Gaswärme-Institut e.V.
Essen

theoretical and experimental research on the heat transfer of natural gas flames and the reduction of NOx

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development of new burner systems
for regenerative glass furnaces

regenerative furnaces I &II

efficiency improvement for glass furnaces

SPEKTRAL

ARBEITSGEMEINSCHAFT INDUSTRIELLER FORSCHUNGSVEREINIGUNGEN
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SCHOTT
glass made of ideas

NOx reduction and energy saving for regenerative furnaces (end port furnaces)

- system: super structure (flame, crown, flue gas) + glass melt
- utilisation of existing burners
- e. g. soot formation for local increase of energy transport
- e. g. diluted combustion
  ➔ repositioning temperature peak
- raise of temperature at source point inside the glass melt
  ➔ improvement of quality and throughput
- delayed combustion and effective radiation
  ➔ NOx reduction

- wide range of operation
- applying knowledge from other areas of industrial combustion

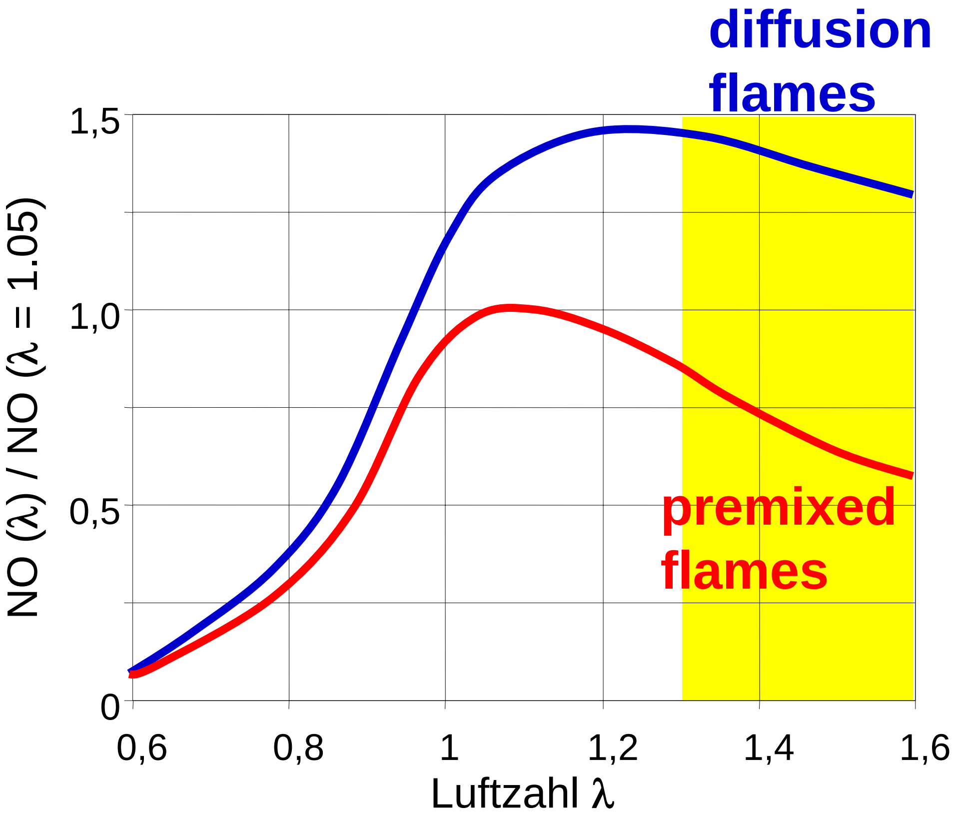
1) delayed combustion
2) internal flue gas recirculation
3) inclination of flue gas
4) air staging
5) fuel staging

1) delayed mixing and reaction

- already applied in modern regenerative furnaces
- low momentum – weak mixing – strongly fluctuating flames
- side effect: fuel preheating – cracking – CxHy-formation – partial soot production – radiation ↑ - heat transfer ↑ - cooling ↑ - NOx ↓

