations in Electric Arc Furnaces
- → REBOX® 180+ installations in Reheating & Annealing
- → OXYGON® 200+ installations in Ladle Preheating
- → OPTIMELT® Technology for energy efficient Glass Melting







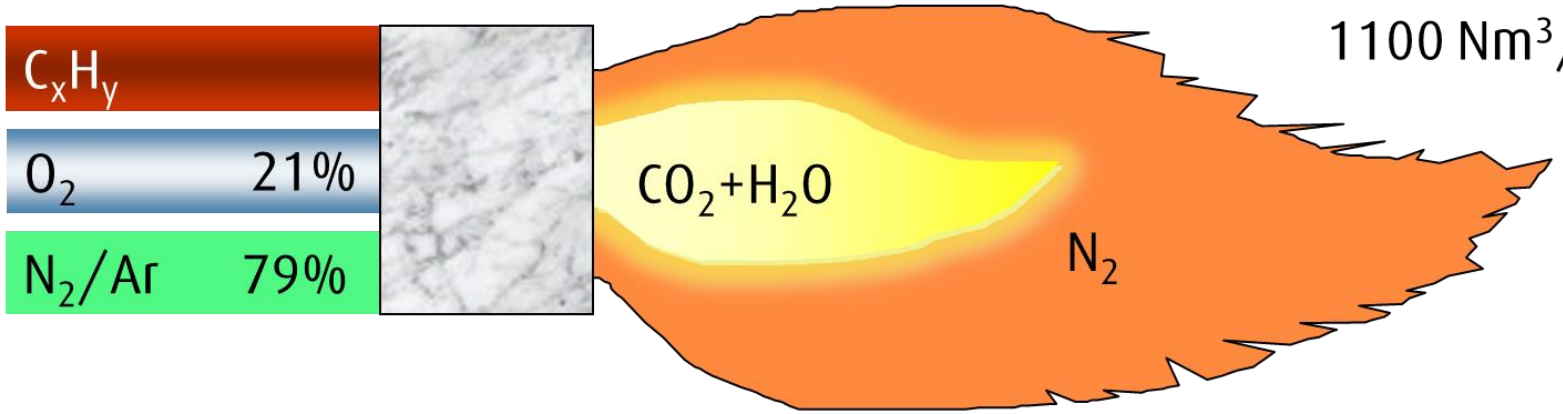
Route to Decarbonize Industrial Combustion Operations



Oxyfuel

Combustion without Nitrogen Ballast

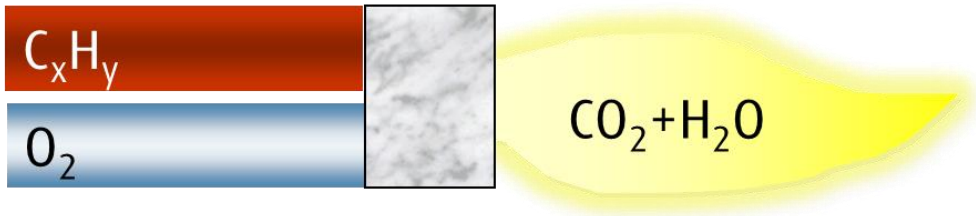
Air-fuel



1100 Nm³/MWh

$$CH_4 + 2\,O_2 + + 8\,N_2 \Rightarrow CO_2 + 2\,H_2O + 8\,N_2$$

Oxy-fuel

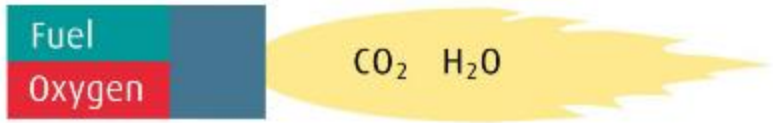


300 Nm³/MWh
(-73%)

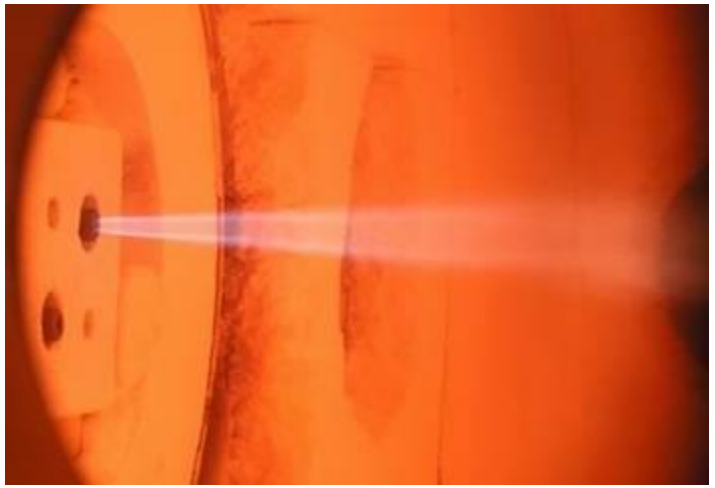
$$CH_4 + 2\,O_2 \Rightarrow CO_2 + 2\,H_2O$$

Conventional Oxyfuel and Flameless Oxyfuel

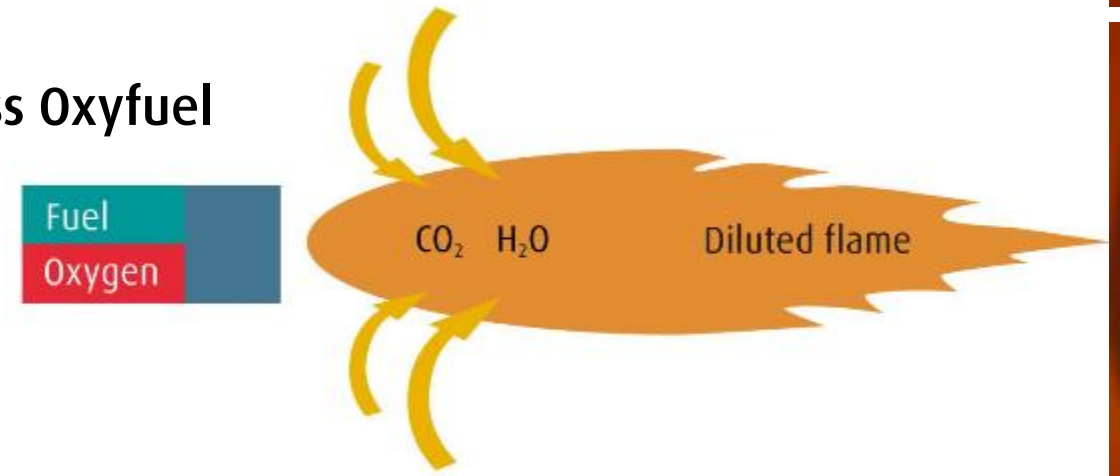
Conventional Oxyfuel



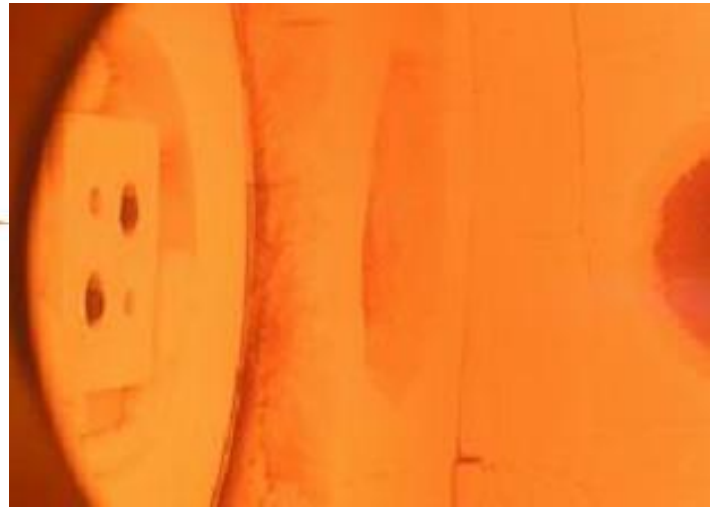
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + HEAT



