REBOX® HLL

June 2021

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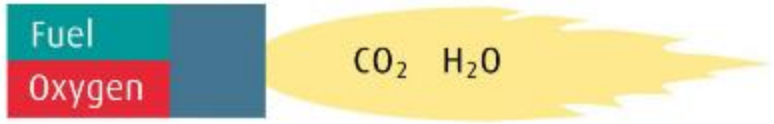
Making our world more productive

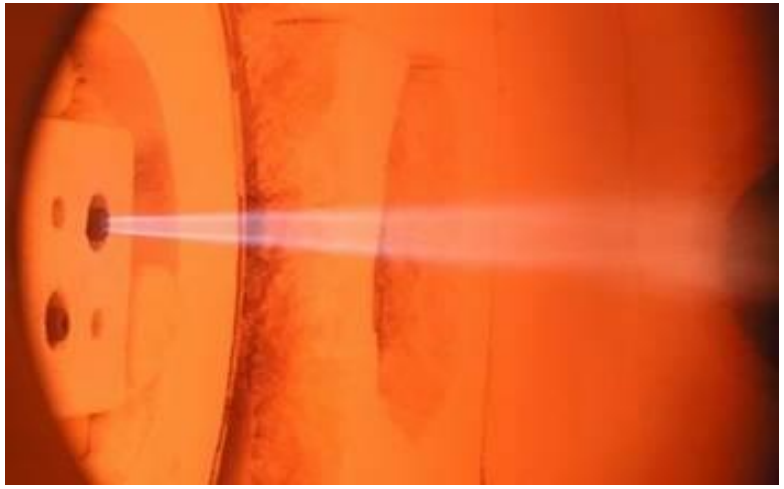
Conventional Oxyfuel and Flameless Oxyfuel

First Flameless Oxyfuel Installations in 2003 at Outokumpu, Sweden

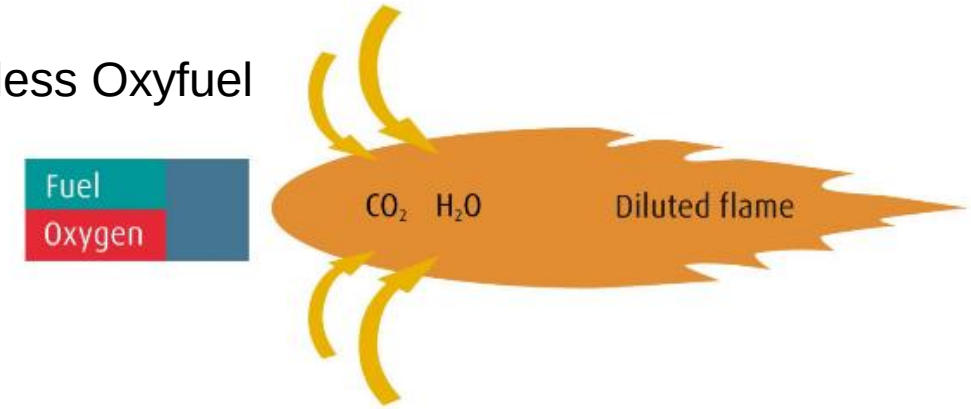
Conventional oxyfuel



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

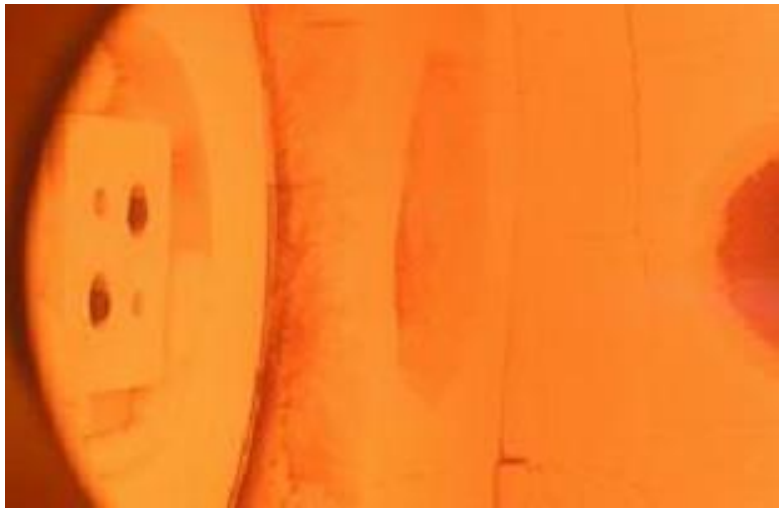


Flameless Oxyfuel



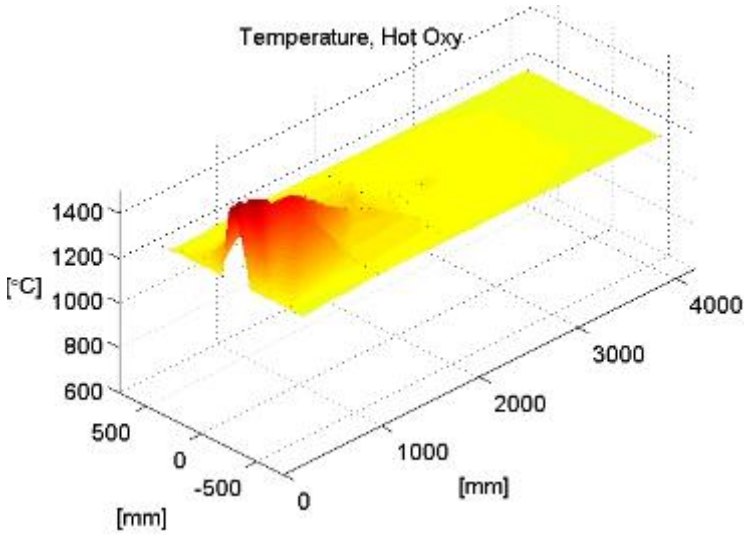
$CH_4 + 2O_2$ + Hot furnace gases $\rightarrow CO_2 + 2H_2O$ + HEAT

$H_2 + \frac{1}{2}O_2$ + Hot furnace gases => H_2O + HEAT

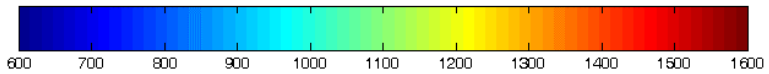


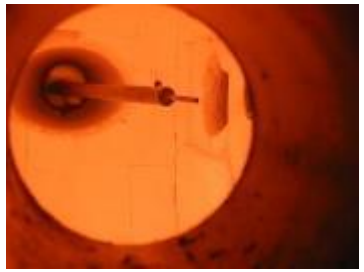
Flame Temperature Profiles
Conventional and Flameless Oxyfuel

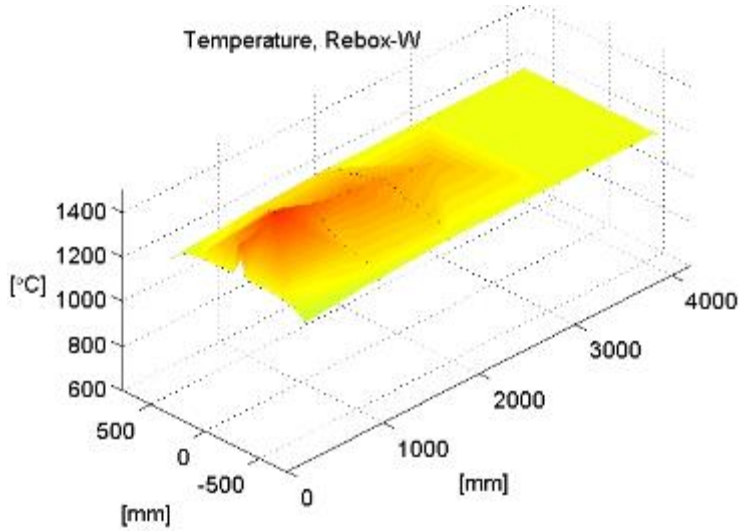
Data from evaluation by Royal Institute of Technology (KTH), Sweden; furnace at 1200°C