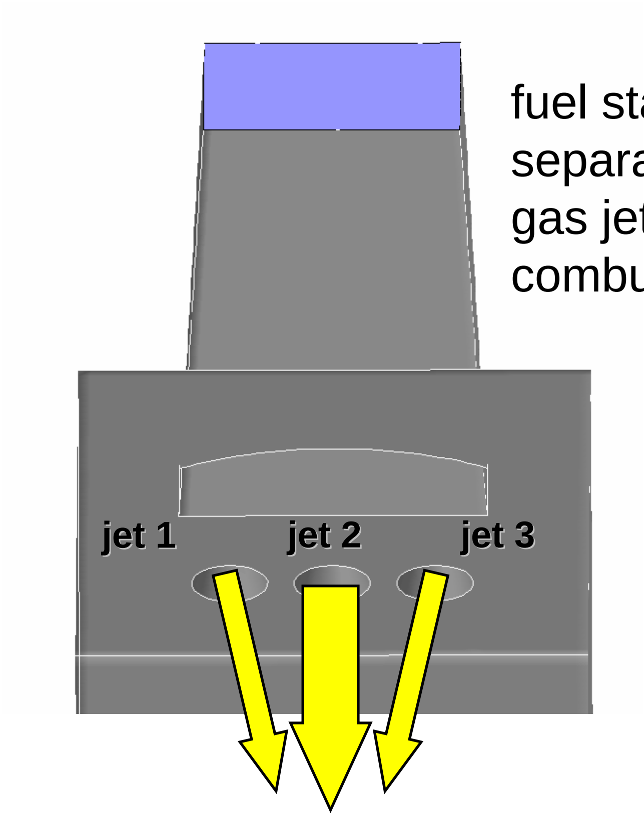
5) fuel staging

- not as strong as air staging but an effective NO_x reduction method
- easy to set up method
- combinations of cascade, underport, throughport or sideport systems
- additional methods