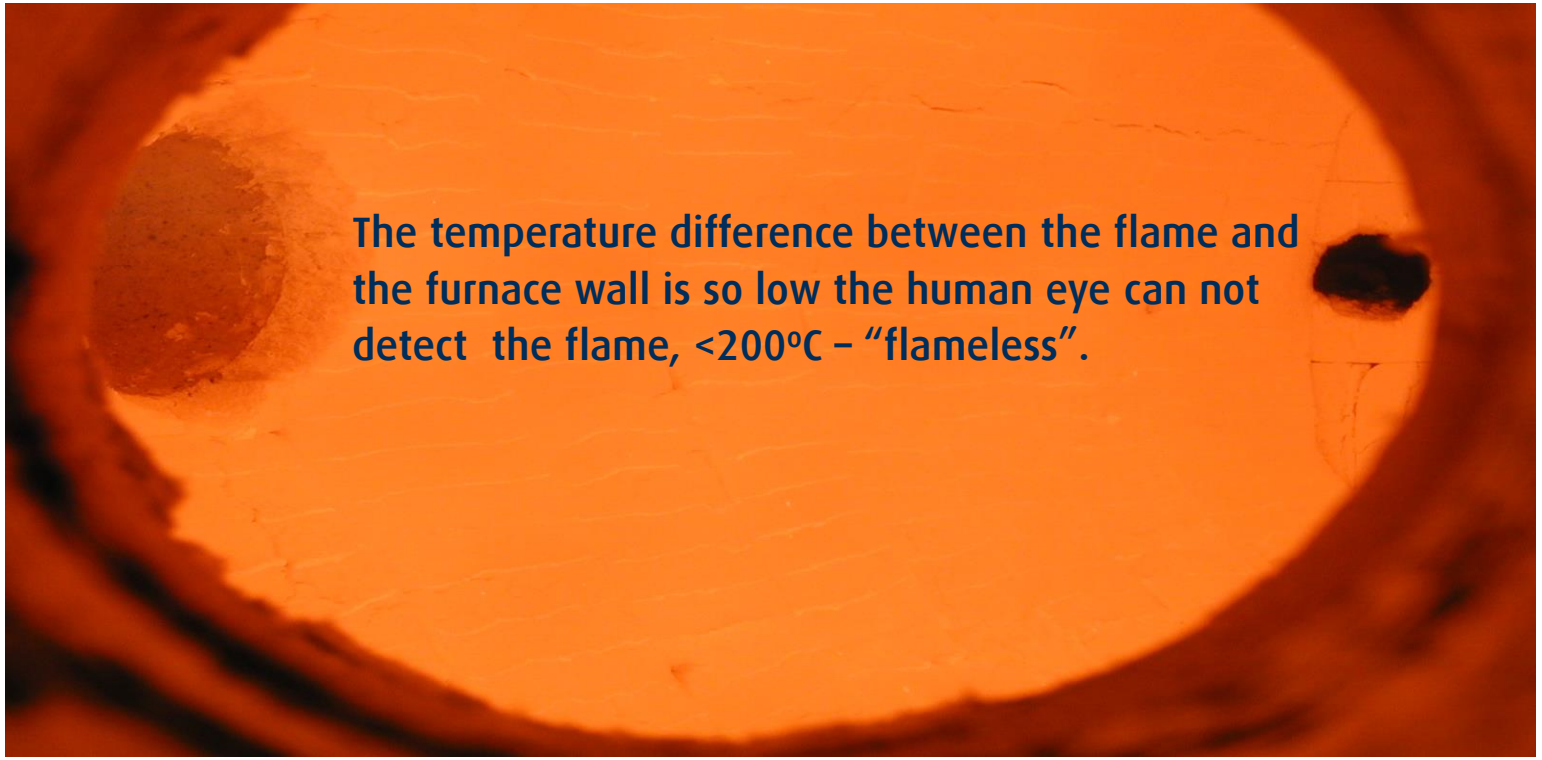
Flameless Oxyfuel



$CH_4 + 2O_2$ + Hot furnace gases $\rightarrow CO_2 + 2H_2O$ + HEAT



Diluted Oxygen Combustion Using Flameless Oxyfuel



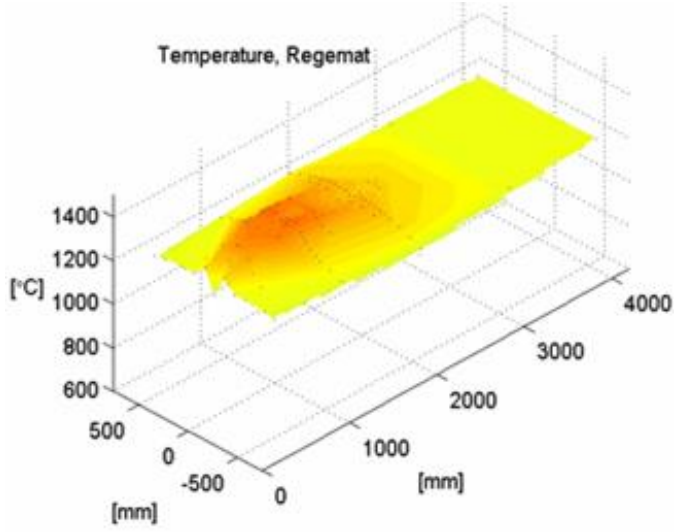
Same Peak Temp as Air-fuel, but Better Uniformity

No generation of Thermal NOx

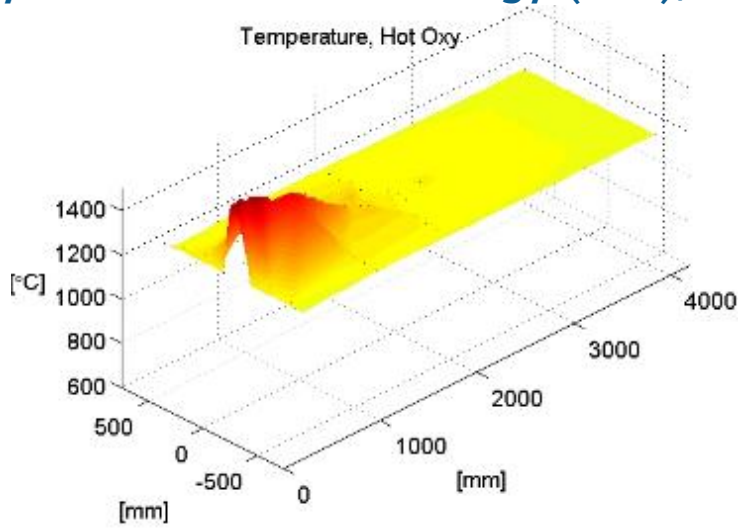
Diluted Oxygen Combustion (DOC)

Low Temperature Flames

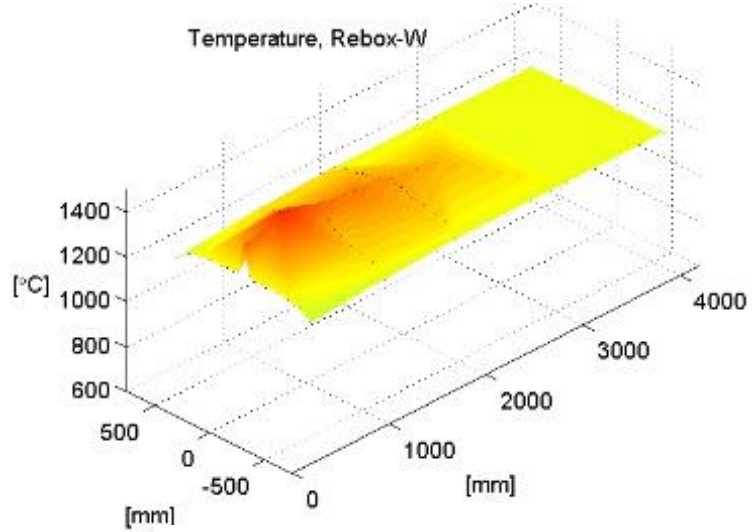
Data from evaluation by Royal Institute of Technology (KTH), Sweden; furnace at 1200°C



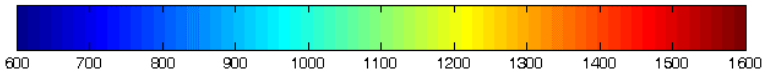
Regenerative Air-fuel



Conventional Oxyfuel



Flameless Oxyfuel



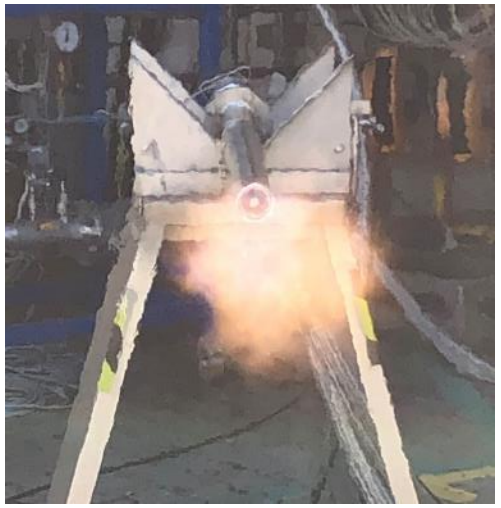
Burner	Measured Peak Flame temp.
Conventional air-fuel	1404˚C
Regenerative air-fuel	1398˚C
Flameless oxyfuel	1434˚C

Same Peak Temp. as Air-fuel, but better Uniformity

No generation of Thermal NO_x

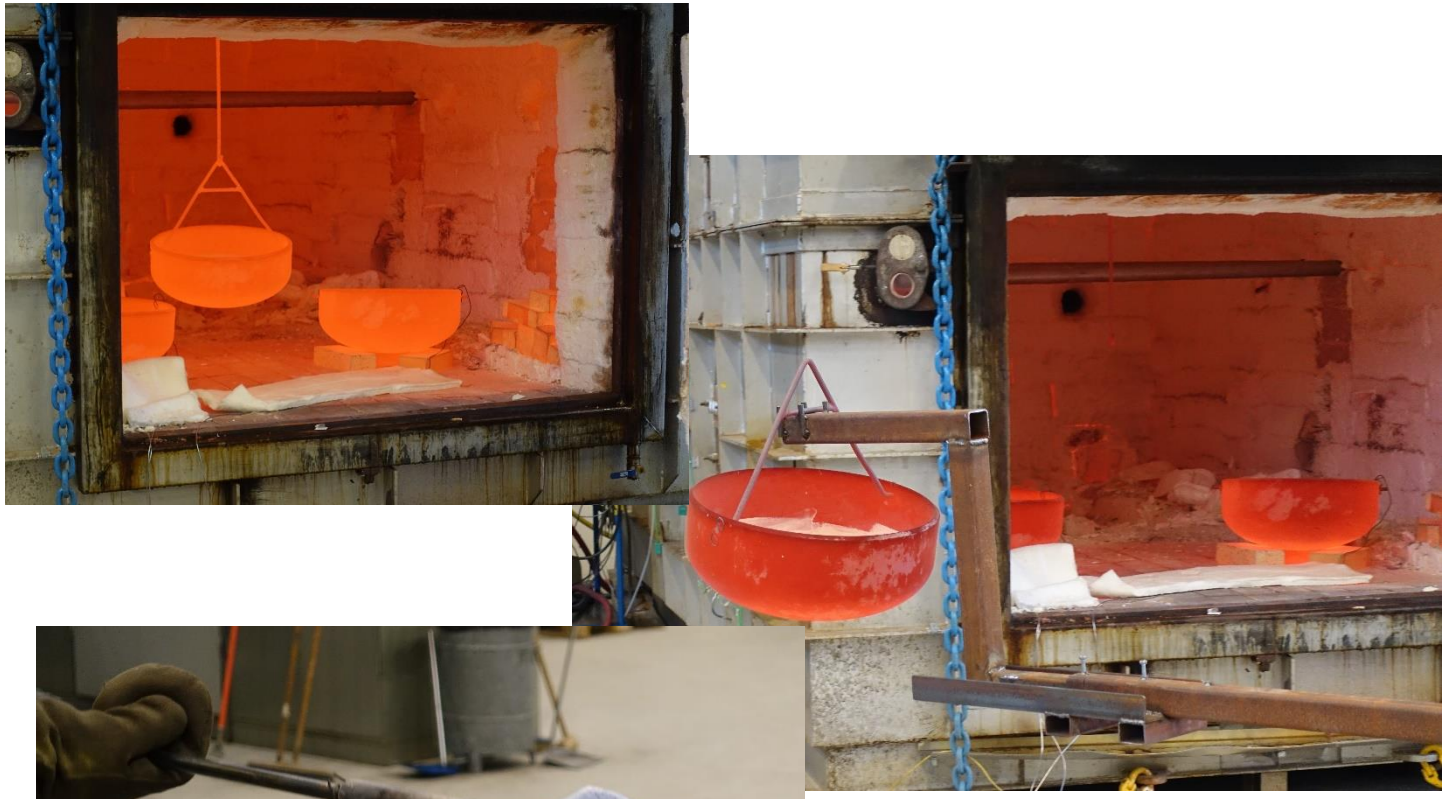
Linde Technology Centre Munich
Hydrogen Trials Spring 2019

Open air firing of 300 kW COROX burner for Glass melting



High concentration of Water Vapour creates infrared radiation

Aluminium Melting: LTOF with 100% Hydrogen Tests at Linde's Technology Centre in Sweden



To evaluate the consequences of H_2-combustion, Linde together with Alcoa, Benteler, Hydro, Real Alloy, Speira, and Sintef carried out multiple series of tests.

