Gaswärme-Institut e.V.
Essen

# State-of-the-art oxyfuel solutions for reheating and annealing furnaces in steel industry

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  - energy
  - scale formation
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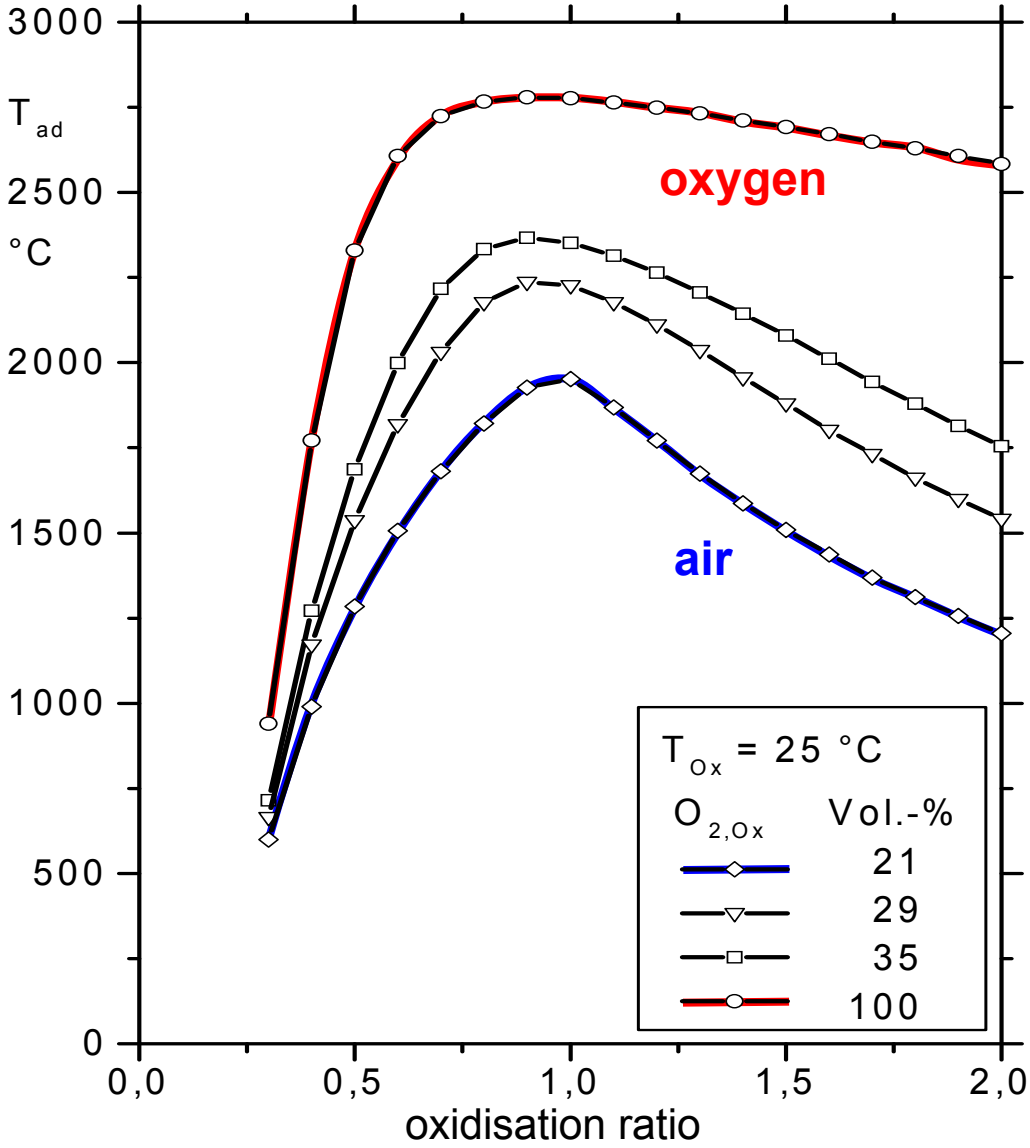
# Introduction – advantages & disadvantages

- no nitrogen ballast
- high efficiency – no heat recovery equipment
- moderate peak temperatures even using oxygen
- reduced scale formation
- steel production is a combination of process steps – demand for flexibility
- increased throughput capacity and higher flexibility using oxyfuel