Conventional Oxyfuel





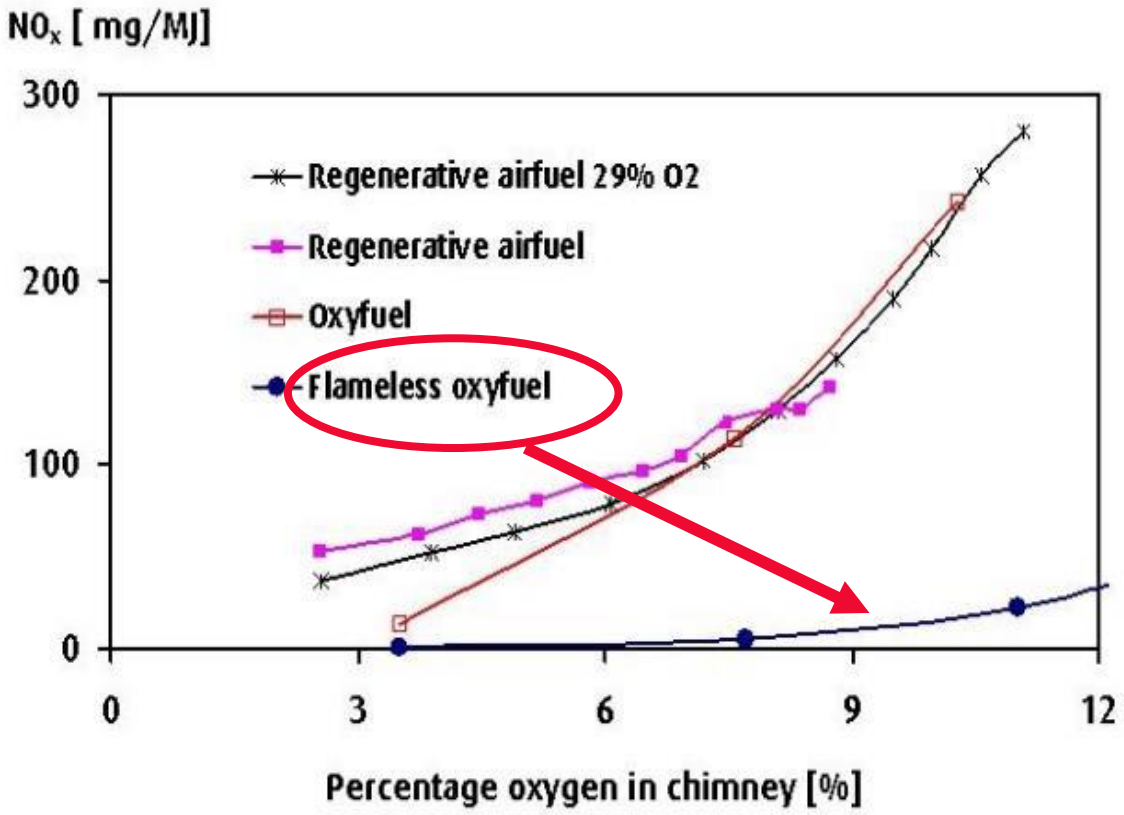


Flameless Oxyfuel

Burner	Peak flame temp
Flameless Oxyfuel	1434˚C
Regenerative burner	1398˚C
Air-fuel burner	1404˚C

Flameless Oxyfuel
90% Lower NOx Emissions

Measured NO_x, data from evaluation by Royal Institute of Technology (KTH), Sweden
NOx levels much less sensitive to in-leakage of air



REBOX®

Installations of REBOX® Oxyfuel solutions in steel reheating have resulted in:

- Capacity Increase by up to 50%
- Fuel Savings of up to 50% (some cases 65%)
- Reduction of CO_2 Emission by up to 50%, by 100% with H_2
- Reduction of NO_x Emission
- Improved temperature uniformity, <5°C
- Decrease of Scaling Losses by up to 50%

180+ REBOX® Oxyfuel installations at 40+ steel mills across the world

Examples of Sites with Installations in Reheating and Annealing

Amsteel, Bukit Raja (MY)
ArcelorMittal, Galati (RO)
ArcelorMittal, Indiana Harbor (US)
ArcelorMittal, Shelby (US)
Ascométal, Les Dunes (FR)
Ascométal, Fos-sur-Mer (FR)
Bei Ye, Beijing (CN)
Celsa, Mo i Rana (NO)
Dongbei Special Steel, Dalian (CN)
Electrosteel, Kharda (IN)
Ellwood City Forge, Ellwood City (US)
Evraz Steel, Claymont (US)
Gerdau Cosigua, Rio de Janerio (BR)
Hospet Steel, Hospet (IN)

Jindal SAW, Nashik (IN)
Jindal Stainless, Hisar (IN)
Kalyani Carpenter Special Steels, Pune (IN)
Mahindra Sanyo Special Steel, Khopoli (IN)
Malaysia Steel Works, Bukit Raja (MY)
Malaysia Steel Works, Petaling Jaya (MY)
Marienhuette, Graz (AT)
Masteel, Ma'anshan (CN)
Michigan Seamless Tube, South Lyon (US)
North American Forgemasters, New Castle (US)
Nucor, Auburn (US)
Outokumpu, Avesta (SE)
Outokumpu, Degerfors (SE)
Outokumpu, Nyby (SE)
Outokumpu, Tornio (FI)

Ovako, Hofors (SE)
Ovako, Smedjebacken (SE)
POSCO, Pohang (KR)
Sandvik Materials Technology (SE)
Scana Steel, Björneborg (SE)
Siam Yamato Steel, Rayong (TH)
SSAB, Borlänge (SE)
ThyssenKrupp Steel, Bruckhausen (DE)
ThyssenKrupp Steel, Finnentrop (DE)
TMK Ipsco, Koppel (US)
Vedik Ispat, Hindupur (IN)
Yongxing Stainless Steel, Huzhou (CN)
Zhongxing Energy, Haimen (CN)

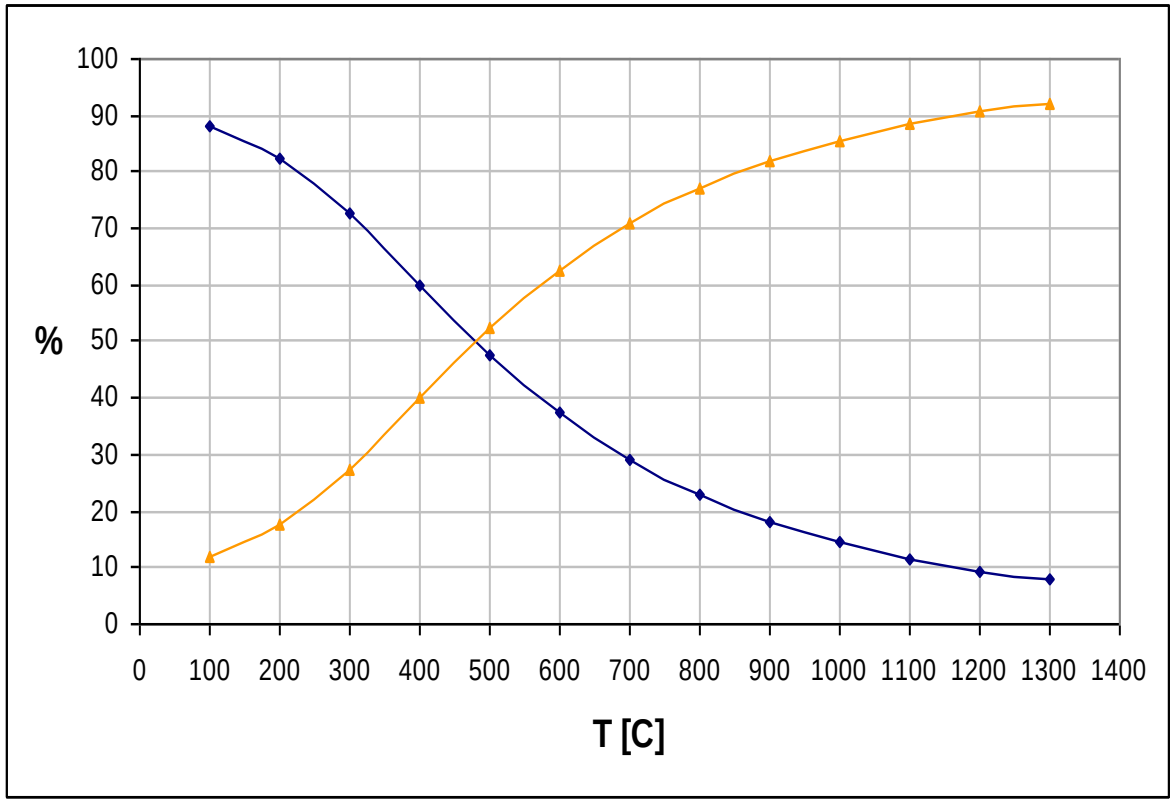
REBOX® HLL

No full conversion, but more capacity and less fuel consumption

- Add-on solution to existing air-fuel burners
- Minimum installation down time
- Great flexibility, can be turned on and off with a response time of 1 minute
- Optimized in response to fluctuating fuel cost and productivity requirement
- Beneficial use of LCV fuel
- Capacity increased 20%, fuel saving 15%