Melting and holding 10 kg samples of 5xxx and 6xxx alloys in various atmospheres using LNG, H_2 and mixtures thereof as fuel.

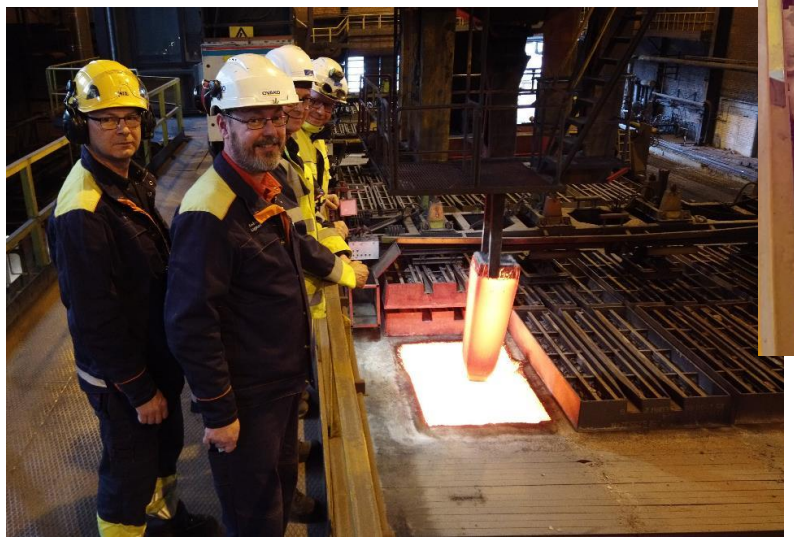
Evaluation of the results indicate no increased oxidation and no negative impact on the final product.

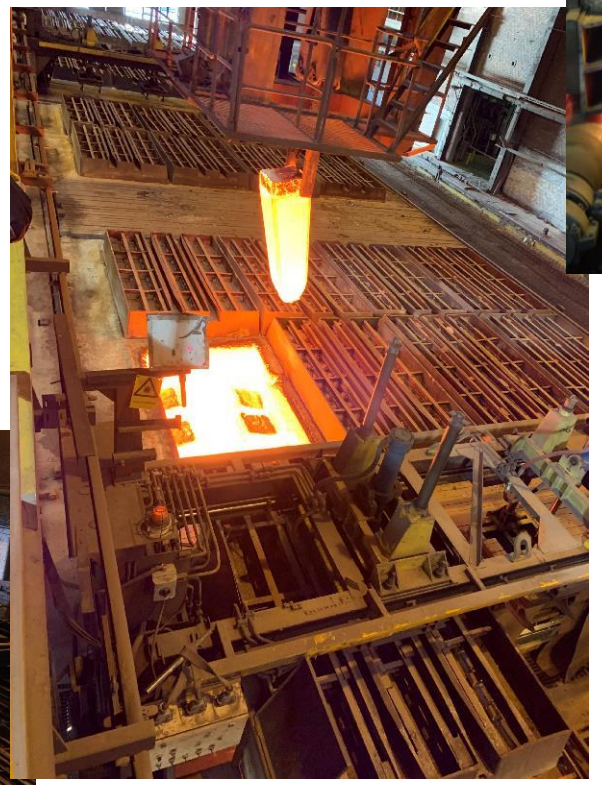
World's First Fossil Free Heated Steel

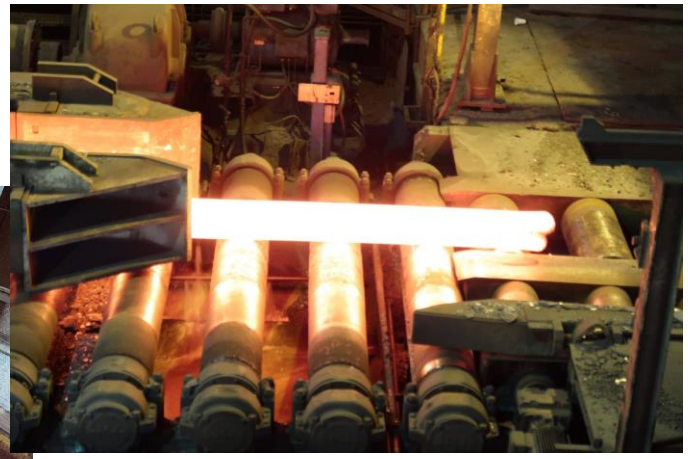
Ovako Steel, Hofors, Sweden
18th of March 2020

25 tons of ball bearing steel heated with Flameless Oxyfuel using 100% Hydrogen as fuel

Both Hydrogen and Oxygen produced with Electricity from Renewable Energy sources







Full-scale permanent installation
to be commissioned in 2024
24 Soaking Pit Furnaces
Saving 20,000 t CO_2 annually

H_2

H_2/N_2 Poling – Aurubis

Using Hydrogen as a Reductant in Fire Refining at Aurubis Hamburg's "Down-town" Smelter
Edens, T. and Steindor, J. (2023)

Table 2. Performed tests. During four of the experiments, the hydrogen concentration of the gas mixture was changed in the 2nd half to control the temperature of the copper.

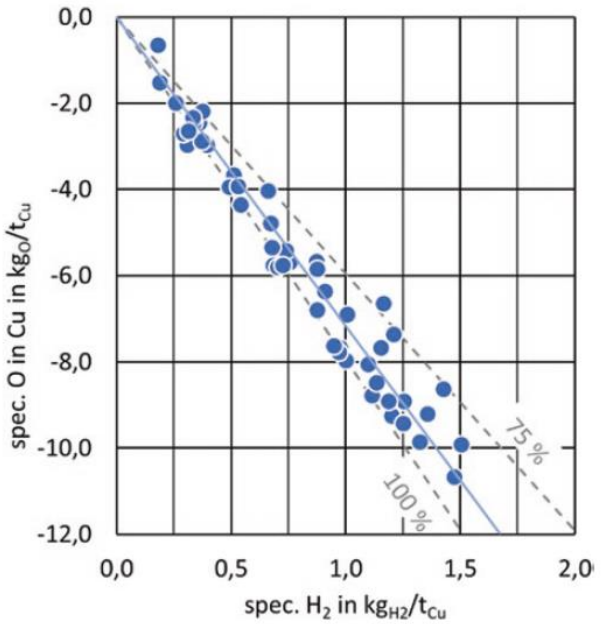
Test	H_2/N_2	Cu	Tuy.	T_{start}	T_{end}	$[O]_{start}$	$[O]_{end}$	η	Comment
	%/%	t	mm	°C	°C	g/t	g/t	%	
1	70/30	269	16	1182	1239	>10,041	160	94	
2	70/30 (90/10)	245	8	1160	1258	9835	1393	62	Burner $\lambda > 1$
3	70/30 (85/15)	255	8	1172	1256	>10,041	101	83	
4	85/15 (100/0)	308	11	1190	1245	8741	92	75	Burner clogged
5	85/15	275	8	1191	1269	8571	609	68	Tuy. fails
6	85/15	260	11	1156	1248	9552	277	97	
7	75/25 (70/30)	275	11	1230	1269	8987	59	90	
8	80/20	240	11	1187	1264	11,340	656	78	
9	85/15	291	11	1161	1243	8707	638	91	
10	100/0	239	11	1181	1263	10,011	1022	83	Clogging of tuyeres
11	60/40	275	8	1209	1239	10,890	5115	93	½ flow rate
12	60/40	273	16	1178	1230	9125	627	94	
13	60/40	285	16	1183	1235	8133	444	92	
14	70/30	272	11	1207	1248	9089	160	94	

Using Hydrogen as a Reductant in Fire Refining at Aurubis Hamburg's "Down-town" Smelter

Torben Edens[1] and Johann Steindor[1]

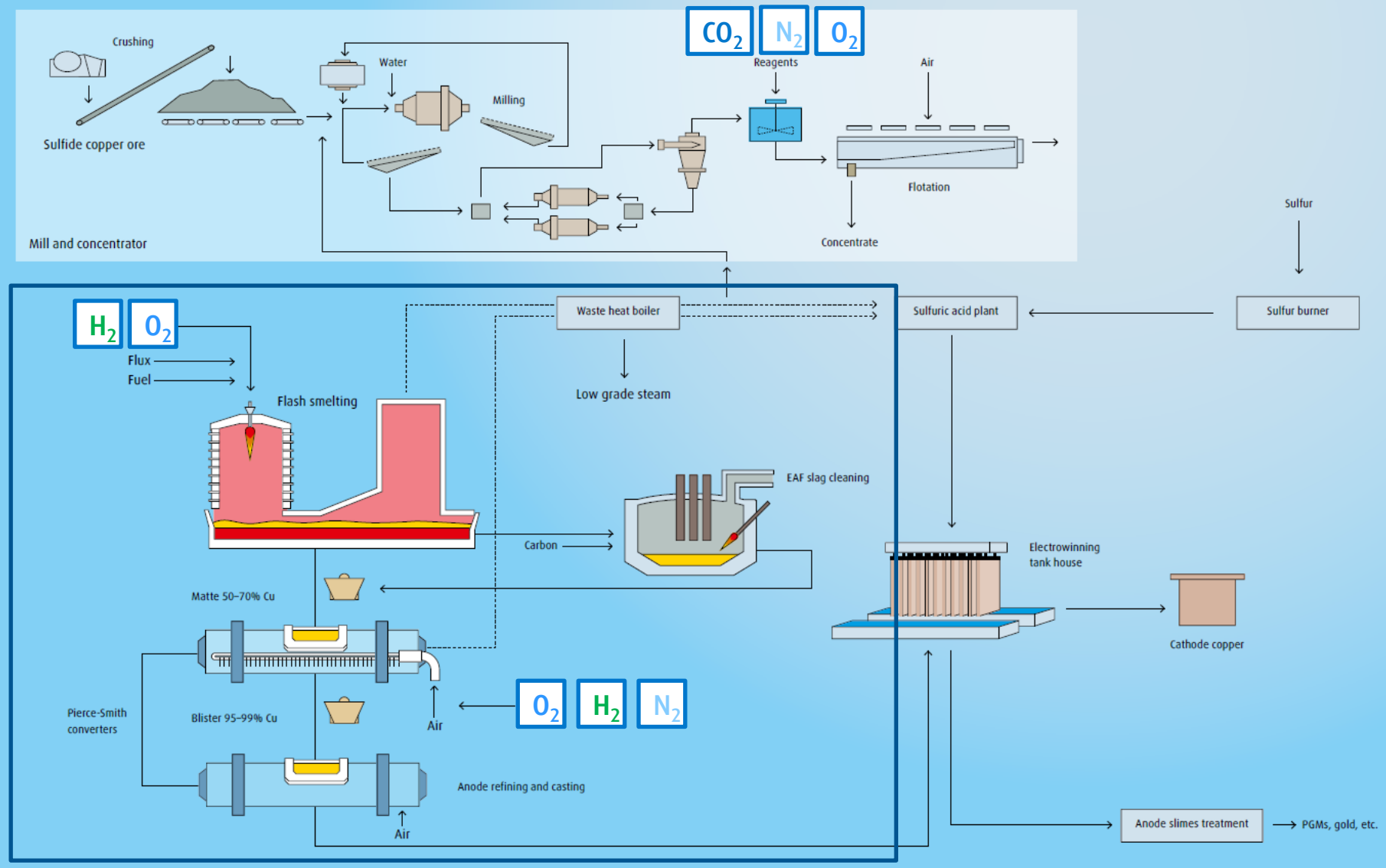
[1] Aurubis AG, Hamburg, Germany
t.edens@aurubis.com