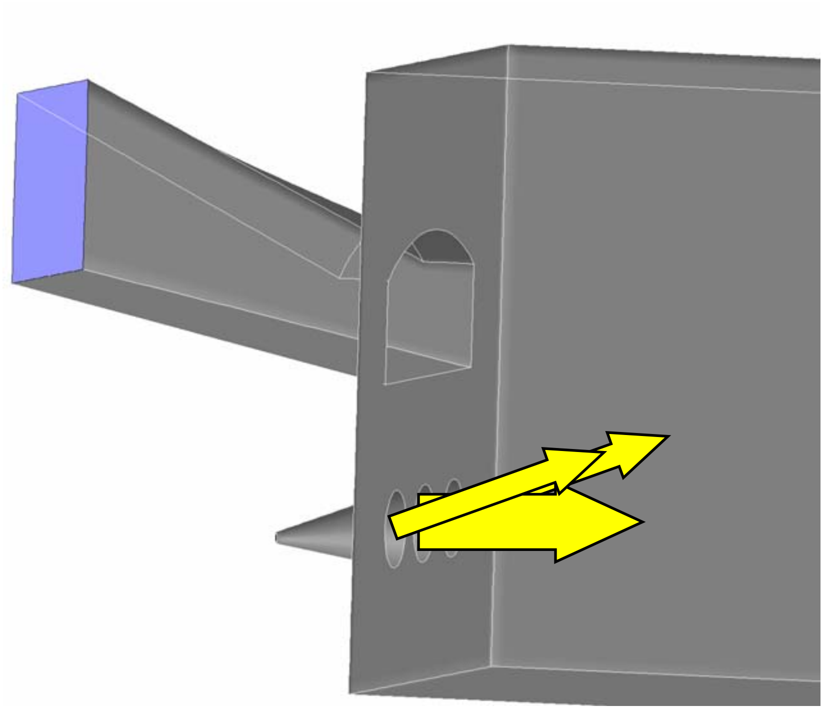


GWI high temperature test rig

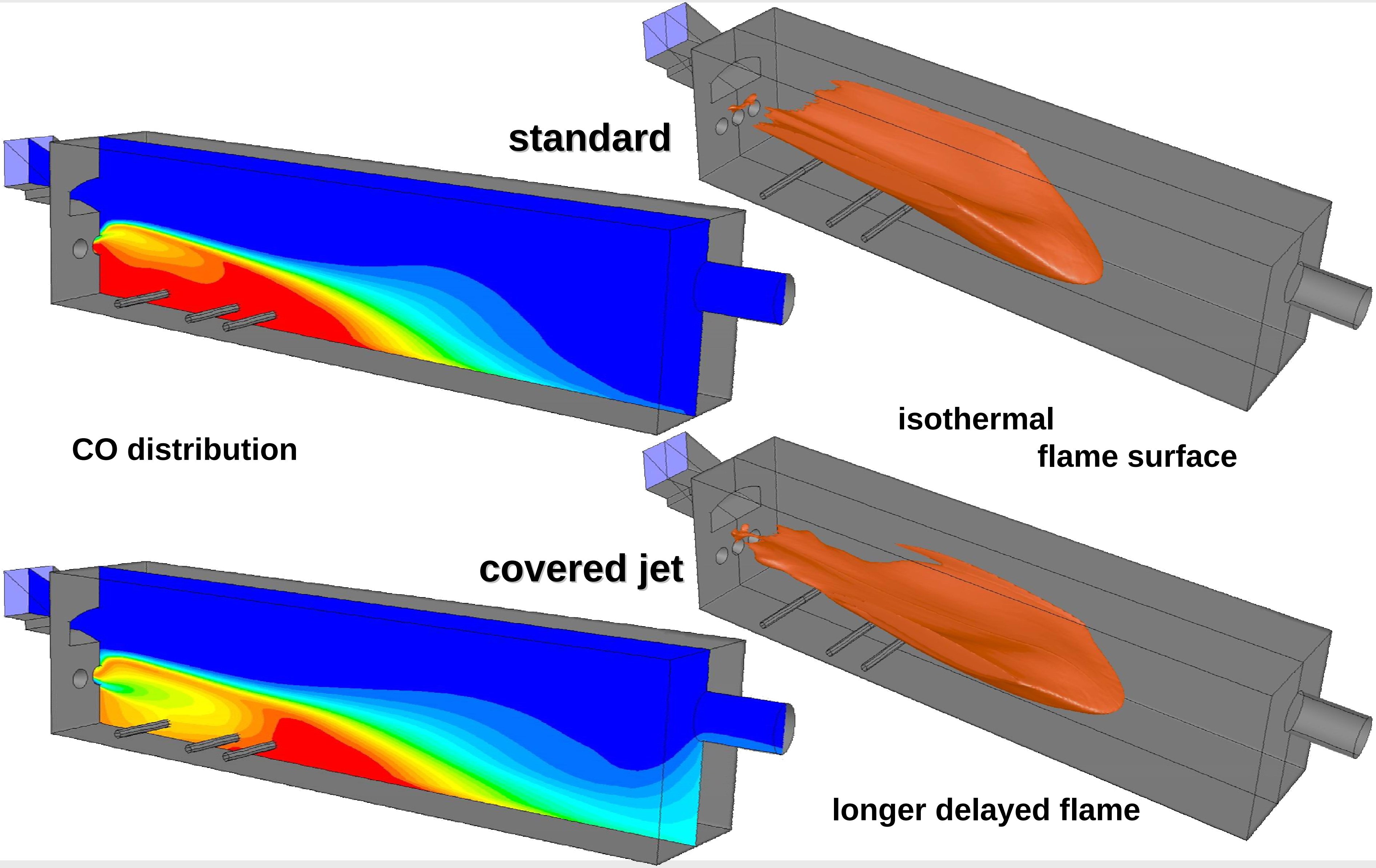
- power: 1,5 MW
- air flow: 1250 Nm³/h
- fuels: natural gas, fuel oil, mixed gases
- air preheating = 1350 °C
- furnace temperature ≈ 2500 °C
- furnace wall temperature < 1650 °C