REBOX HLL at Outokumpu, Tornio (Finland)

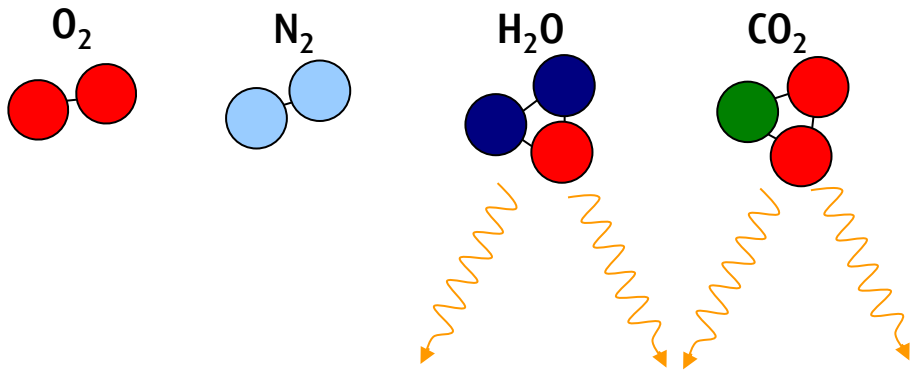
Heat transfer mechanism

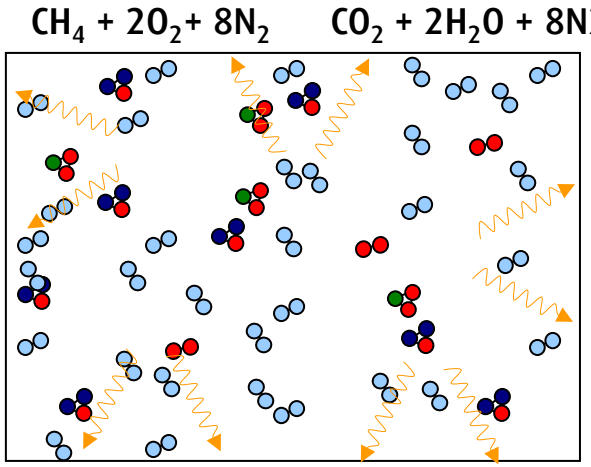


Convection

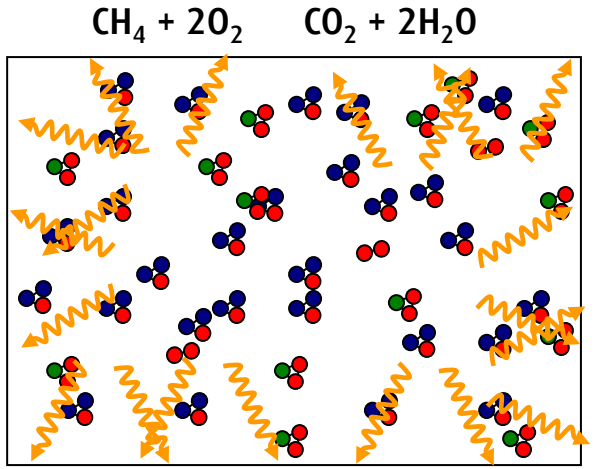
Radiation

Gas radiation



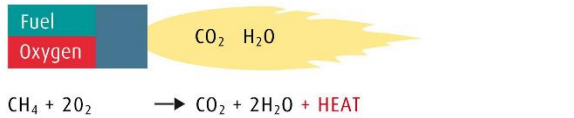


Conventional Air Fuel burner

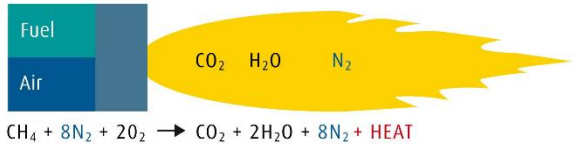


Oxyfuel burner

HLL compared with conventional solutions

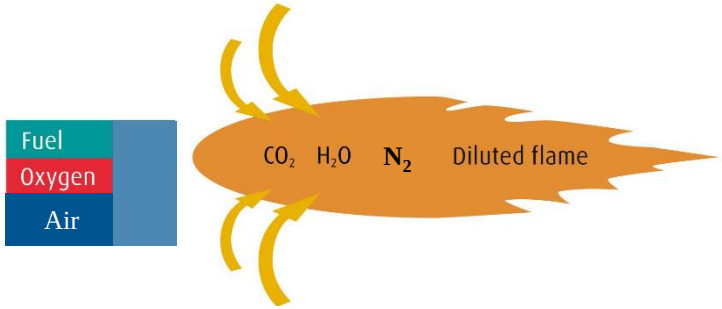


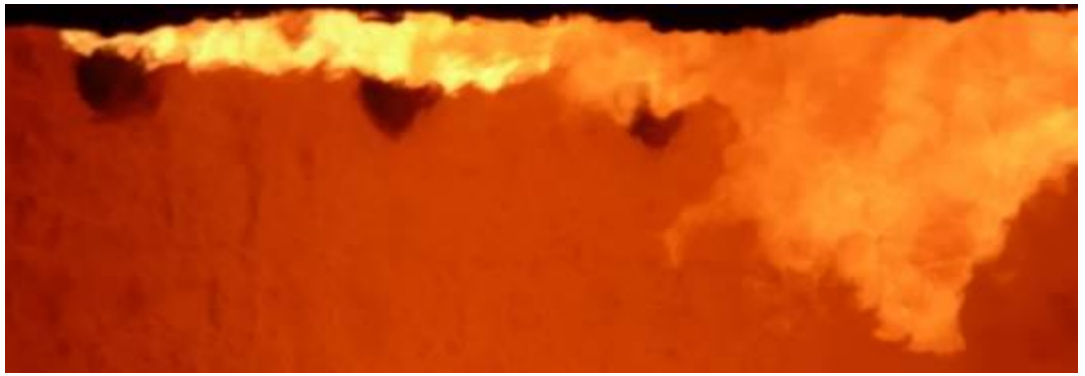
Oxyfuel



Air Fuel

HLL (sub-stochiometric air flows with separate O_2 injection)





$CH_4 + 2O_2 + \sim 2N_2$ + Hot furnace gases => $CO_2 + 2H_2O + \sim 2\ N_2$ + HEAT