- costs for $O_2$

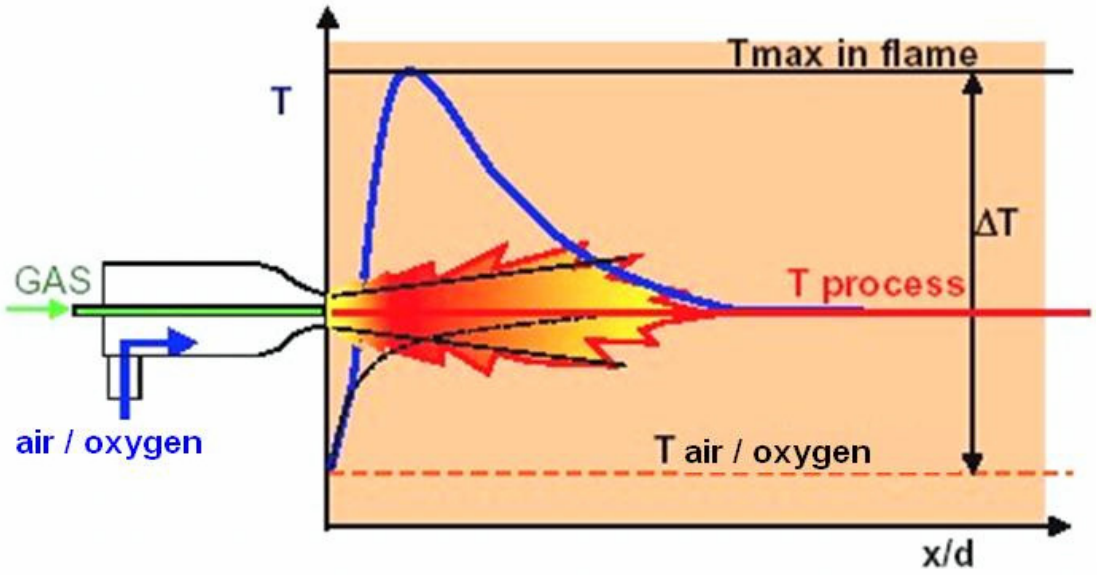
explanations & examples

# Introduction - temperatures




theoretical adiabatic combustion temperature using high calorific natural gas and different oxidators

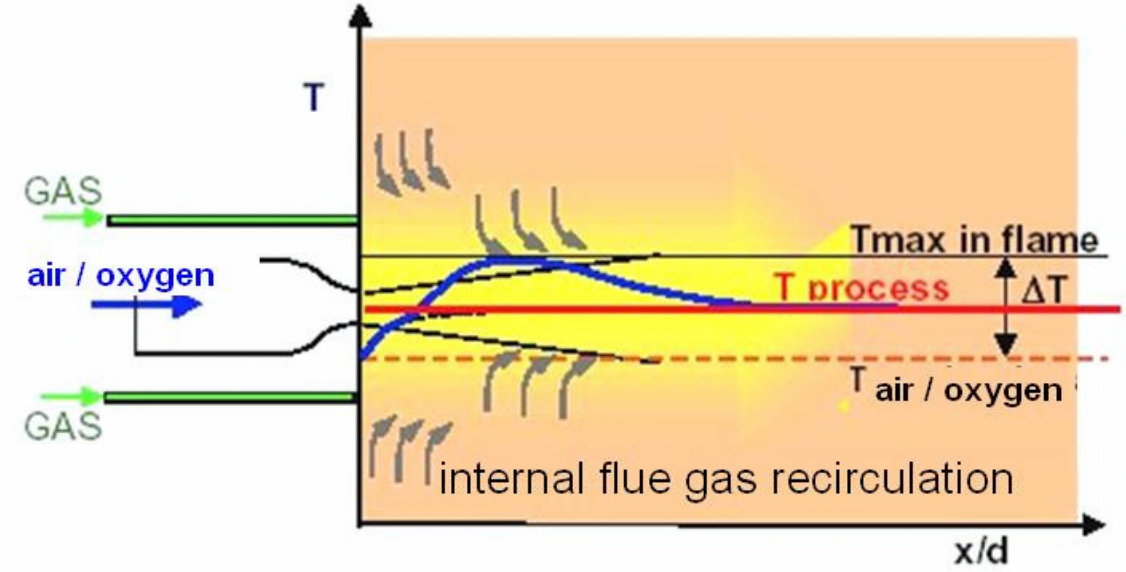
# Introduction - temperatures




standard combustion

moderate temperatures based on internal flue gas recirculation

state of the art
- diluted combustion
- mild combustion
- flameless oxidation
- flameless oxyfuel



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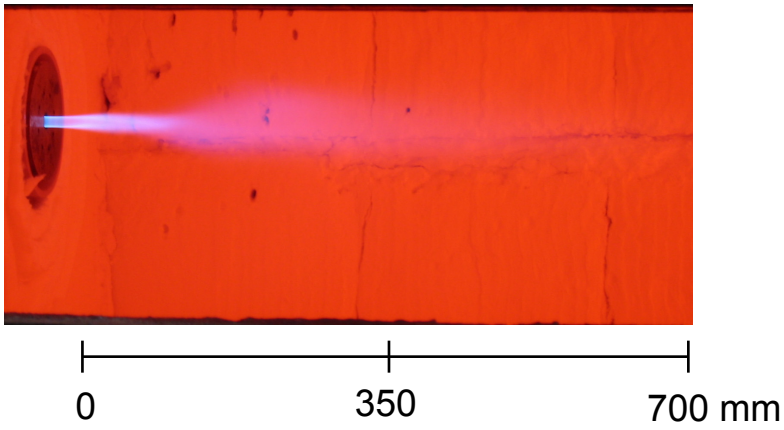
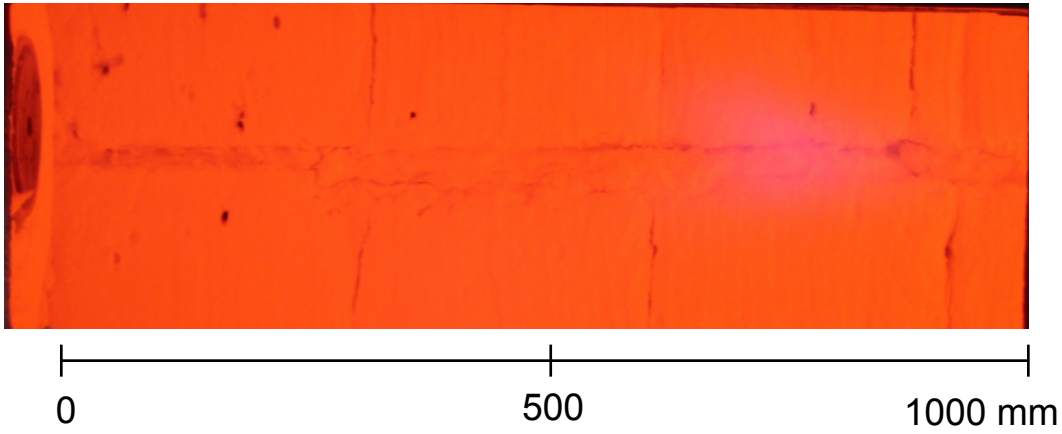