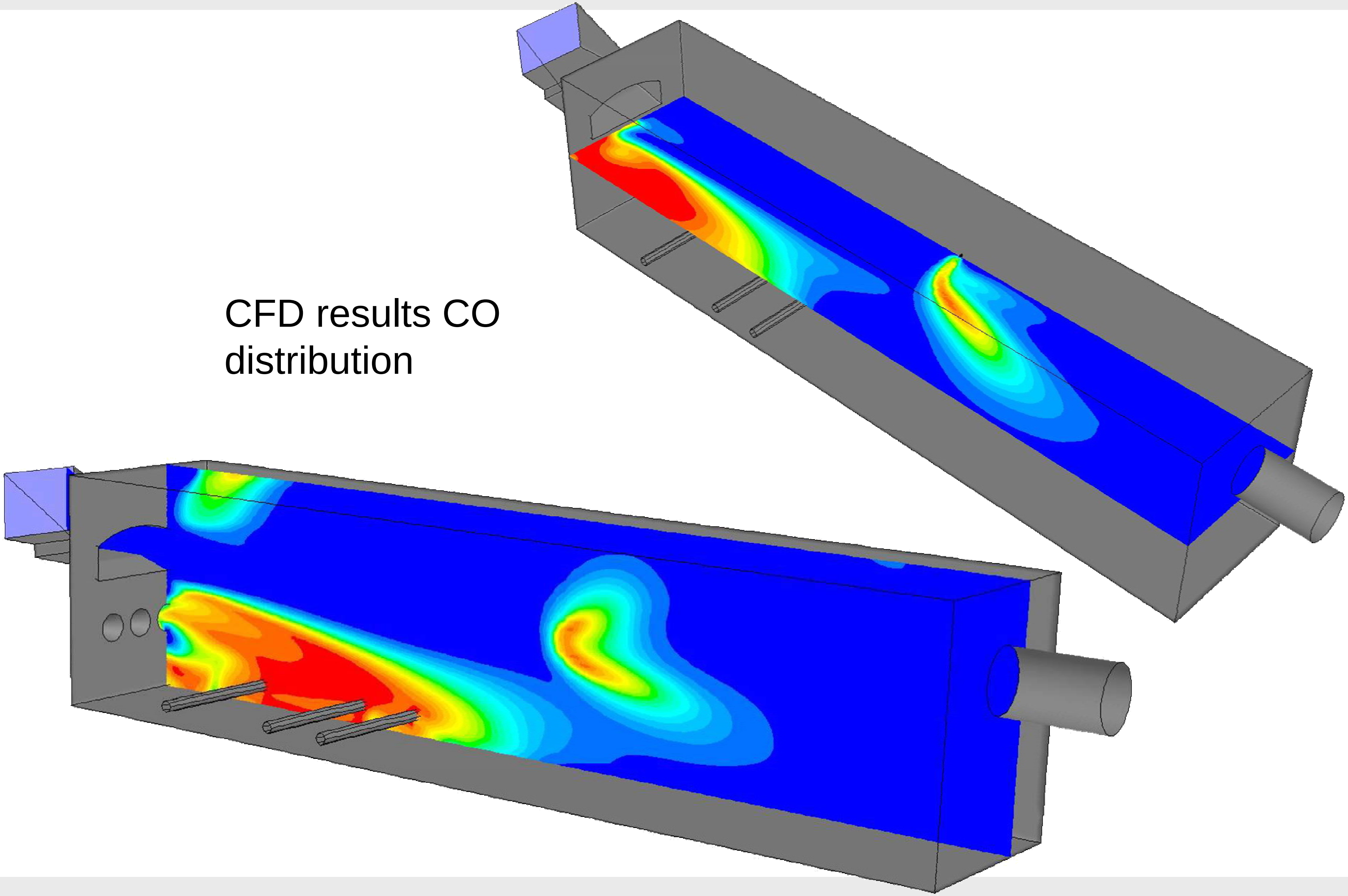


fuel staging by separating main gas jet from combustion air