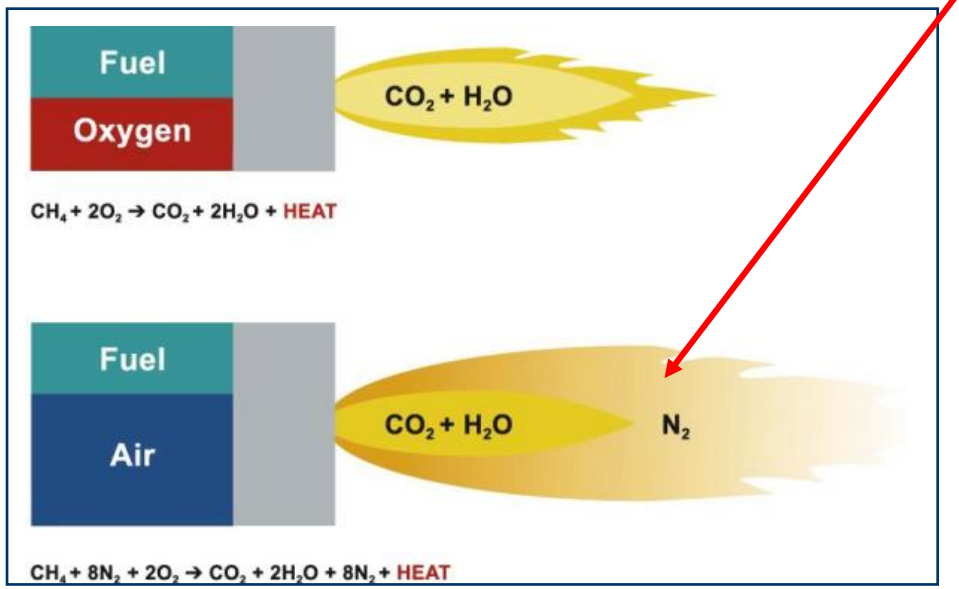
1,5 from 02
0,5 from air

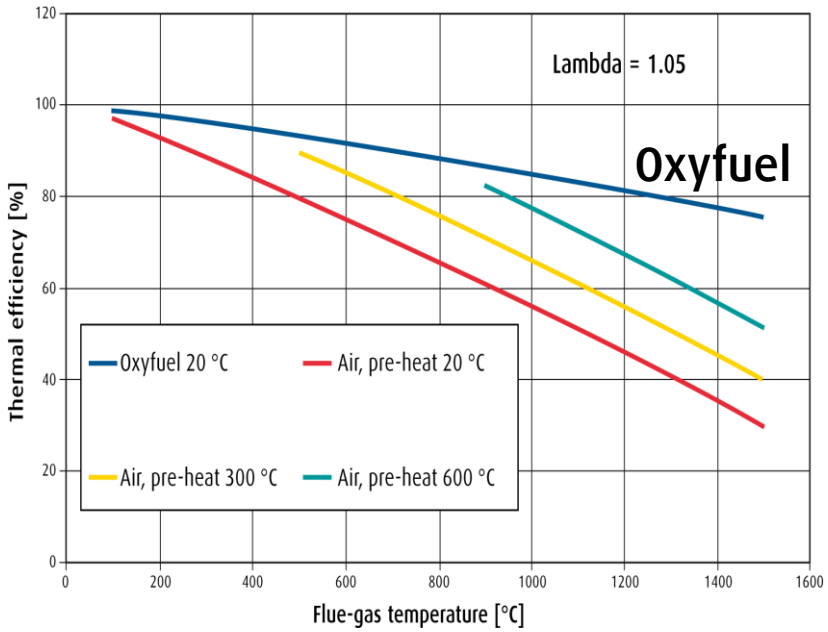
Oxyfuel Solutions

Energy efficiency, increased throughput, lowered emissions

- Low flue-gas losses due to low flue-gas volume
- Low flue-gas losses even at high flue-gas temperatures
- Radiating compounds, H_2O & CO_2
- Low flue-gas volumes allows longer time for radiation
- Possible to use high power input
- Possible to use Low Calorific Fuels

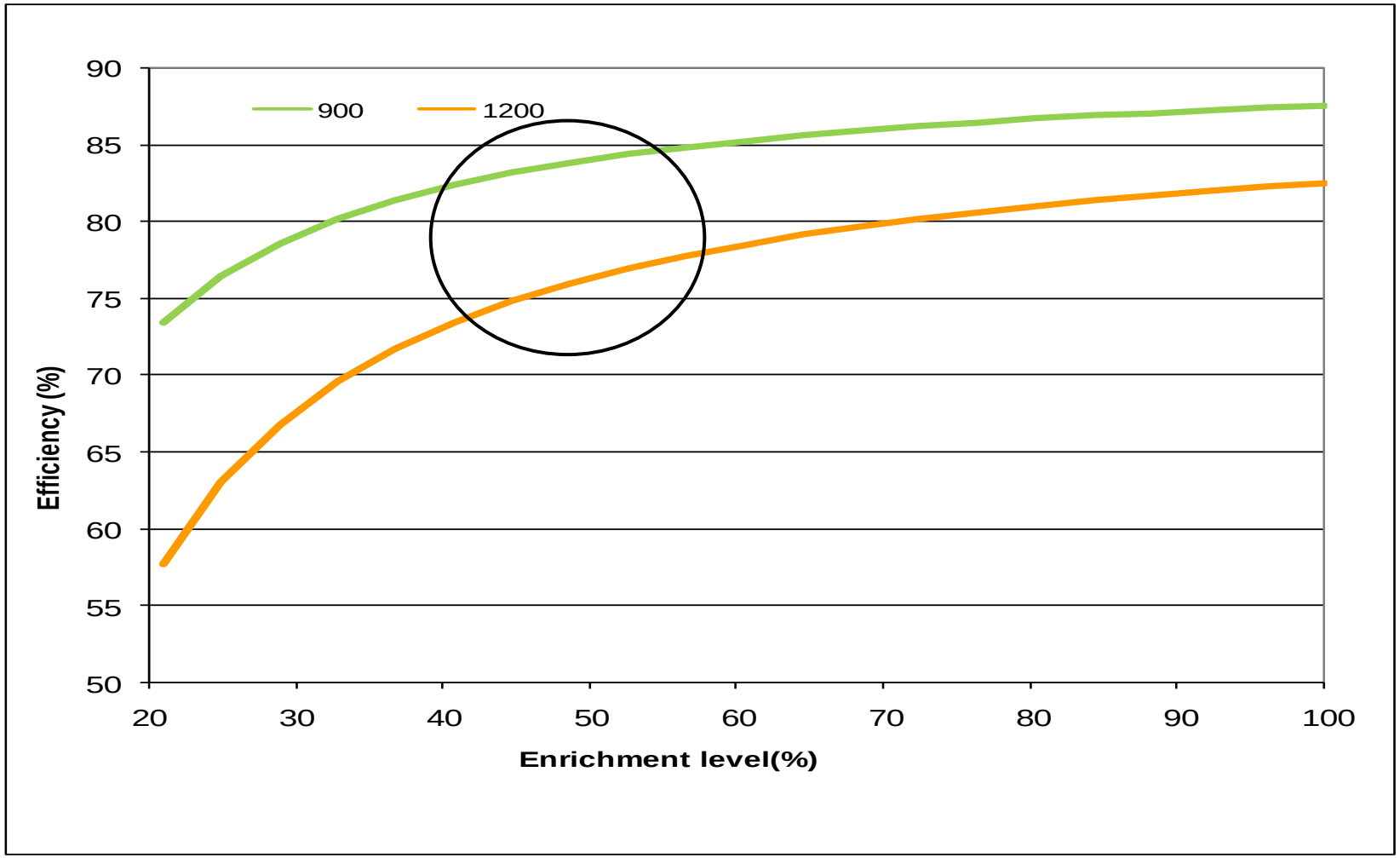
8 Molecules of Nitrogen Ballast!