oxyfuel staged combustion
with 5 % primary oxygen




flameless oxyfuel

# Introduction – scale formation

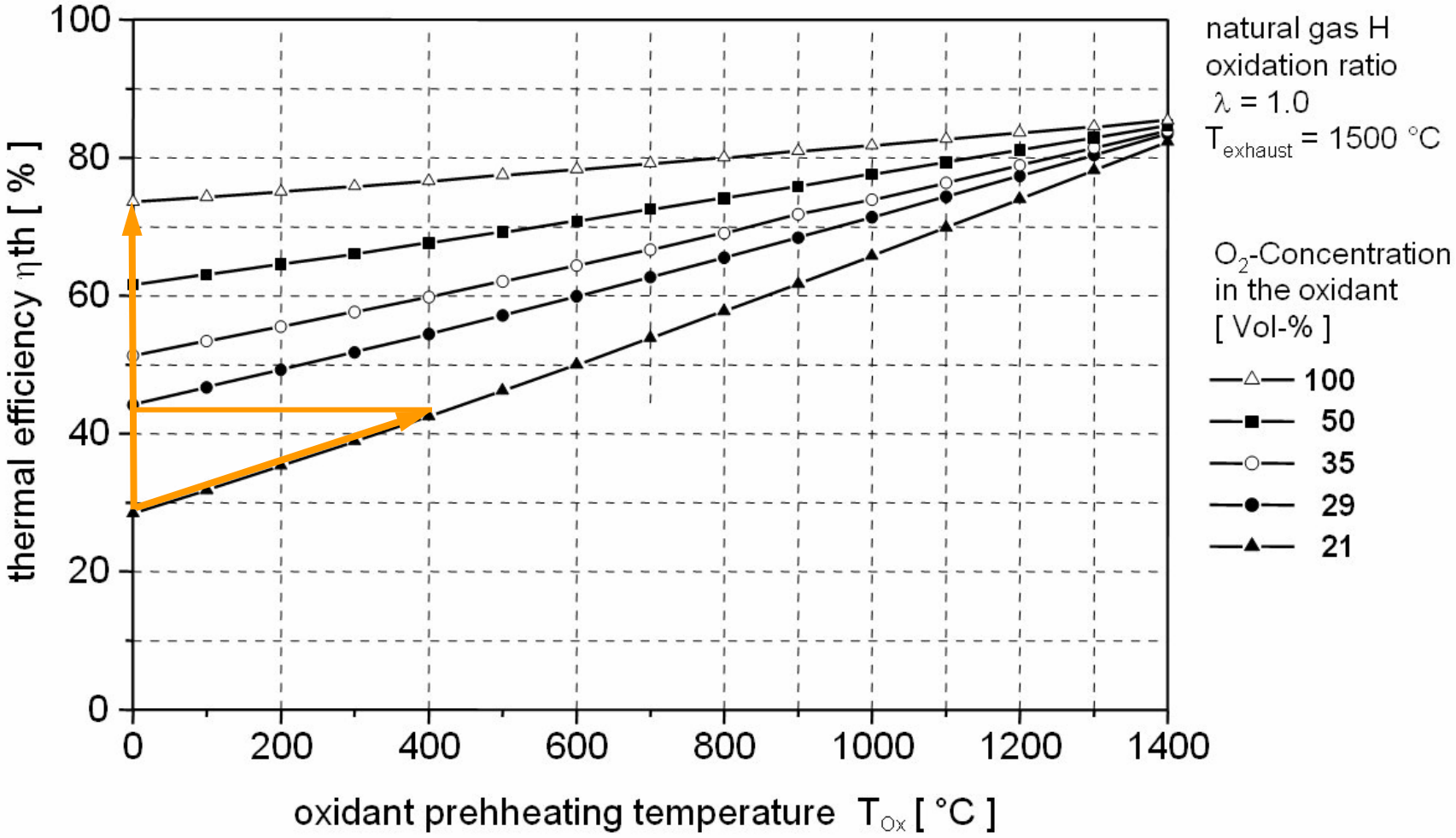
$$\dot{m}_{scale} = f\left(p_{O_2}, \Delta t, \ldots\right)$$

- recirculation and dilution due to flue gas entrainment
- reduced local partial pressures of $O_2$
- avoiding temperature peaks
- reduced resident time of product in furnace