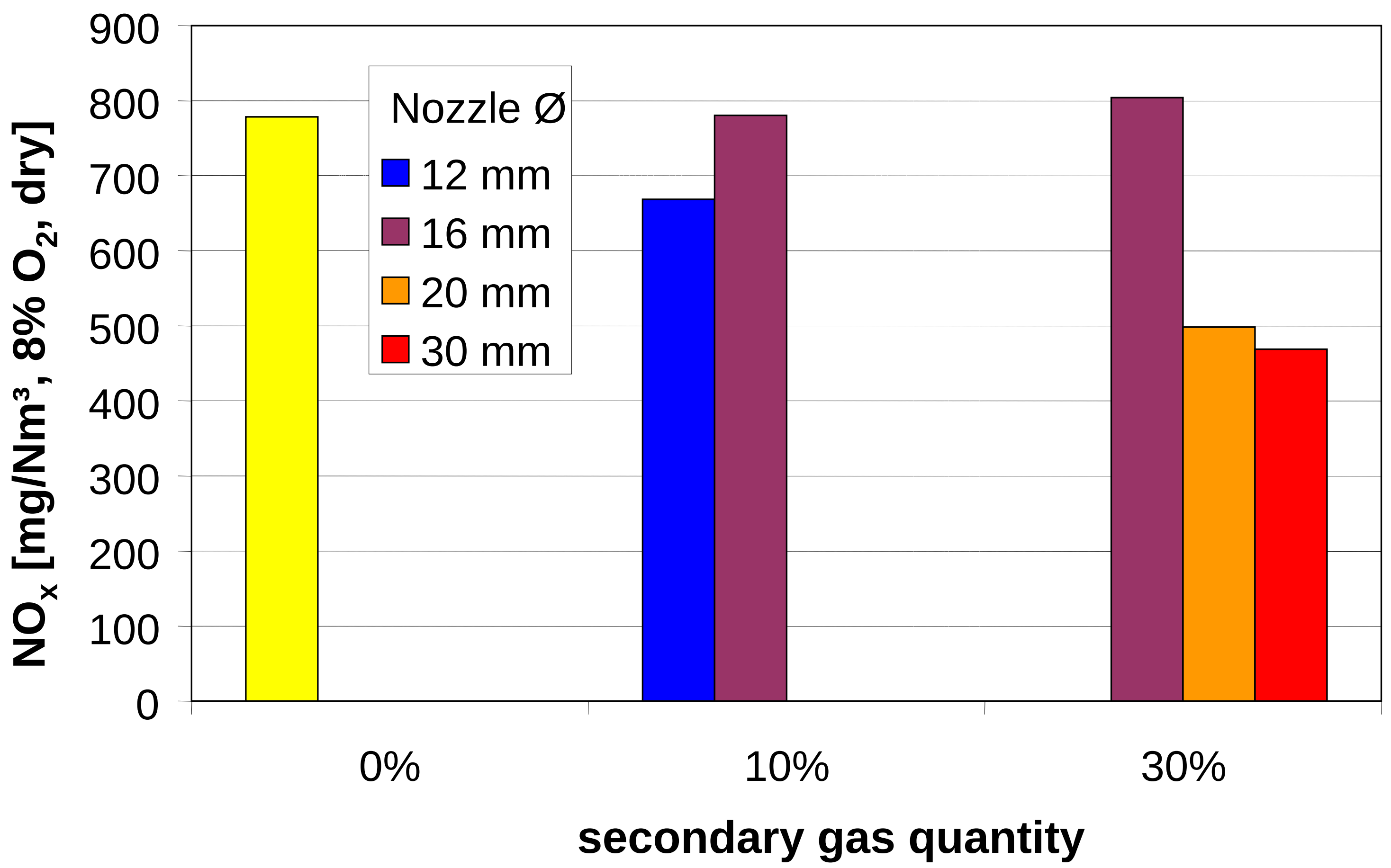
comparison


standard
CO distribution
isothermal
flame surface
covered jet
longer delayed flame