Proceedings of the 61st Conference of Metallurgists, COM 2022,
https://doi.org/10.1007/978-3-031-17425-4_31



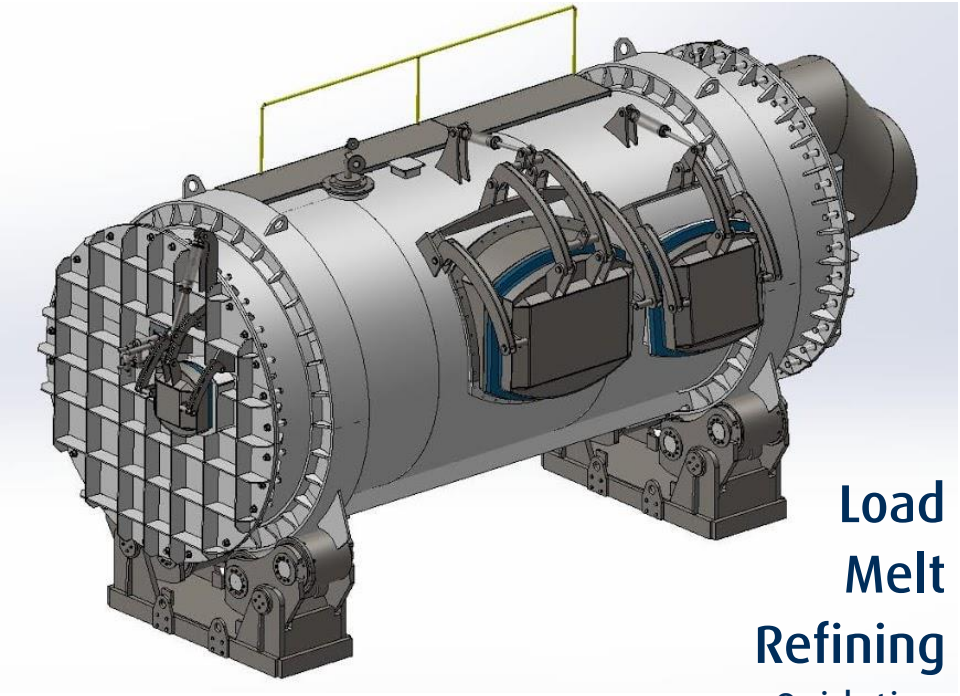
Linde at Copper Smelters

Sulfide copper ore flash smelting process.



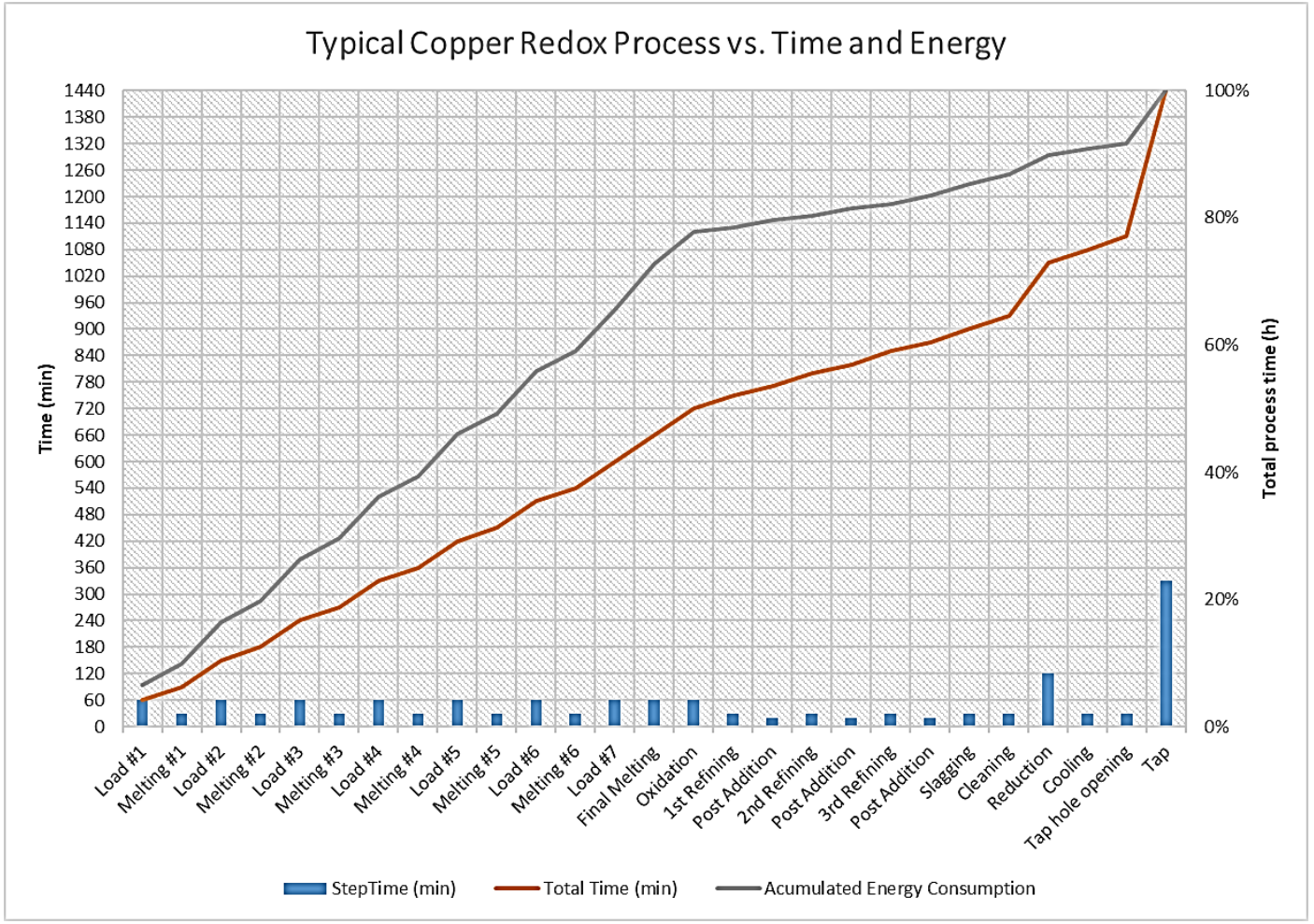
Secondary Copper Process

Melting and refining processes



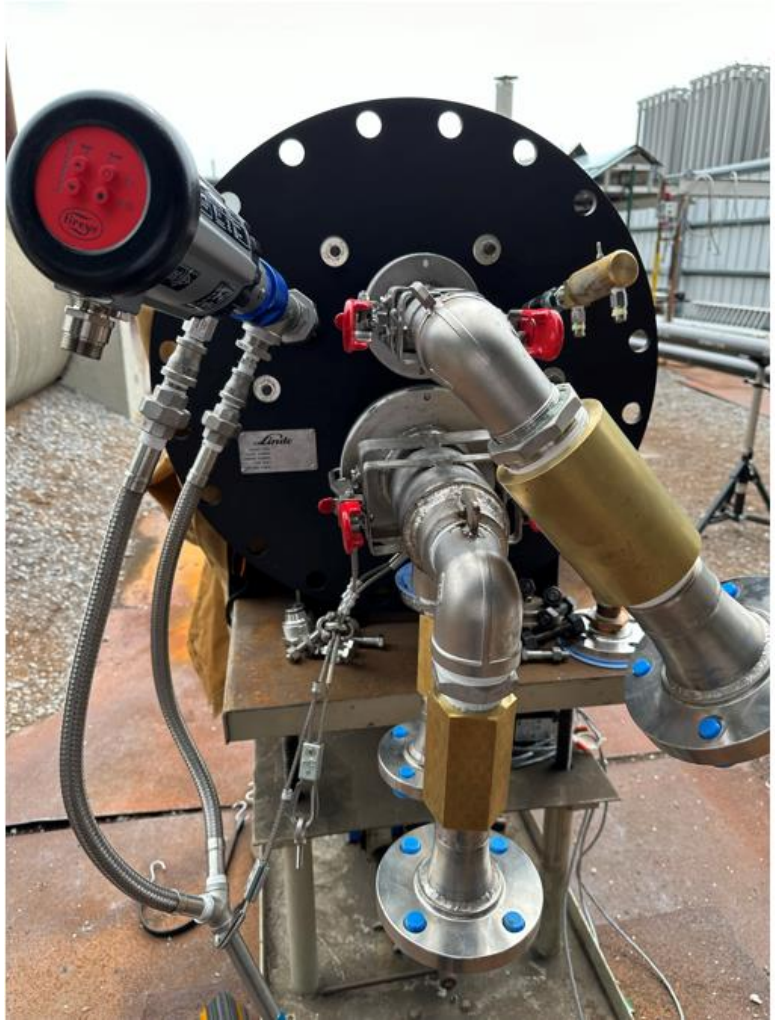
Load
Melt
Refining
Oxidation
Chemical Refining
Slag removal and Skim
Reduction/Poling
Tap