reduced scale formation

# Introduction - energy

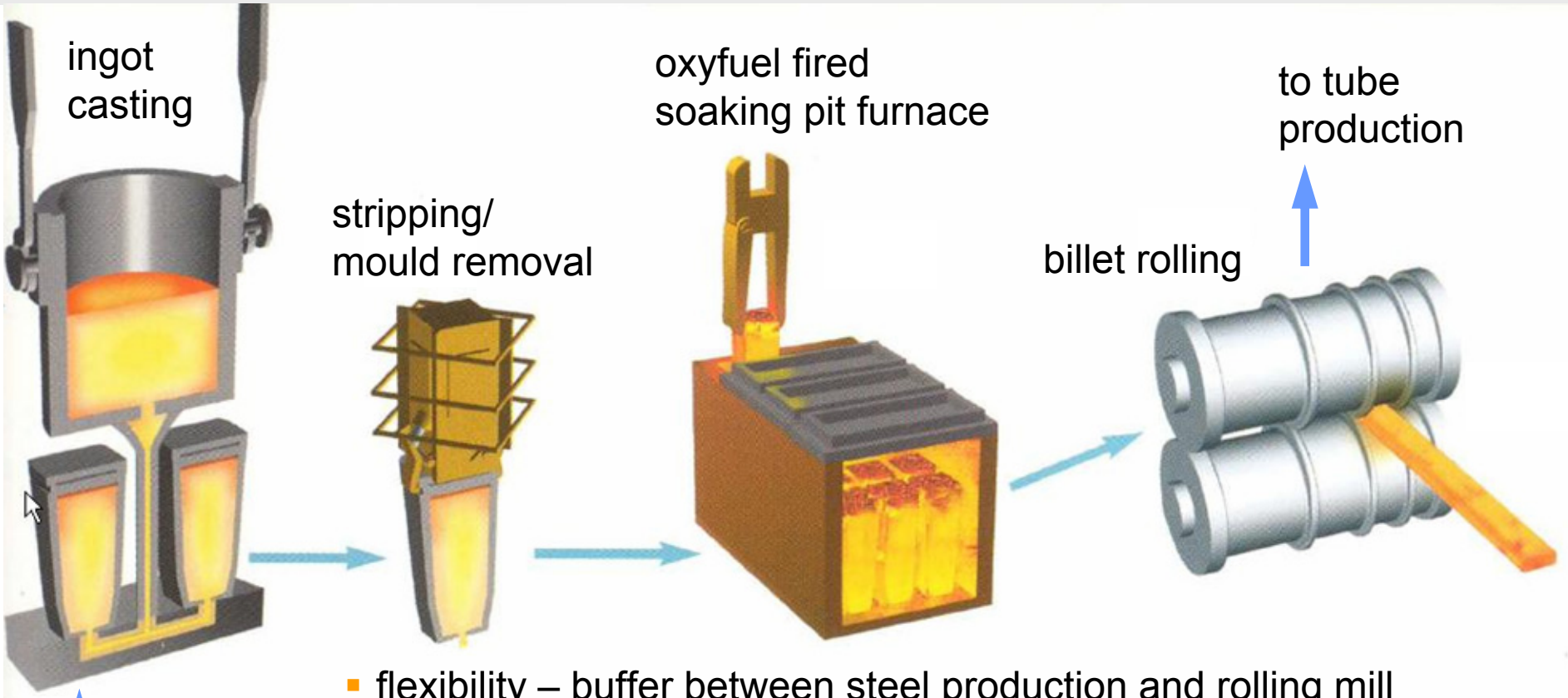
high efficiency for oxyfuel – even without heat recovery



# Ovako – soaking pit furnaces

48 furnaces converted to oxyfuel combustion at Ovako Steel, Horfors works, Sweden