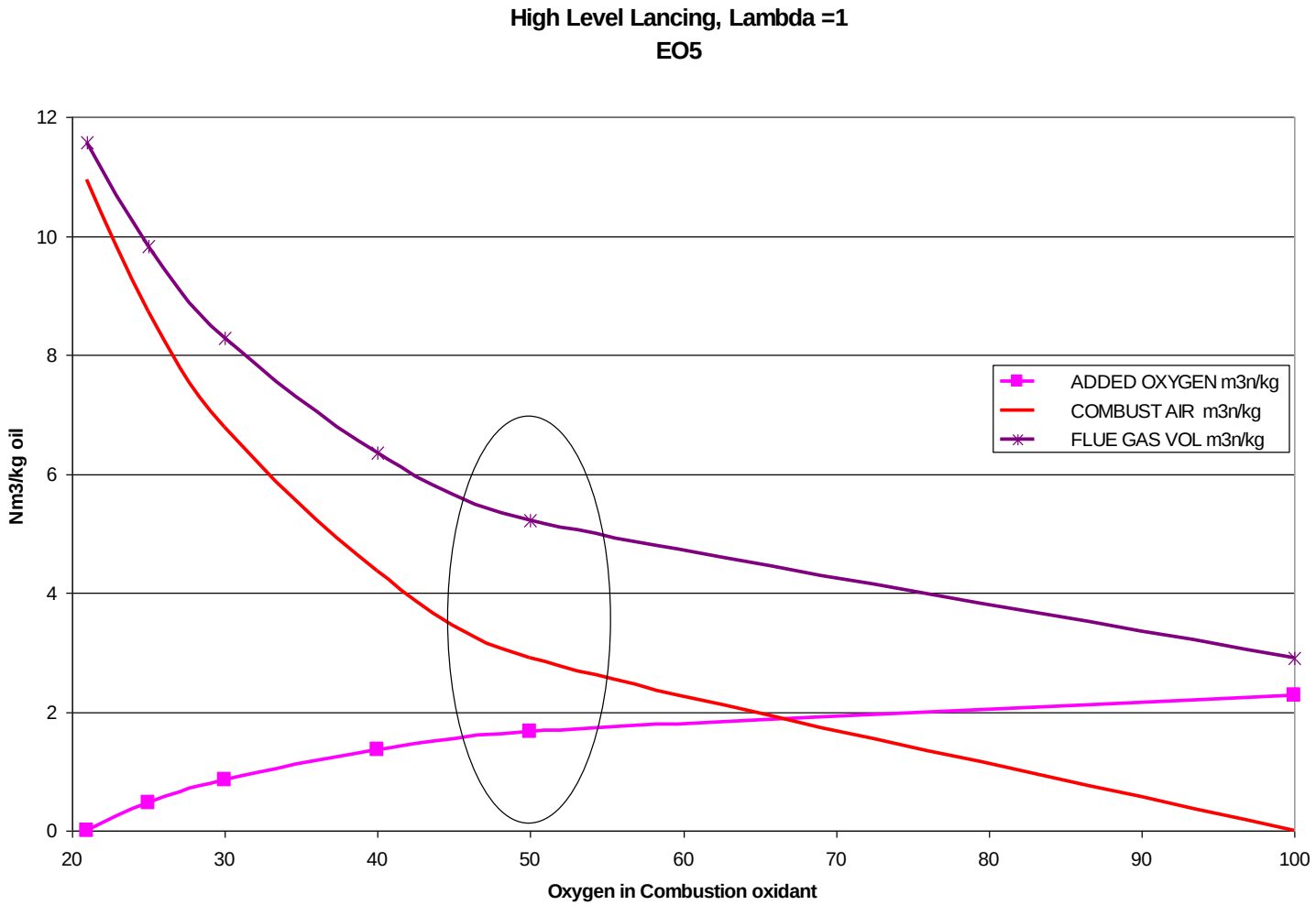


Combustion efficiency

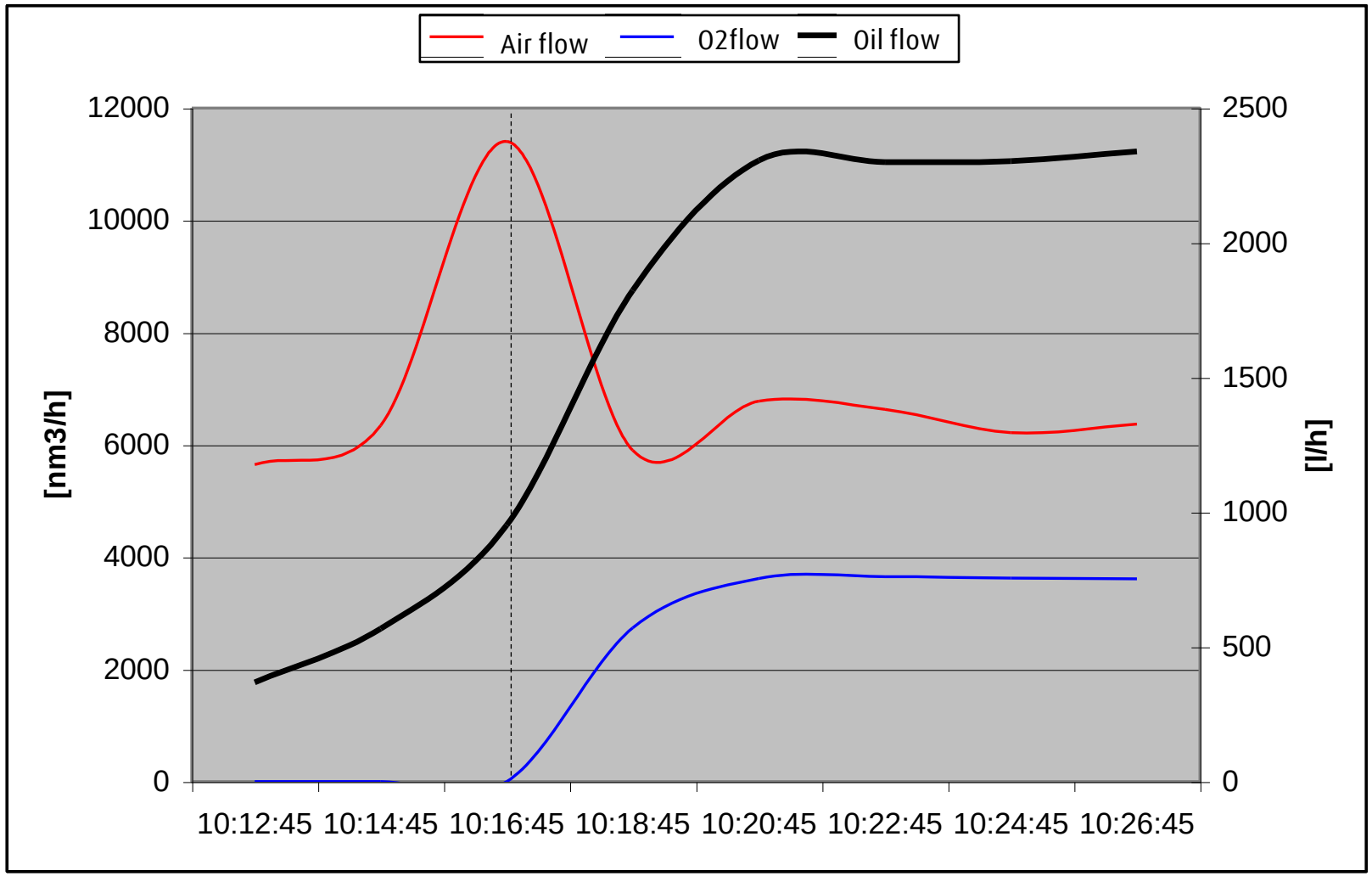
at 400oC Combustion air temp for different zone temperature (oC)