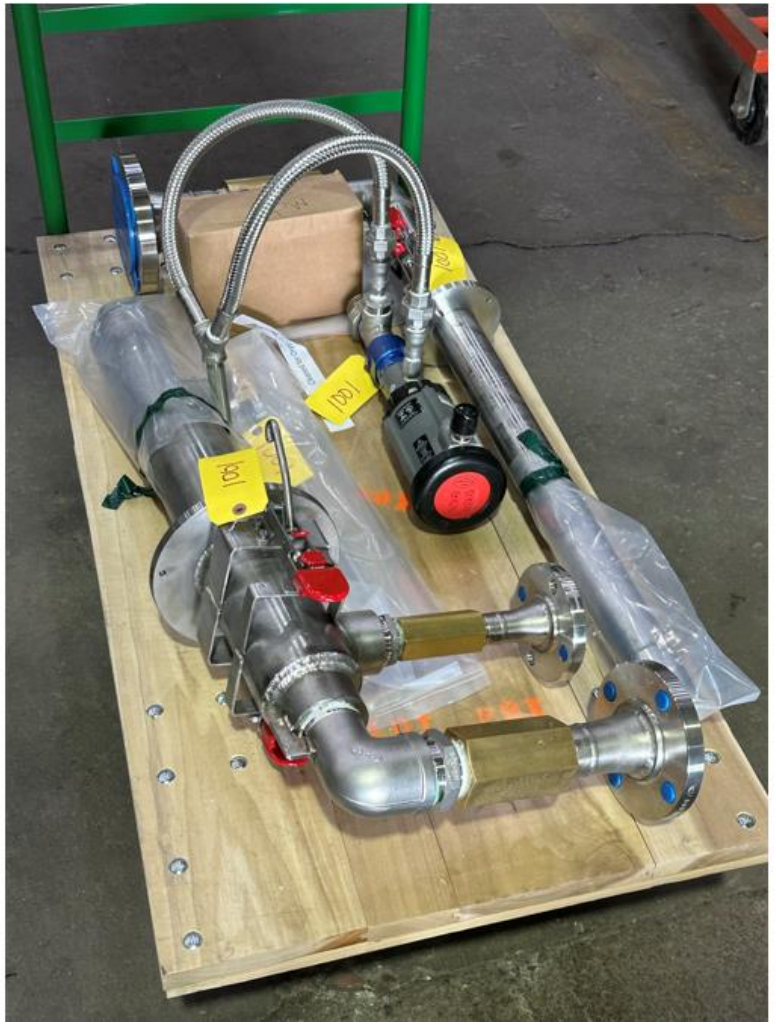
700[1]
kWh/tonne Cu
[1]air-fuel burners



Diluted Oxygen Combustion

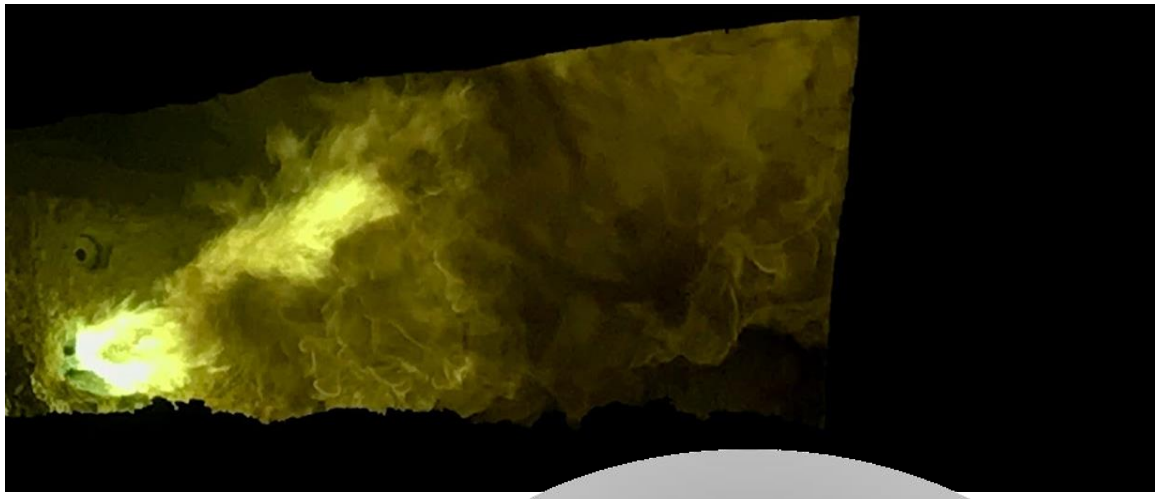
The JL burner

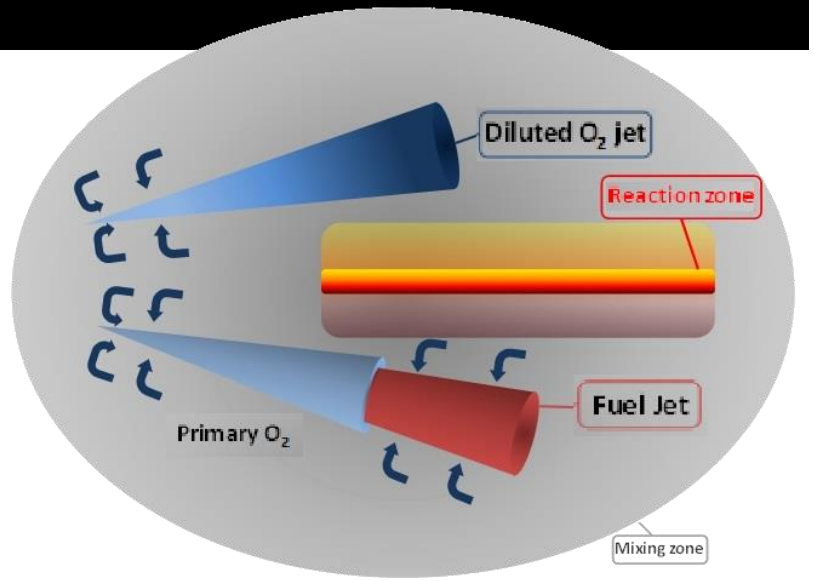


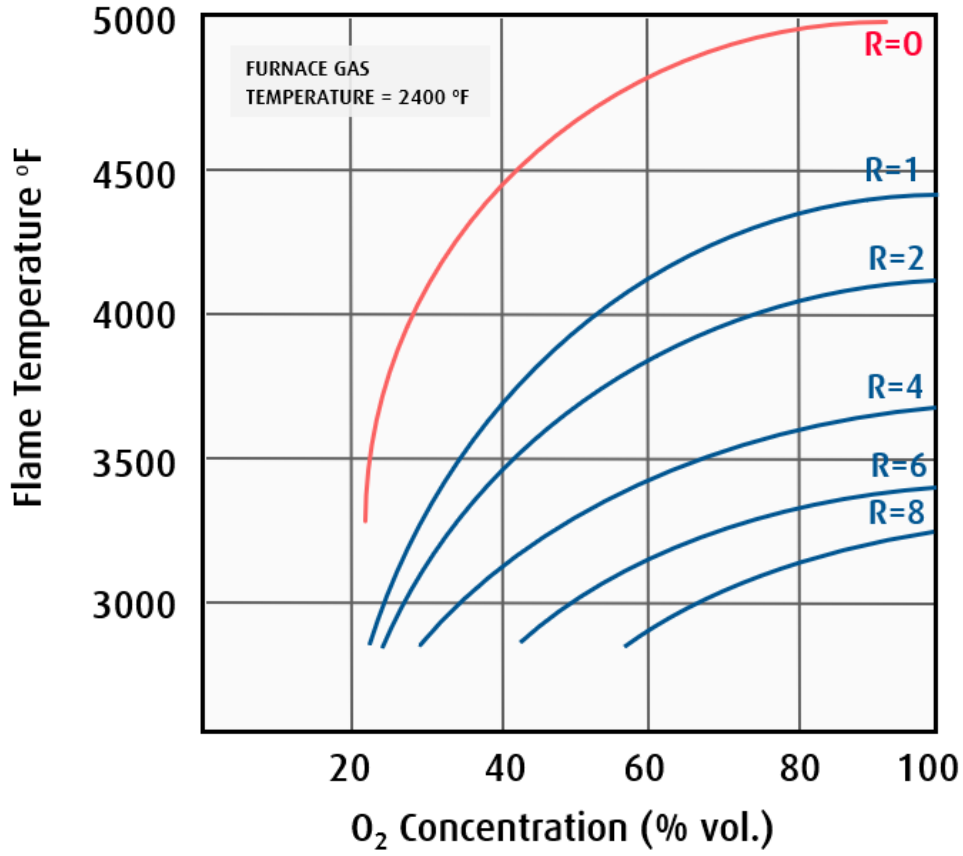


Diluted Oxygen Combustion

The JL burner







Traditional oxy-fuel burners use high flame temperatures for welding and melting.

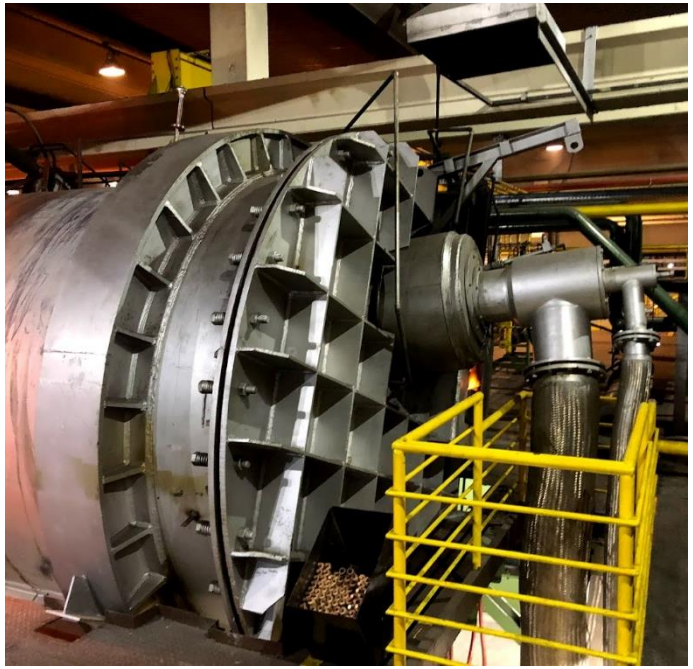
Linde's advanced oxy-fuel burners reduce flame temperature and reduce NOx emissions in industrial furnaces.