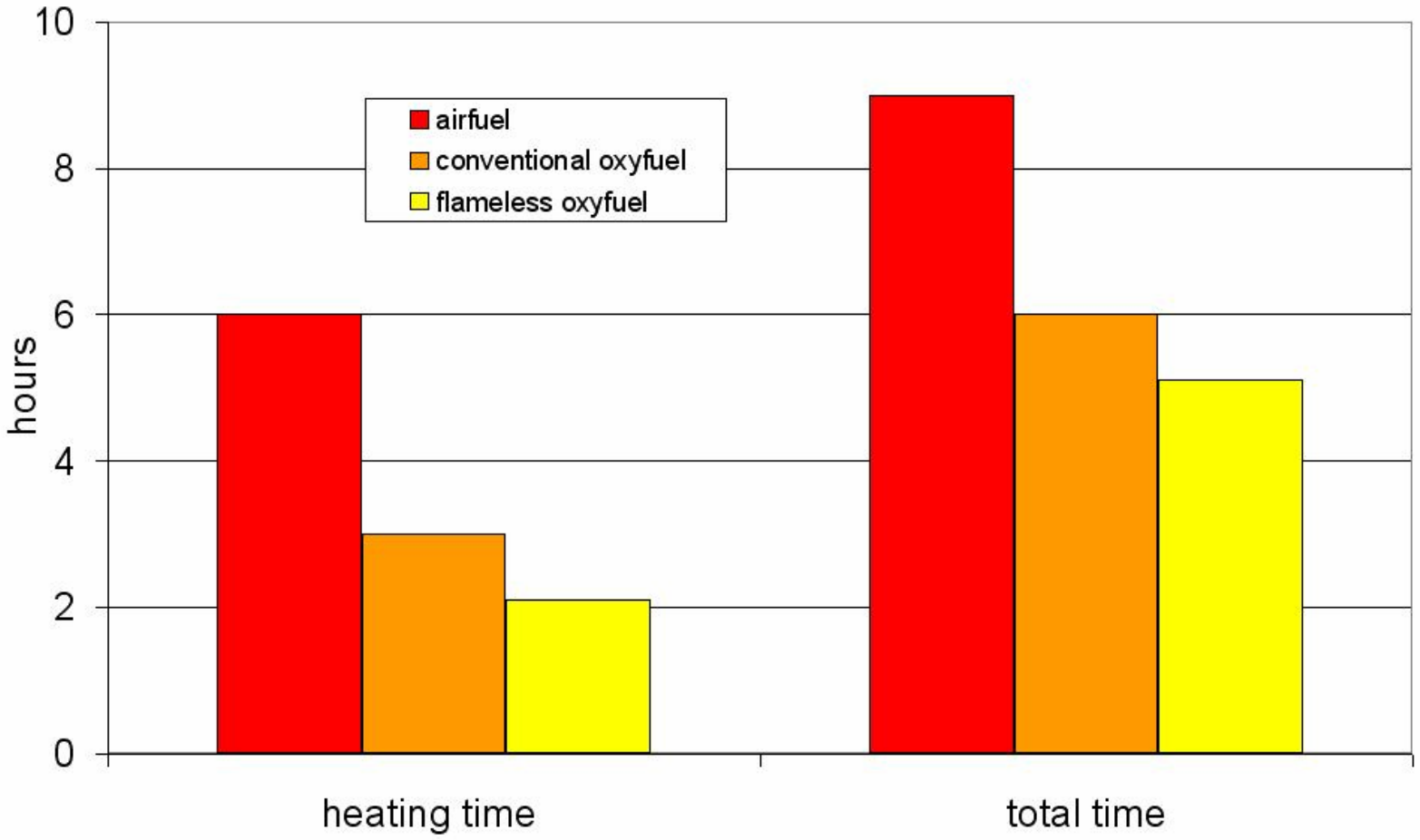
# Ovako – soaking pit furnaces



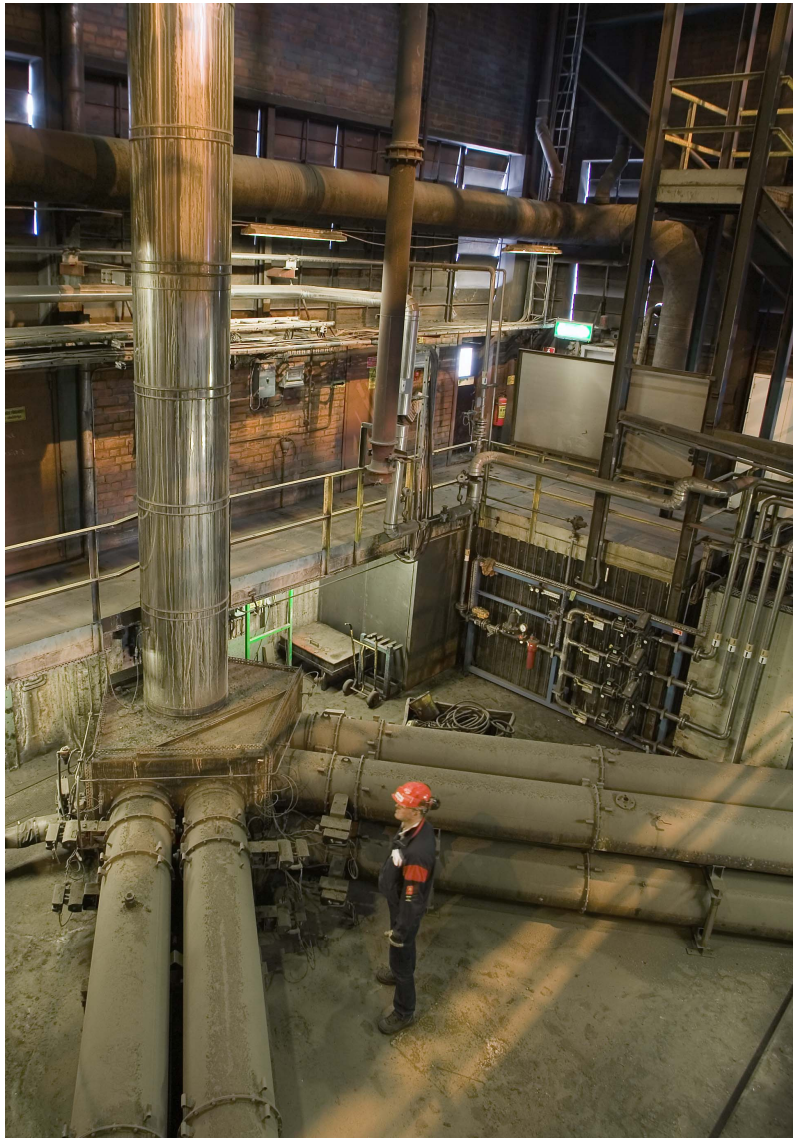

- flexibility – buffer between steel production and rolling mill
  - low energy consumption
  - increased throughput (> 30 %)
- decreased scale formation rate – especially for flameless oxyfuel

# Ovako – soaking pit furnaces

6 → 2 reduction of heating time  9 → 5 reduction of total time



# Ovako – soaking pit furnaces



advantages

- compact exhaust gas system
- reduced constructive amount
- decreased and simplified maintenance
- lower investment costs
- no recuperators and electrical ventilators
- 30-45 % ↓ specific fuel consumption
- pollutant emissions reduction *