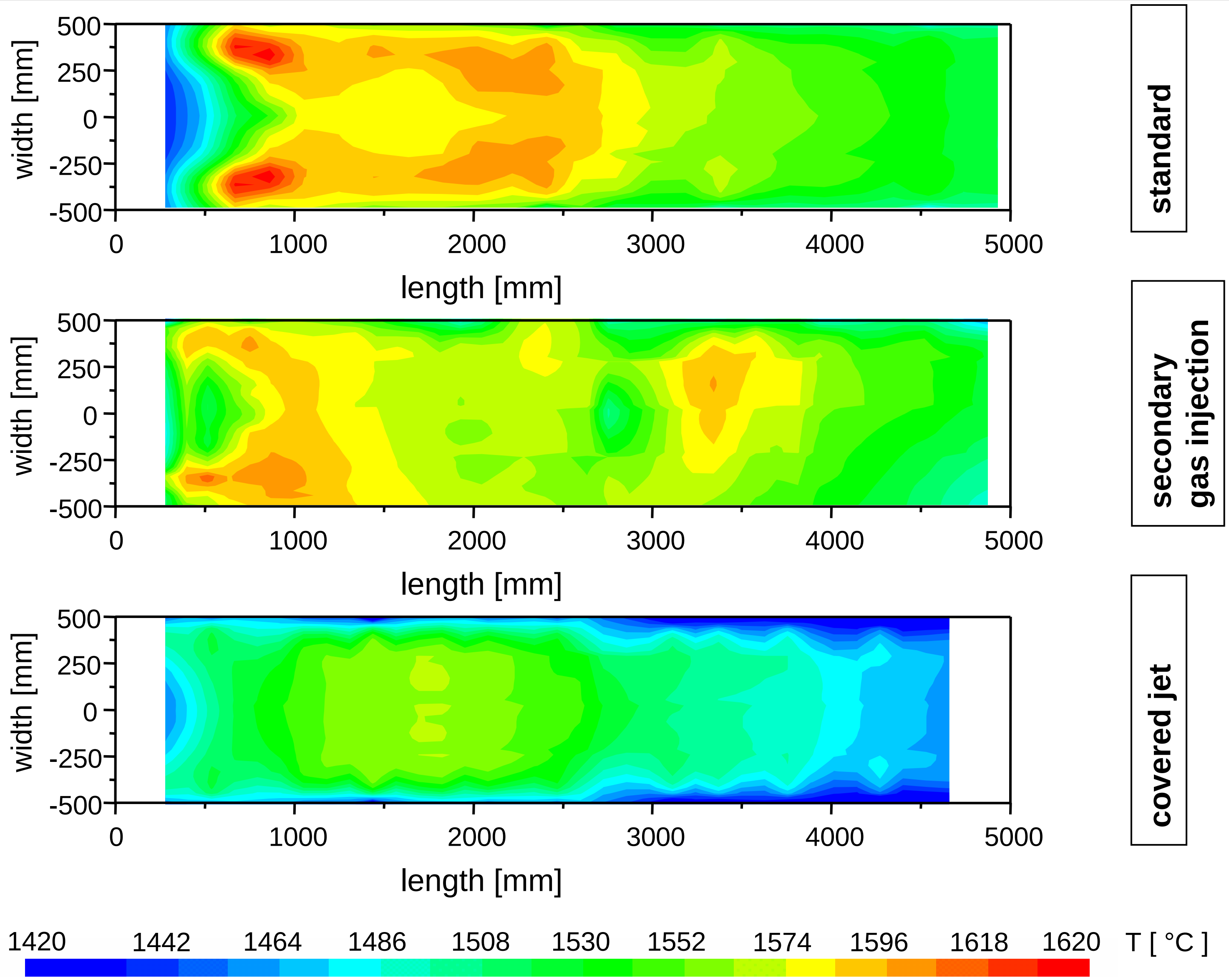


CFD results CO distribution

NO_x measurements