R=Flue gas recirculation ratio

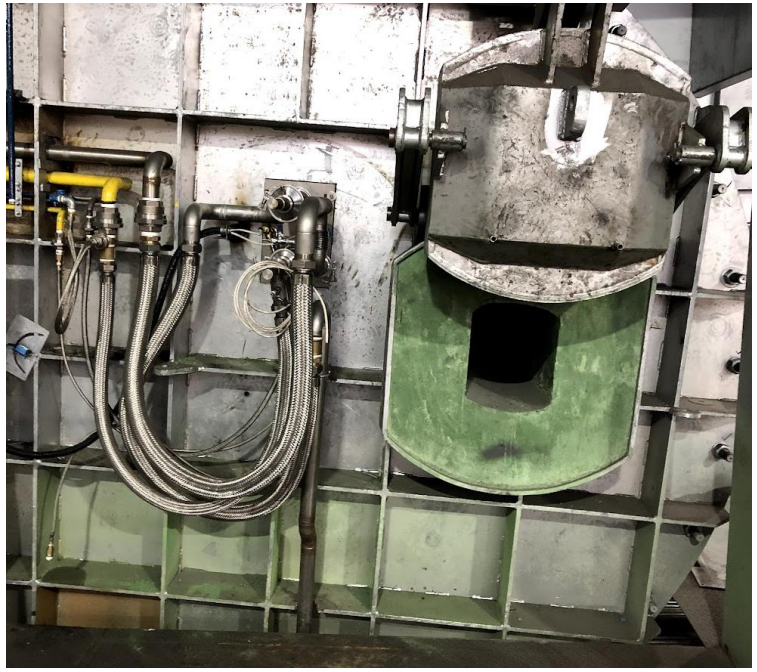
Ultra Low NOx Emissions

JL Burner

Copper scrap furnace



Air-Fuel 8 MW (27 MMBtu)
Scrap Furnace: 75 tonnes
Batch time: 25-28 h
NG Cons.: 6,000 Nm^3/batch

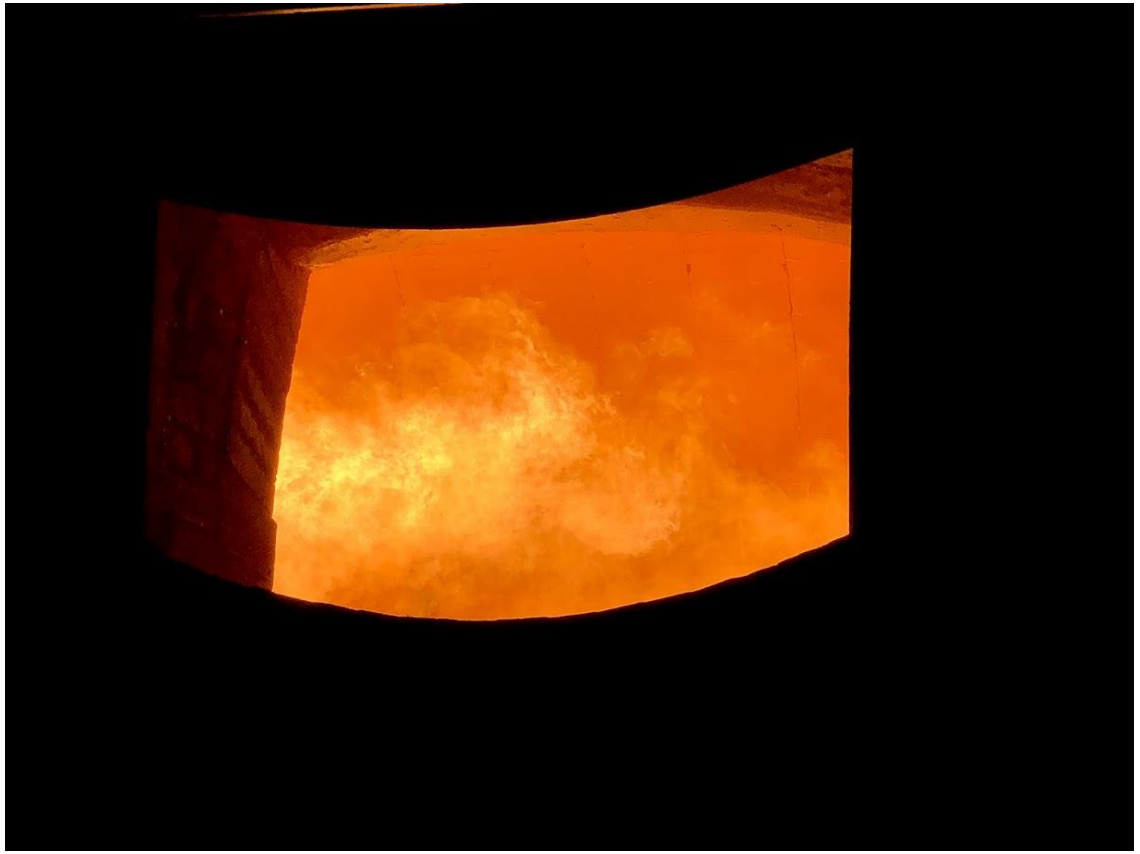


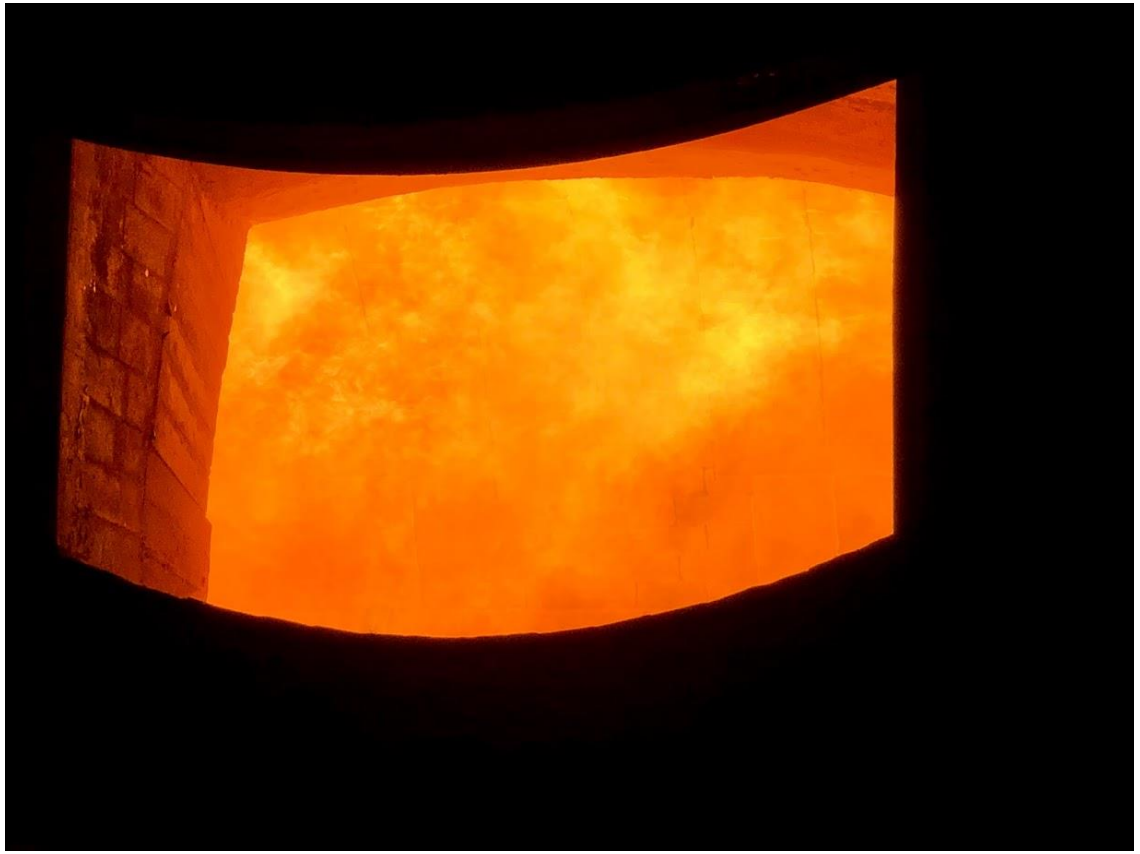
Oxyfuel 3 MW (10 MMBtu)
Scrap Furnace: 90 tonnes
Batch time: 24 h
NG Cons.: 3,000 Nm^3/batch

JL burner 75% Staged Flame
Lance on top, **JL** Burner at bottom
2.4 MW Melting
0.6-0.8 MW Reducing, Tapping