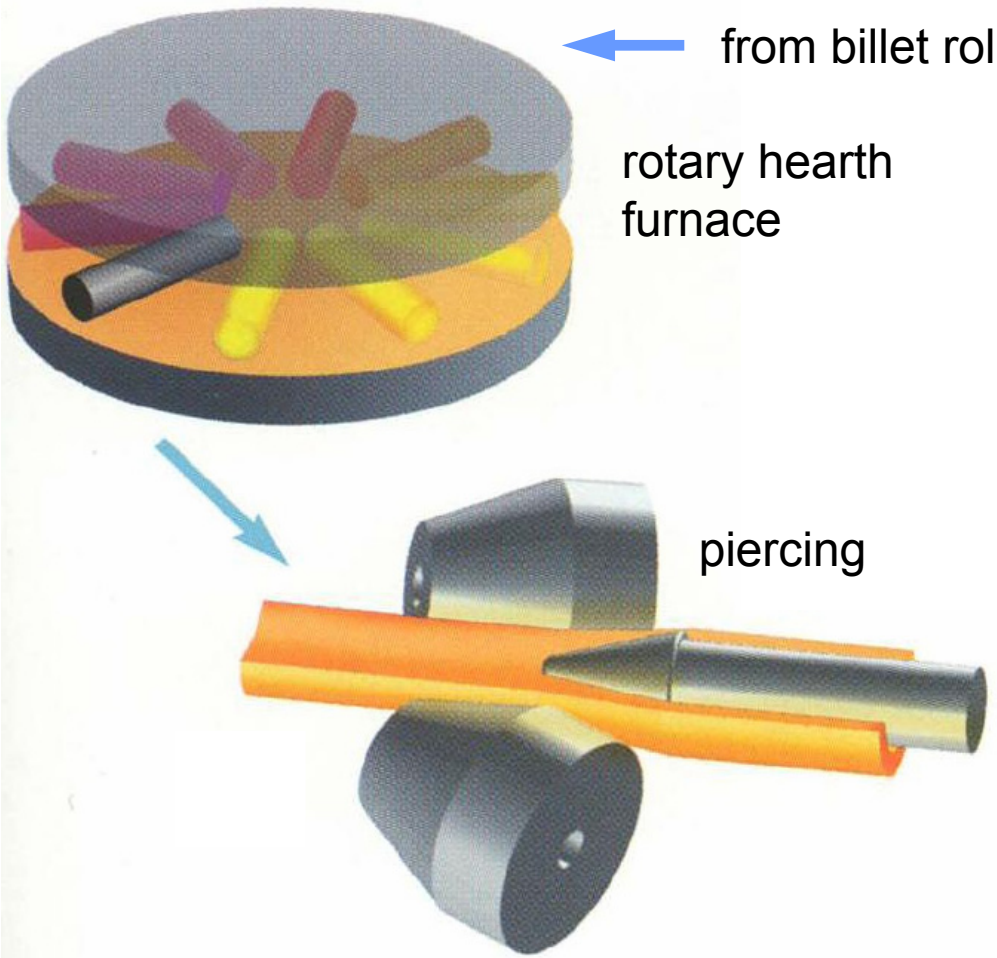
# digression – emission units – rough example

| airfuel | oxyfuel |
| --- | --- |
| ▪ 1 m³/h natural gas, 35 MJ/m³ | ▪ 1 m³/h natural gas, 35 MJ/m³ |
| ▪ 9.5 m³ air (2 m³ $O_2$, 7.5 m³ $N_2$) | ▪ 2 m³ oxygen |
| ▪ hypothetic $NO_x$ formation | ▪ hypothetic $NO_x$ formation |
| 2000 mg/h absolute | 2000 mg/h absolute |
| ▪ flue gas 10.5 m³/h | ▪ flue gas 3 m³/h |
| ▪ 1 $CO_2$, 2 $H_2O$, 7.5 $N_2$ | ▪ 1 $CO_2$, 2 $H_2O$ |
| ▪ dry flue gas 8.5 m³/h | ▪ dry flue gas 1 m³/h |
| ▪ 235 mg/m³ $NO_x$ | ▪ 2000 mg/m³ $NO_x$ |
| | not comparable! |
| 2000 mg/h : 35 MJ/h = | 2000 mg/h : 35 MJ/h = |
| ▪ 57 mg/MJ $NO_x$ | ▪ 57 mg/MJ $NO_x$ |

# Ascometal – soaking pit furnaces

- soaking pit furnaces used to reheat ingots prior to rolling
- first flameless oxyfuel installation in 2004 – replacing airfuel equipment like burners, air ducts, recuperators and blowers
- targets
  - 33 % shorter heating cycles
  - 40 % reduced specific fuel consumption
  - 40 % decreased $NO_x$ emissions
- improved heating characteristics
- less scale formation
- only 9 instead of 13 furnaces deliver same production rate
- energy cost savings, reduced maintenance and improved logistics

# Ovako – Rotary hearth furnaces




- 290 kWh/t for cold charged material
- 1120 to 1270 °C final product temperature

# Ovako – Rotary hearth furnaces

- simple and compact oxyfuel installations at Ovako rotary hearth furnace

# Ovako – Rotary hearth furnaces

Compared with airfuel operation

- higher throughputs > 30 %
- lower emission levels < 100 mg/MJ with staged oxyfuel
- decreased energy consumption
- more uniform heating < 10 °C from top to bottom

Until now oxyfuel burners with staged combustion

- flameless oxyfuel combustion for
  - further more uniform heating
  - higher throughputs
  - lower $NO_x$ emissions

# Outokumpu – stainless steel strip annealing

Nyby works, SE, catenary furnace on the preparatory annealing line

- equipped with flameless oxyfuel burners
- high stirring rates of furnace atmospheres
- increased heat transfer rates towards the product
- small level of $NO_x$ formation
- flexibility

- throughput growth of about 55 %
- same pickling amount – decreased scale formation
- $NO_x$ emissions were kept below 70 mg/MJ
- specific fuel consumption reduction 40 %