Flue gas- Air- and Oxygen volumes

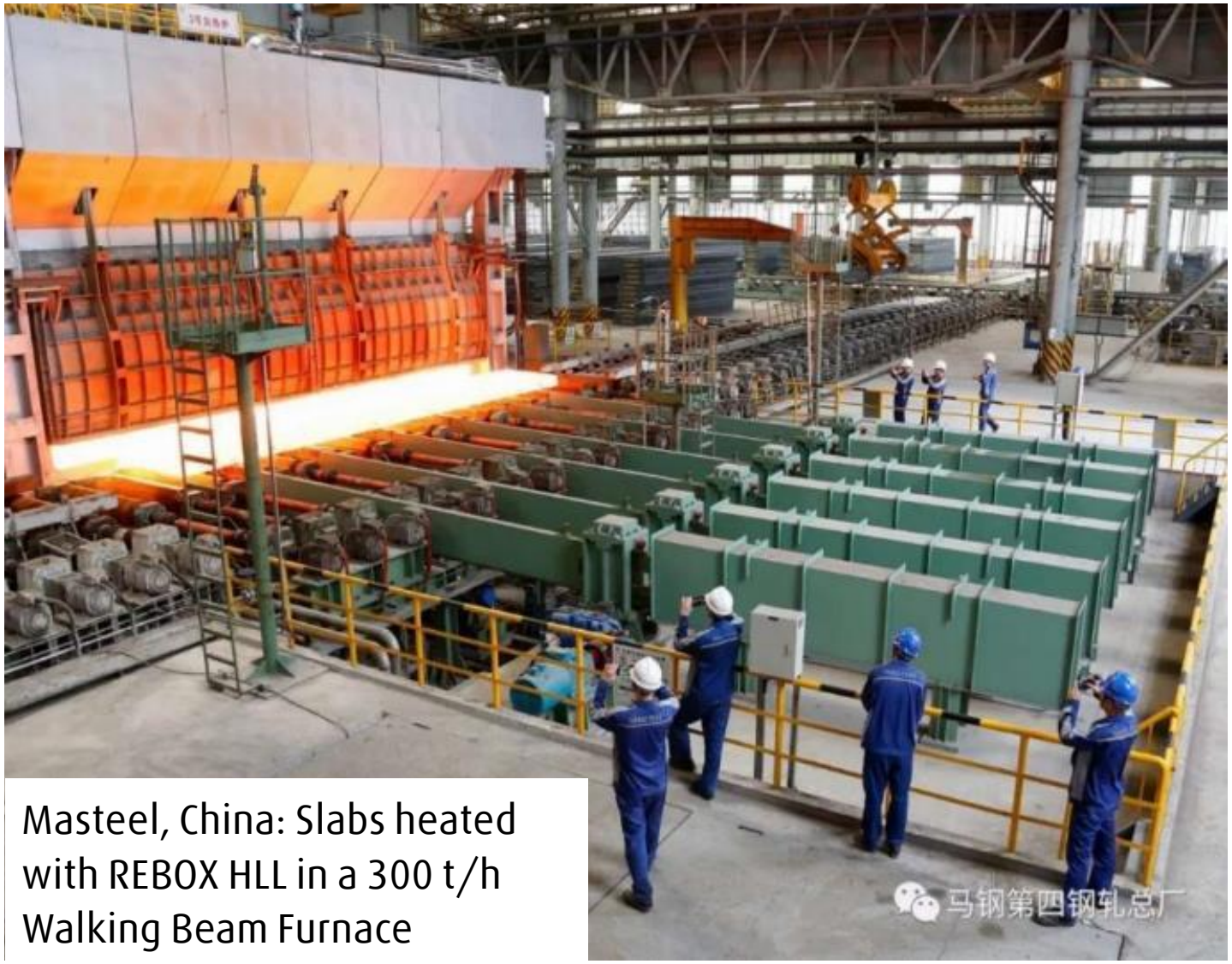


Combustion air, fuel and oxygen flows at increasing power



REBOX® HLL

Masteel, China



Masteel, China: Slabs heated with REBOX HLL in a 300 t/h Walking Beam Furnace

Add-on system, typically put in the pre-heating and/or heating zones

10-30% lower fuel consumption and CO_2 emissions, lower NOx emissions

2021 REBOX HLL – Commissioned and New Contracts:

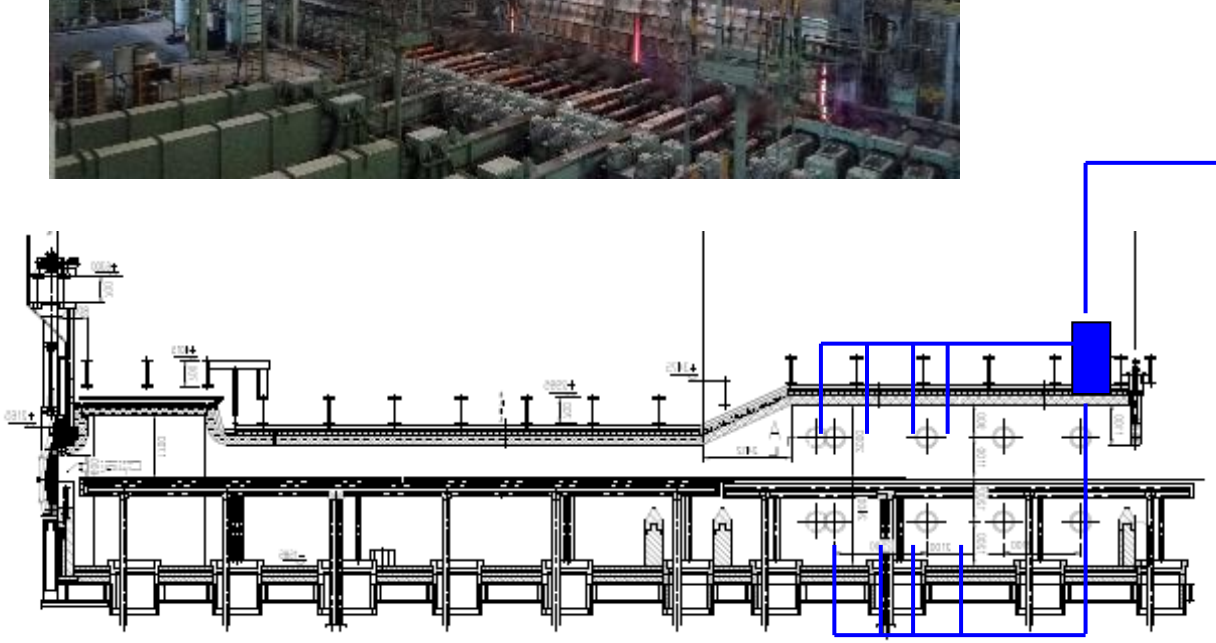
- Jindal Stainless, India
- Celsa, Norway
- Amsteel, Malaysia
- ArcelorMittal, Germany

REBOX® HLL - MaSteel, China

300 t/h Walking Beam Furnace

Furnace Capacity

300 tph



REBOX® HLL at Masteel, China

Benefits in the Rolling Mill

Comparison of Rolling Force applied on the Slabs

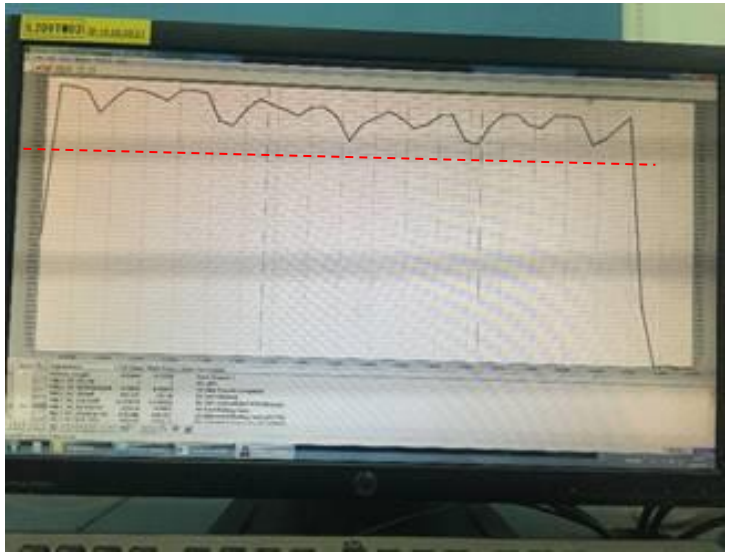
HLL Status	Rolling Force - Mill-2 (KN)	Steel Grade
OFF	18,903	Silicon Steel
ON	18,193	Silicon Steel
OFF	20,069	Low Alloy Steel
ON	18,952	Low Alloy Steel

The rolling force applied on the slab is 5% lower when the slabs are heated with HLL