Diluted Oxygen Combustion

Staged Flame at 50% and 75% in Copper scrap furnace





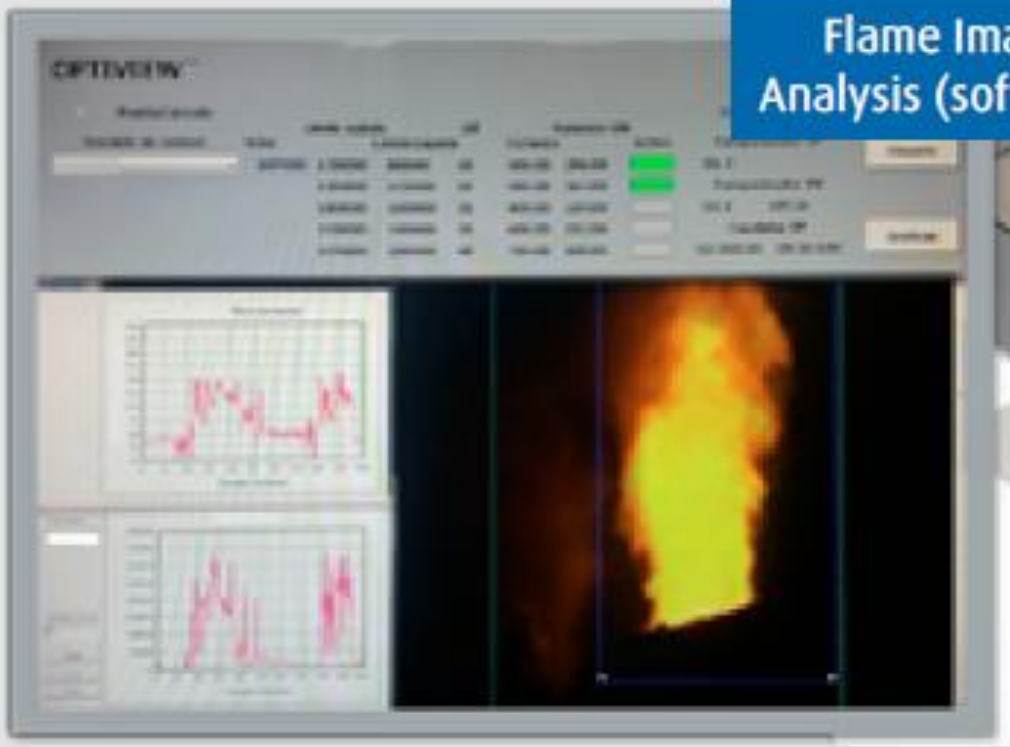
OPTIVIEW®

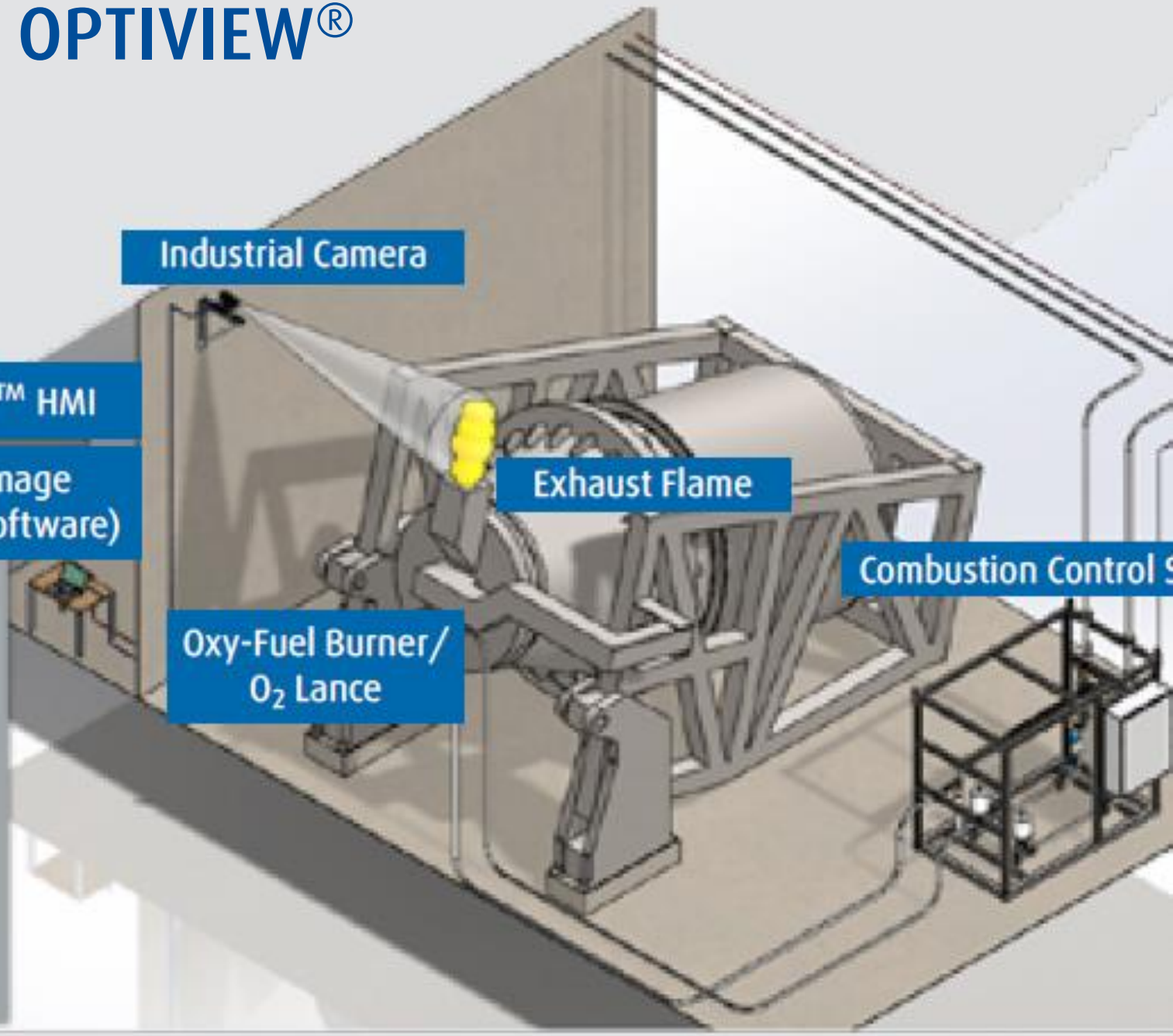
Greater productivity.

Improved energy efficiency.

Reduced emissions.

Lower maintenance costs.



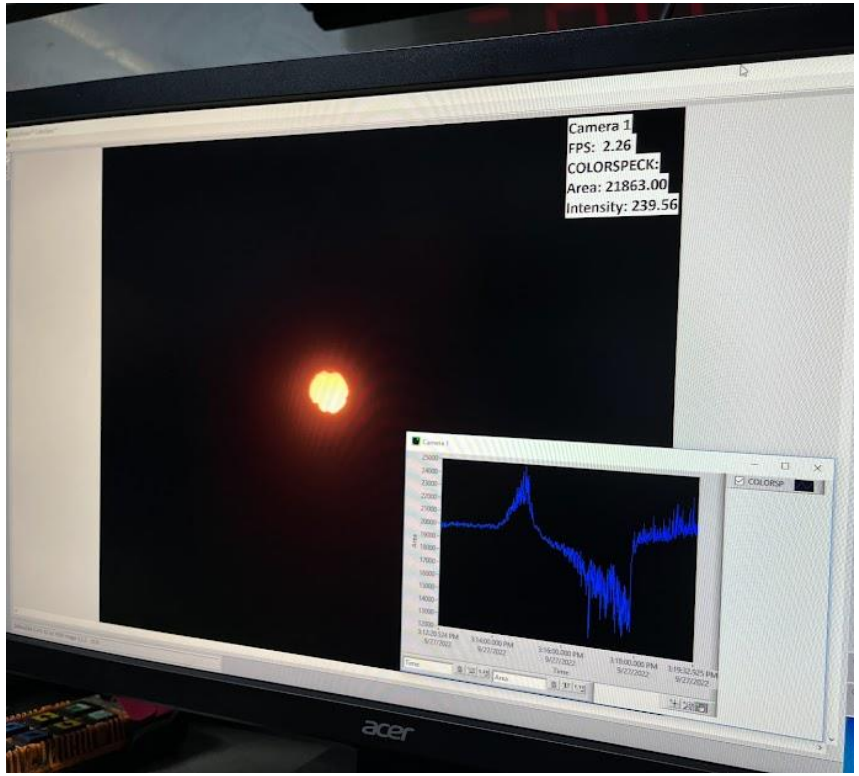


OPTIVIEW®

OPTIVIEW controls additional requirements of Oxygen during the melting step

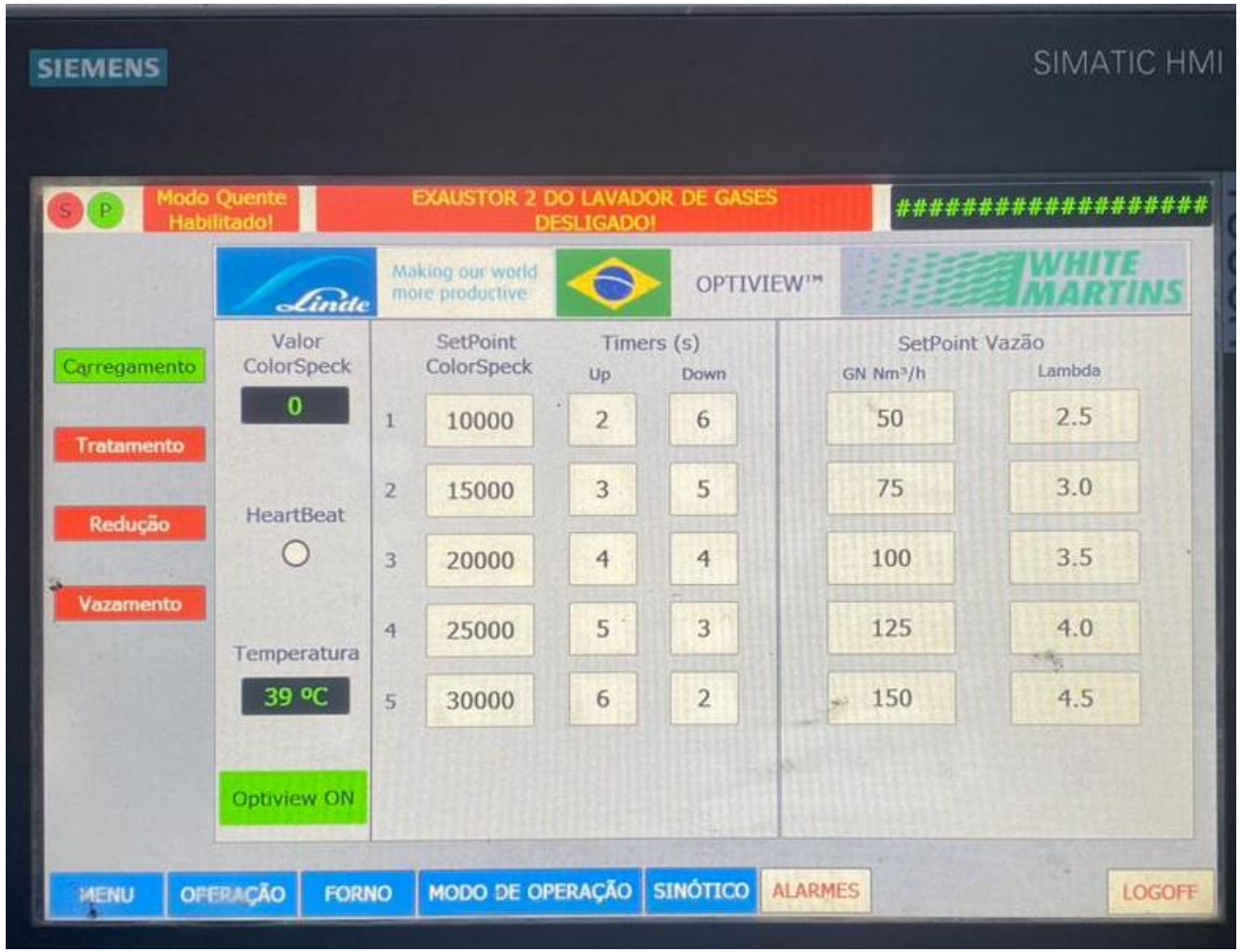
OPTIVIEW camera installed at post-combustion chamber