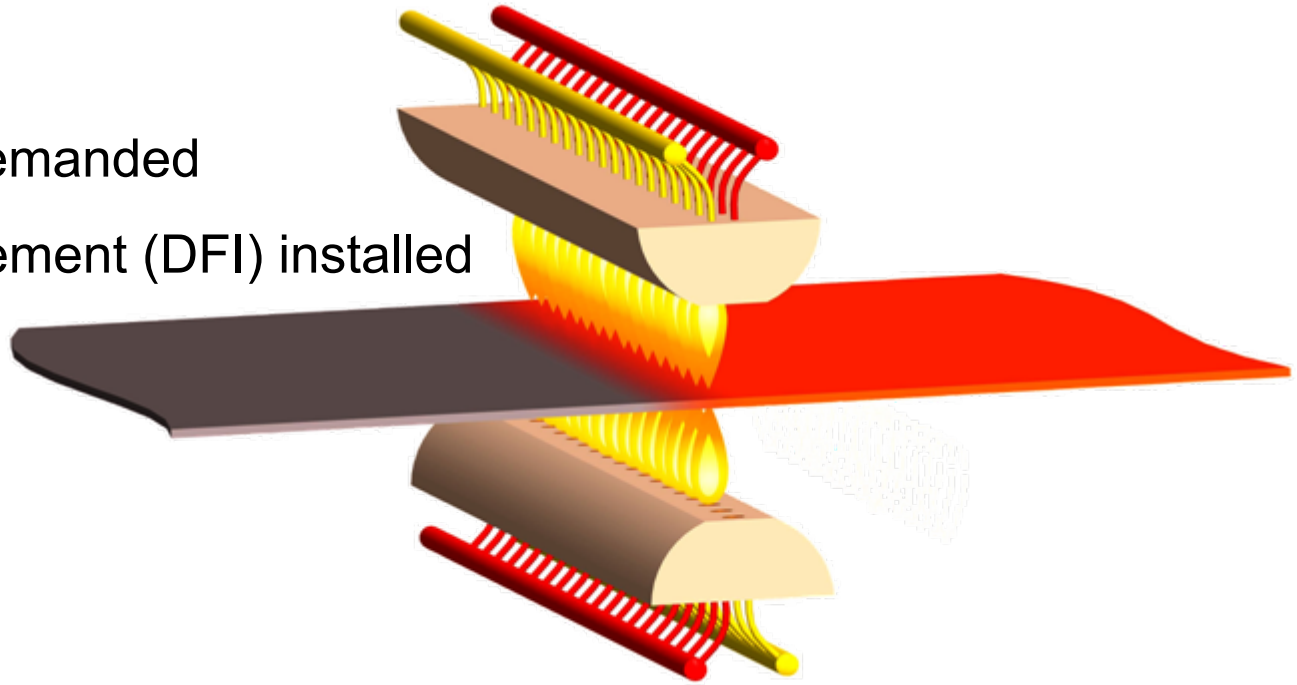
# Outokumpu – stainless steel annealing

second catenary furnace at finish annealing line

- change from airfuel to oxyfuel
- production capacity increase from 11 to 23 tons per hour

additional capacity demanded

- direct flame impingement (DFI) installed

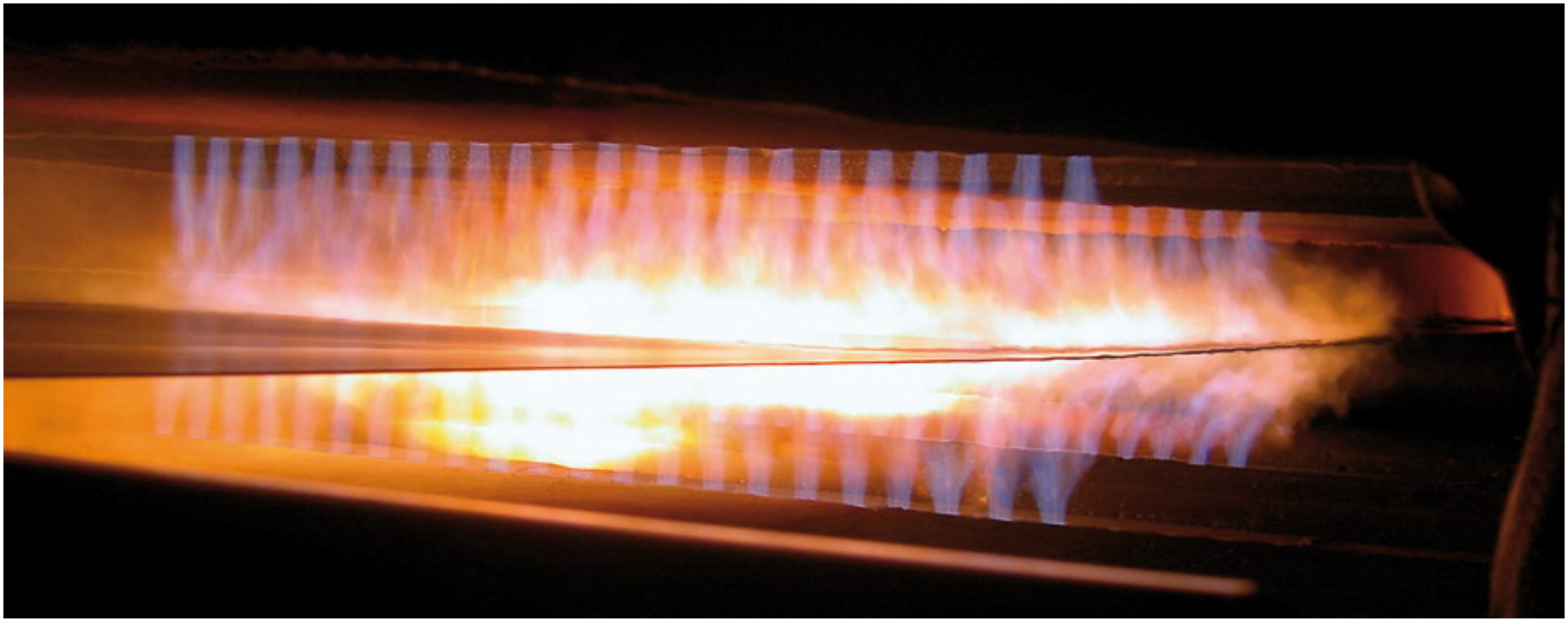


# Outokumpu – DFI for stainless steel

- DFI unit: 120 burner nozzles, 4 burner rows
- heat input 4 MW
- length 1.8 m
- 50 % additional capacity increase