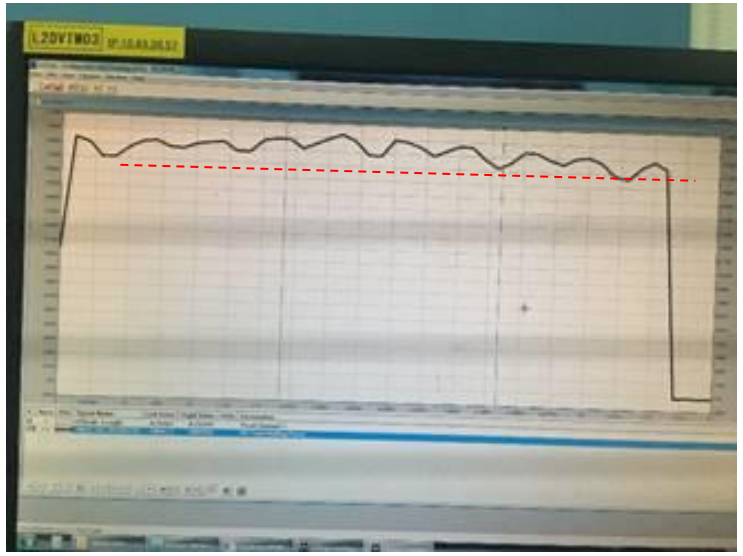
REBOX® HLL at Masteel, China

Benefits in the Rolling Mill

Comparison of Rolling Force applied across Length of Slab



HLL Off



HLL On

The Rolling Force is more uniform when the slabs are heated with HLL

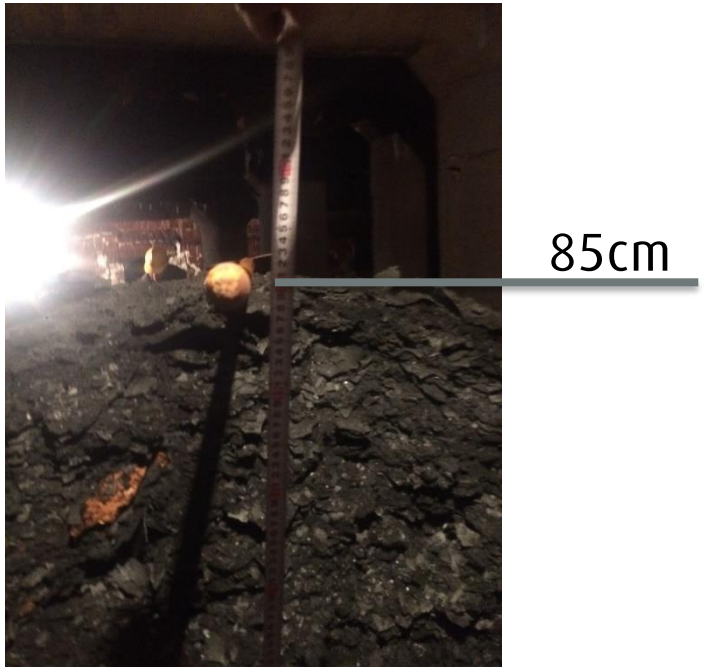
REBOX® HLL at Masteel, China

Some very good results

- Capacity: >20%
- Fuel Savings: >20%
- Scale Losses: Reduced by about 20%
- Temperature Uniformity:

  Large improvement; measurements on Roll Forces show 5% reduction and much more even distribution across the slab length
- NOx Emissions: Although only HLL in one Heating Zone, total NOx emissions are down by >20%.

Reduction of Scale Losses by Using REBOX® HLL at Masteel

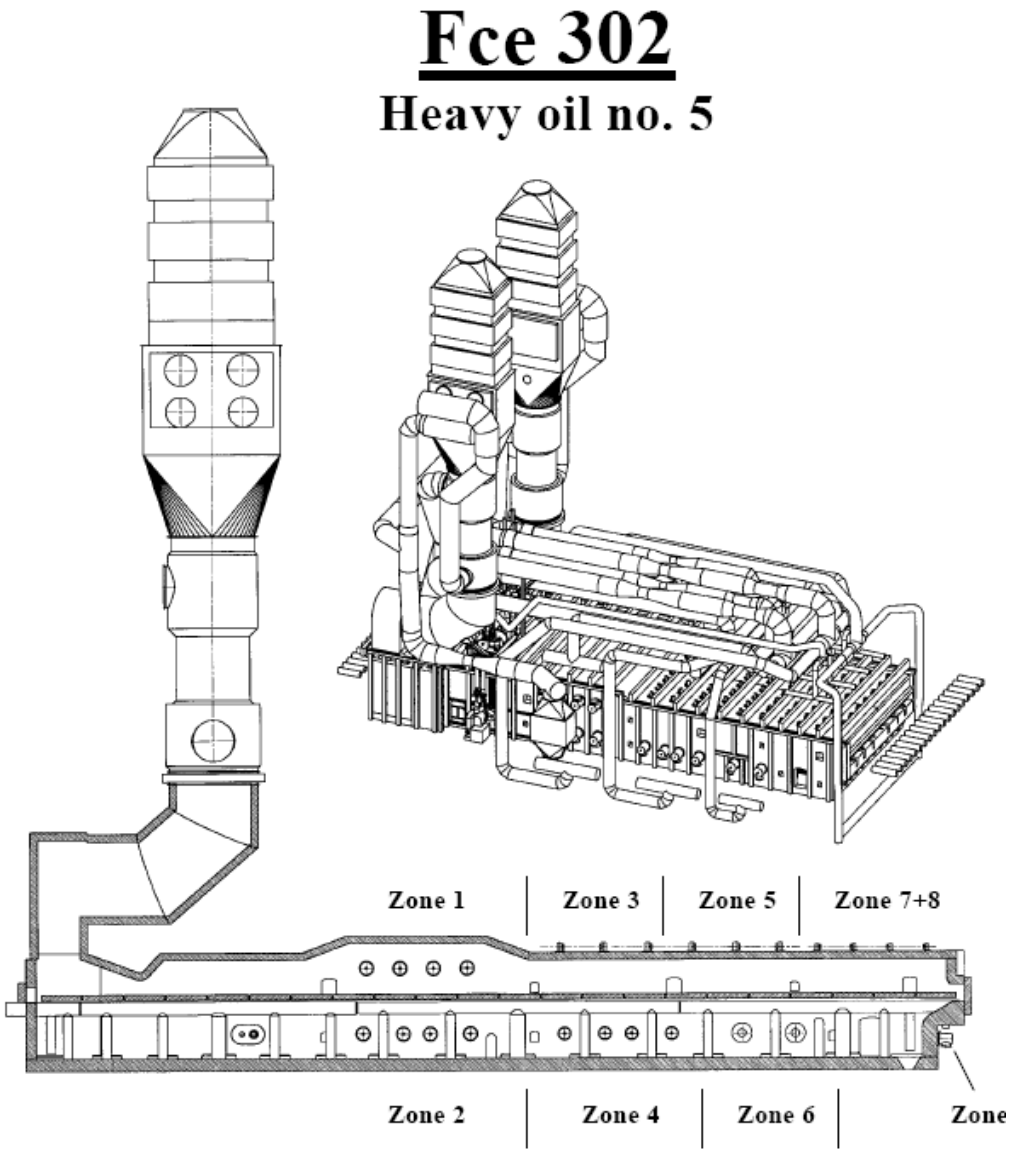


Furnace #3

REBOX HLL in Heating Zone

By measuring the height of the pile of oxide scales at the exit of the almost identical furnaces #2 (without HLL) and #3 (with HLL), after the same amount of time in operation and at the same throughput, it was clear that less scale was created by using HLL. The height of the piles where 85 respectively 105 cm. A reduction of scale corresponding to ~20%