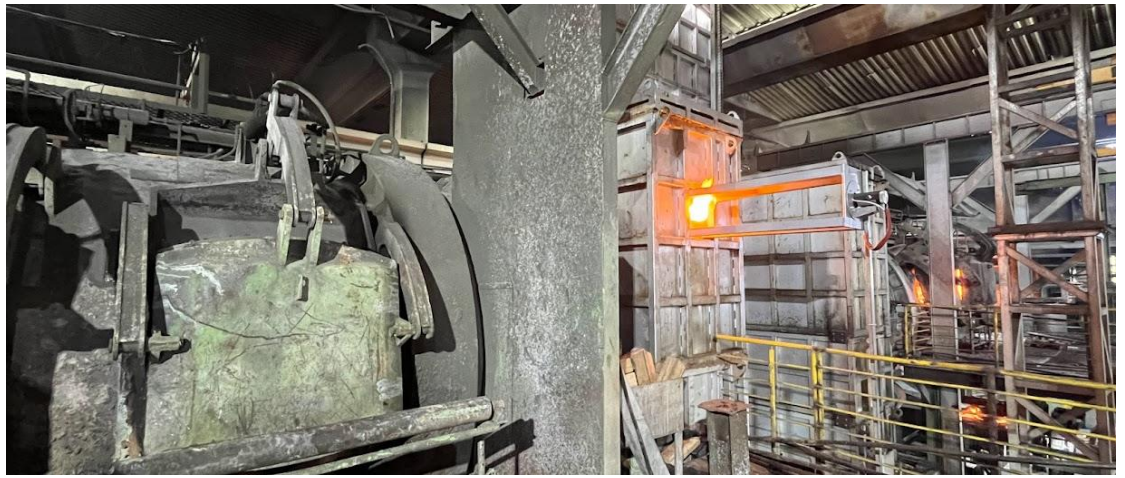
OPTIVIEW Analyses screen



OPTIVIEW®

OPTIVIEW for Copper Smelters





OXYSENSOR

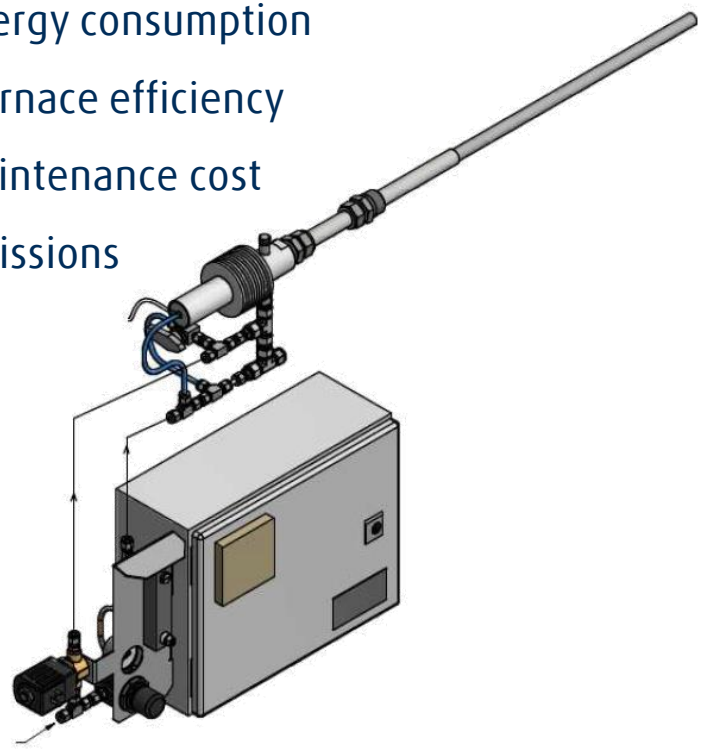
Monitoring the Oxygen concentration inside the furnace with OXYSENSOR is an effective tool to gain control of the leak air situation and therefore:

→ Reduce energy consumption

→ Increase furnace efficiency

→ Reduce maintenance cost

→ Reduce emissions



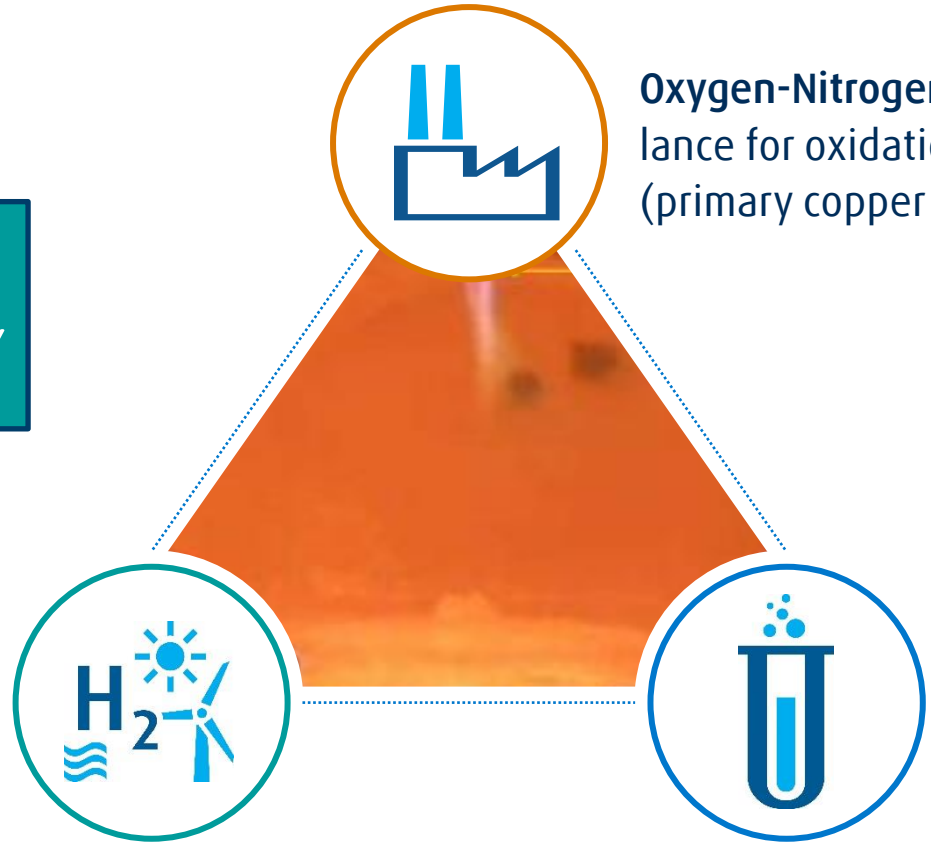
CoJet® Coherent Jet Technology

CoJet® Coherent Jet Technology

Replacing Tuyeres and Lances with different purpose

Hydrogen or Mixes of Hydrogen, Natural Gas, Steam, and Nitrogen for Poling

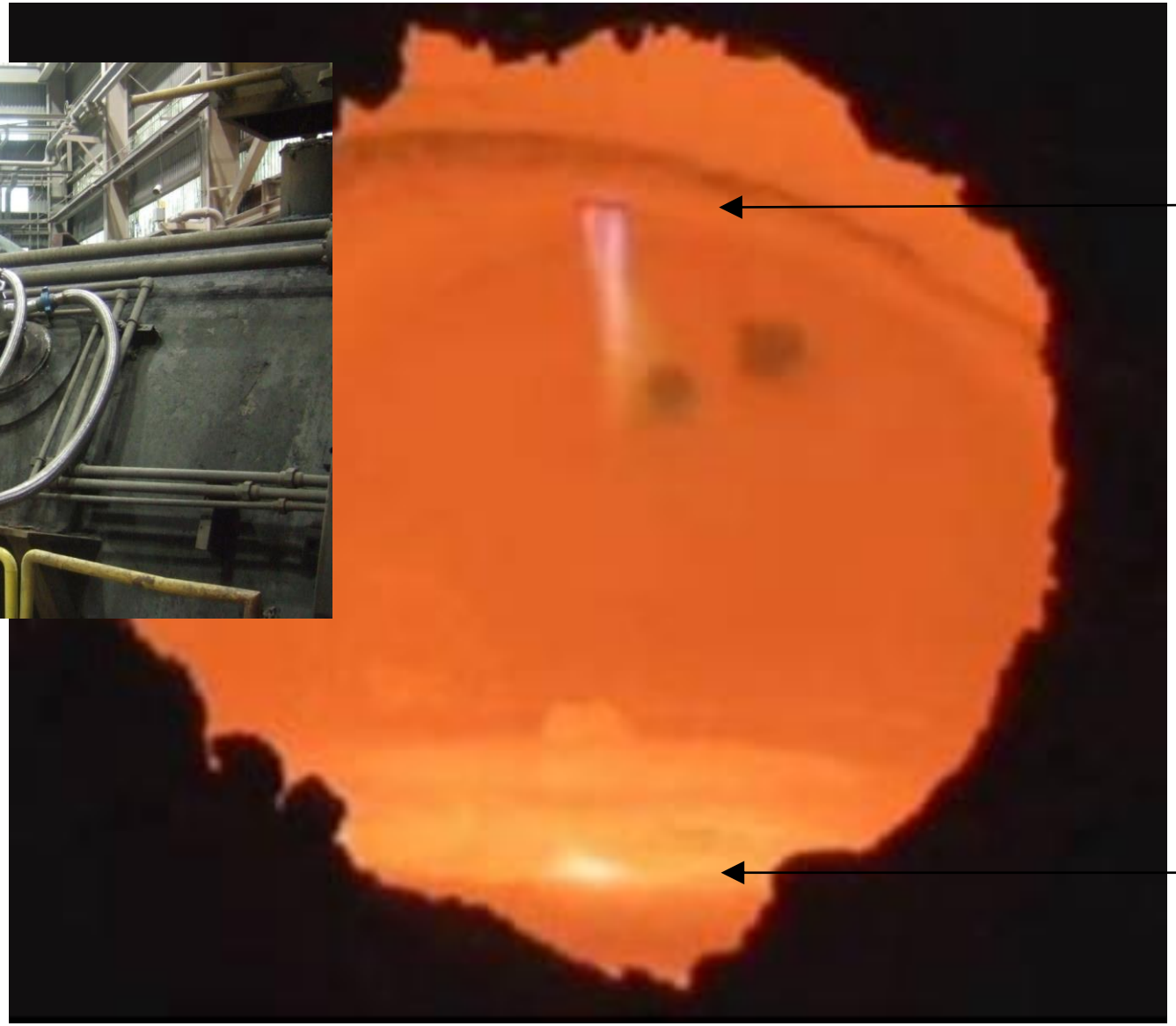
Natural Gas-Nitrogen:
lance for reduction (poling or deoxidation) processes.



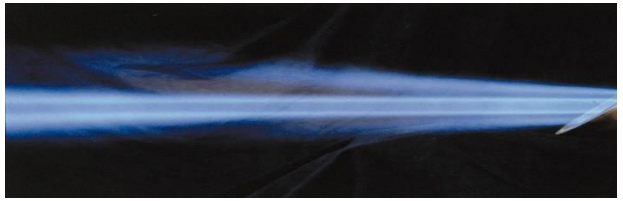
Oxygen-Nitrogen:
lance for oxidation and desulfurization (primary copper production)

Nitrogen:
for stirring

CoJet® Lancing in Copper Production



It has been demonstrated that Hydrogen is the best fuel for CoJet, producing the longest jets!



Thank you for your attention

Joachim von Schéele
Global Director Commercialization
Linde Technology
joachim.von.scheele@linde.com
www.linde.com

Making our world more productive