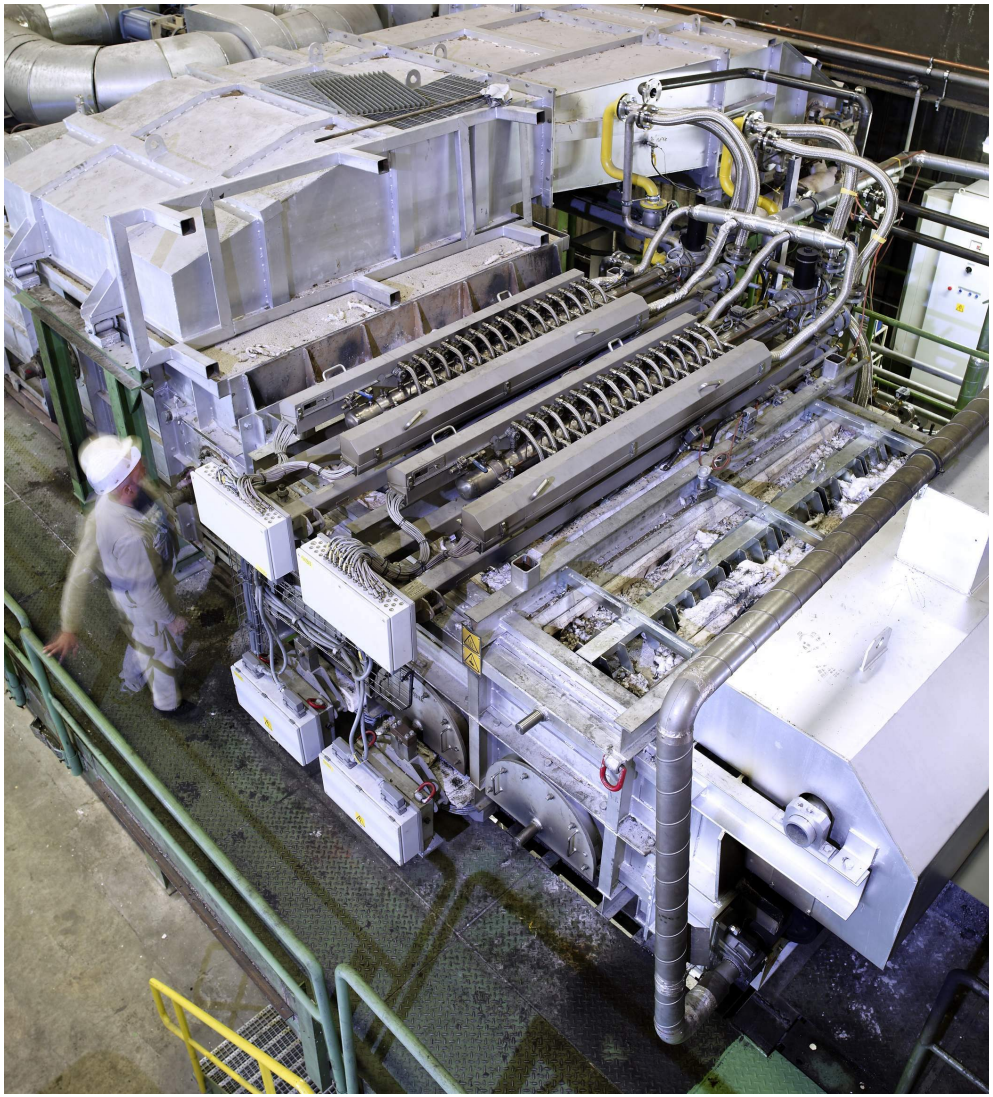
  even for highly reflecting stainless steel strip
- improved temperature control
- flexibility

# ThyssenKrupp Steel – Carbon steel strip galvanising



- DFI oxyfuel unit 5 MW
- additional heat input: ΔT 200 °C at 105 t/h
- 30 % throughput increase
- compact design 3 m
- unit fits into existing line
- instead of recuperative zone

# ThyssenKrupp Steel – Carbon steel galvanising



- precise tuning of strip characteristics
  - surface properties
  - inner temperature distribution
- 25 m pre-cleaning section not necessary any more
- advantages
  - capacity and quality
  - energy savings
  - no pre-cleaning costs
- oxygen supply costs small compared with advantages

# Conclusions 1

- advantages told by plant operators:
  - energy savings
  - increased capacity
  - lower pollutant emissions
  - less but correct scale formation
  - uniform product temperature distribution
  - improved product quality

# Conclusions 2

- oxyfuel combustion with high thermal efficiency
- easy to set up heating systems – reduced maintenance
- oxyfuel application advantageous independent from the used fuel – also for low-calorific fuels
- using combustion knowledge and production experience oxyfuel can be applied with additional economical benefits

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