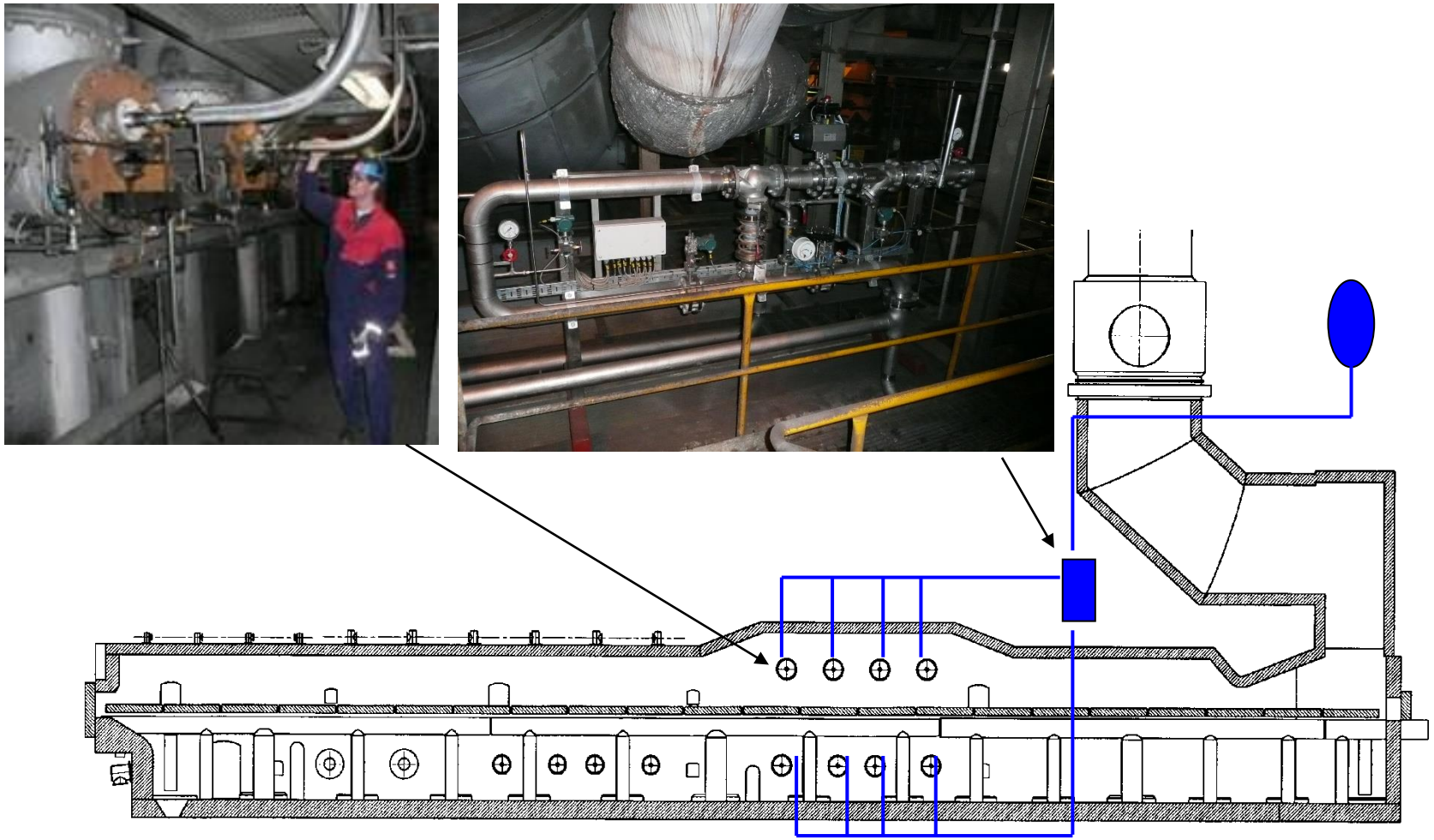
REBOX® HLL reference, SSAB Borlänge, Sweden



Zone	Burners		Capacity each	Total capacity
1	2x4	8	3 540 kW	28 320 kW
2	2x4	8	3 540 kW	28 320 kW
3	3x8	24	657 kW	15 768 kW
4	2x4	8	2 730 kW	21 840 kW
5	3x8	24	657 kW	15 768 kW
6	2x2	4	4 046 kW	16 184 kW
7+8	2x4x4	32	506 kW	16 192 kW
9	1x9	9	1 110 kW	9 990 kW

Furnace size internal	Slab size	Capacity
Length 37 m	Thickness 220 mm	300 tph
Width 12 m	Length 11 m	
	Width <1,5 m	

REBOX® HLL, installation at SSAB



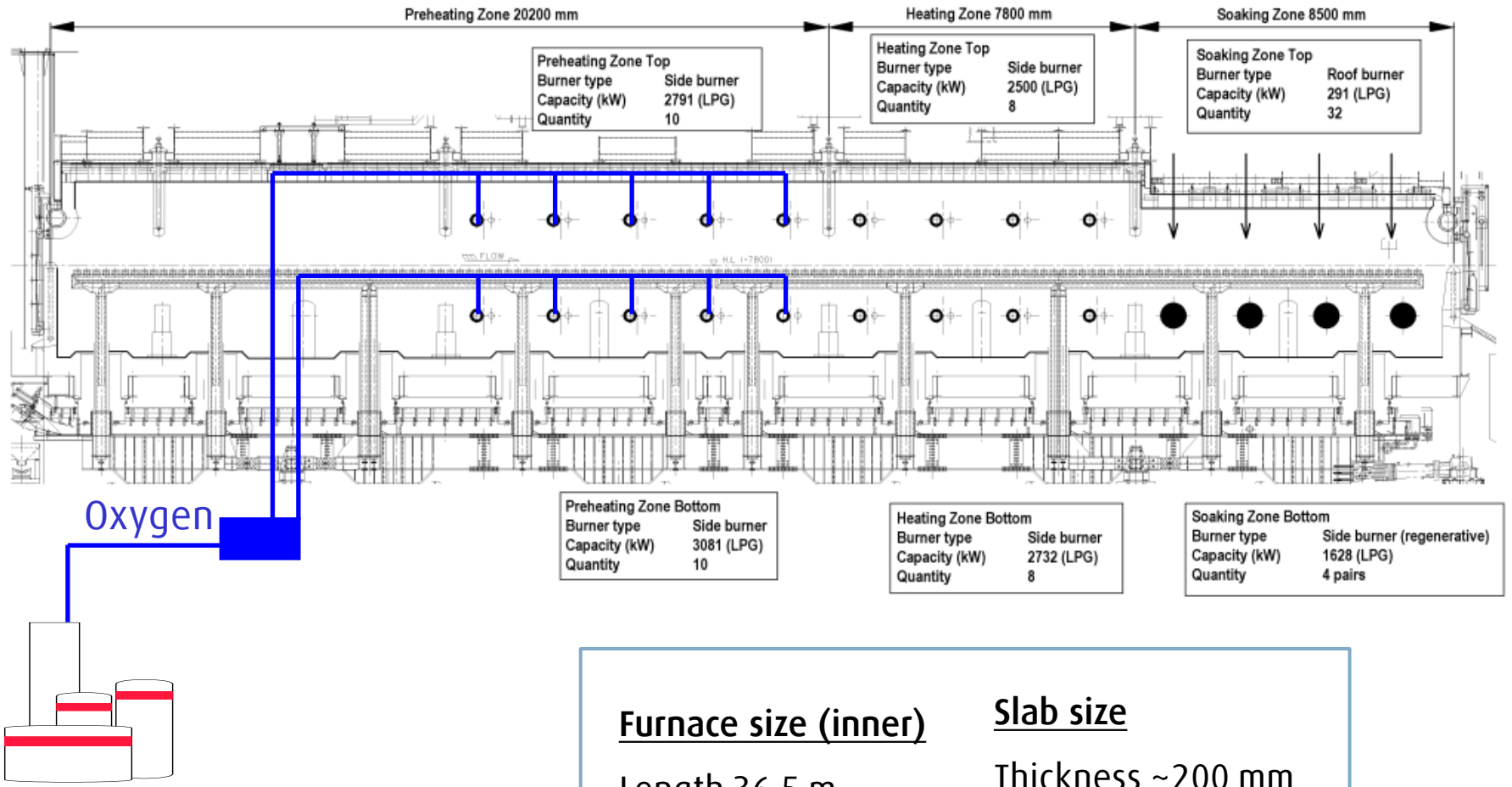
Results from HLL in preheating zones at SSAB

- Total energy consumption down ~15%
- Capacity increase ~15%
- Improved temperature uniformity in furnace & slabs
- Total NOx down ~30% (in kg/ton heated steel)
- No negative influence on surfaces or temp uniformity
- The furnace can easily follow the ideal heating curve from level 2 system
- No restriction in furnace pressure or combustion air capacity
- The crane operators claim that ”less smoke and heat enters the building”

REBOX® HLL Reference, Outokumpu, Finland

Flow control equipment

WBF nr 2 Outokumpu Tornio Works



Furnace size (inner)

Length 36,5 m

Width 14,8 m

Slab size

Thickness ~200 mm

Length 12 m

Width ~1,3 m