measurements at test furnace



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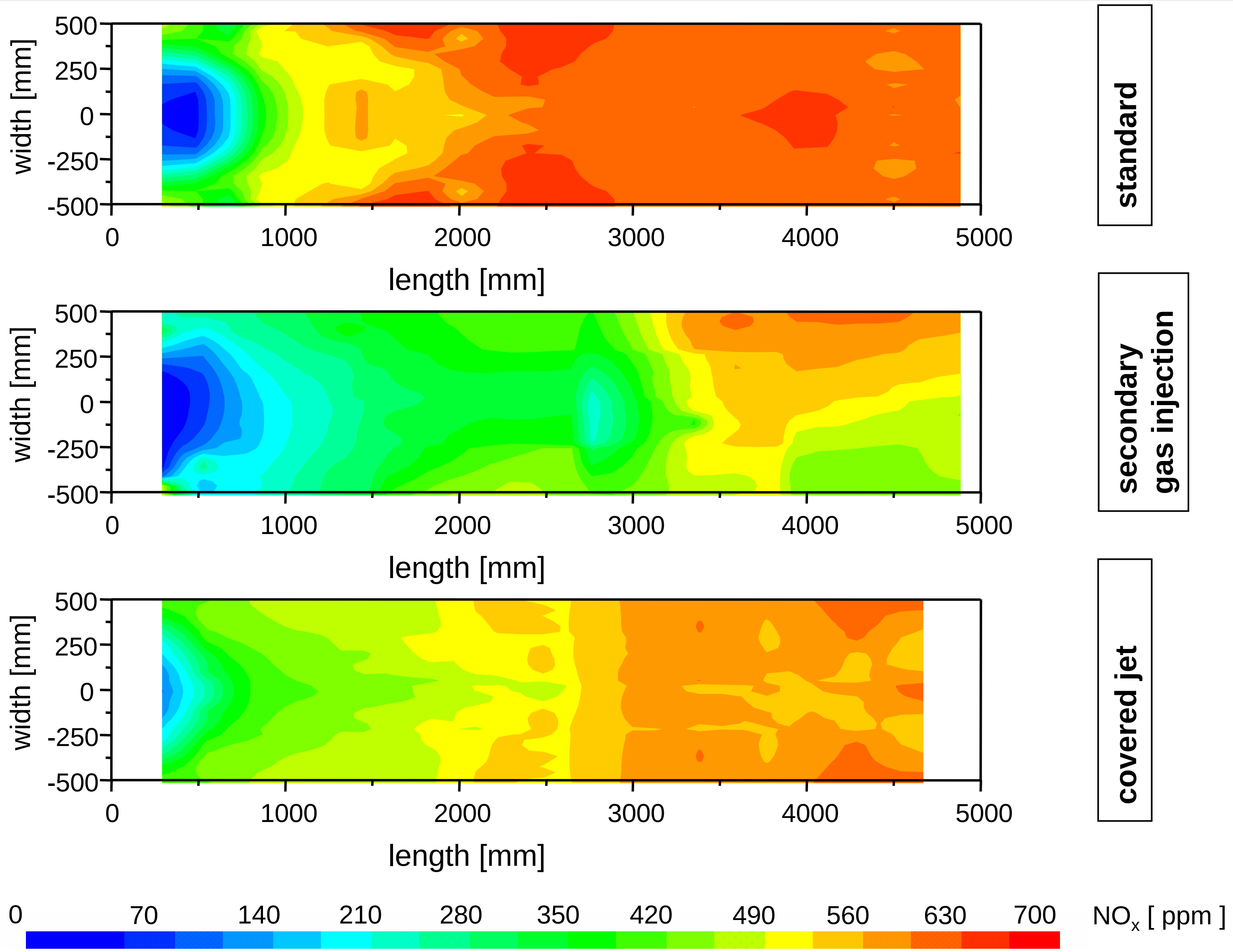
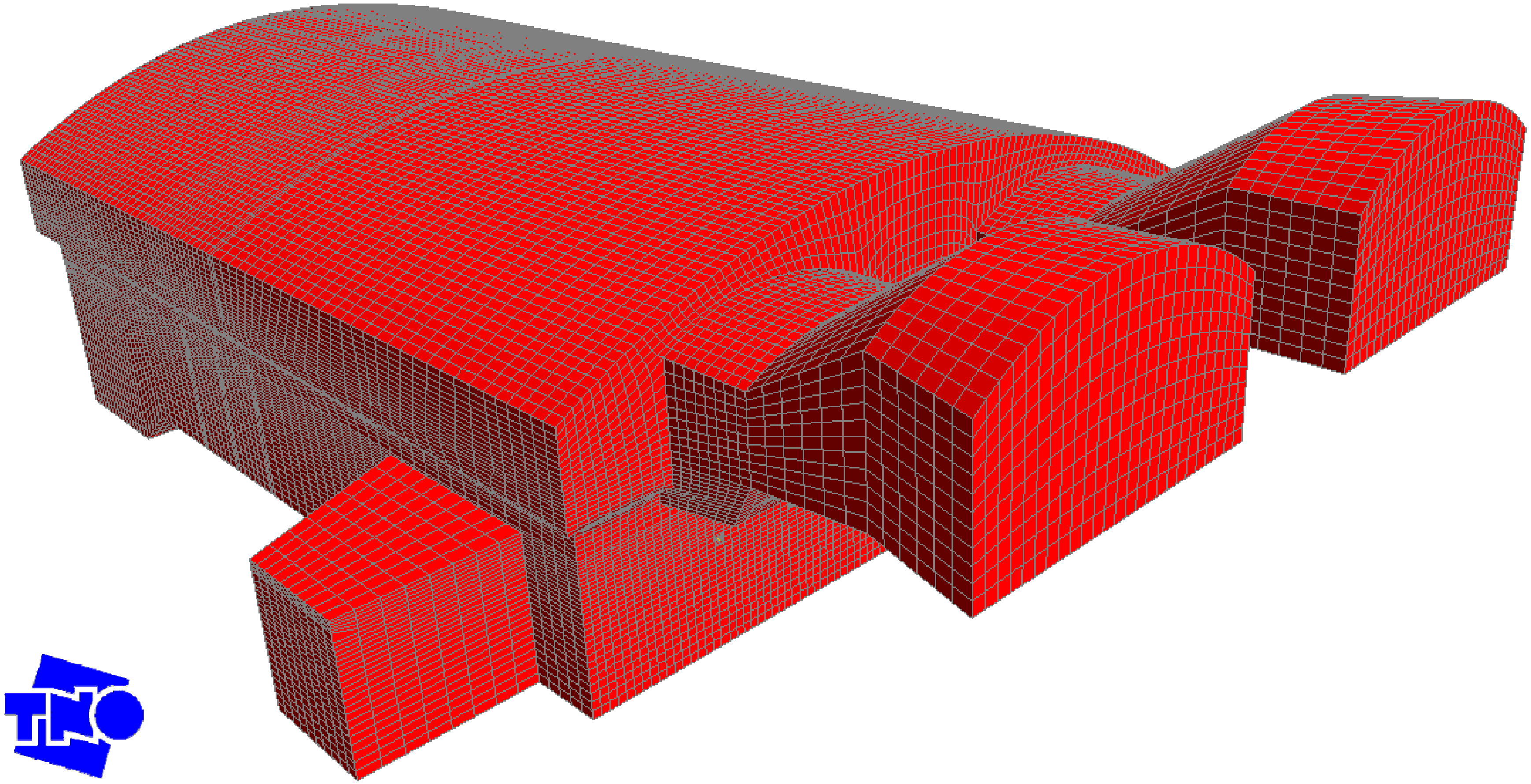
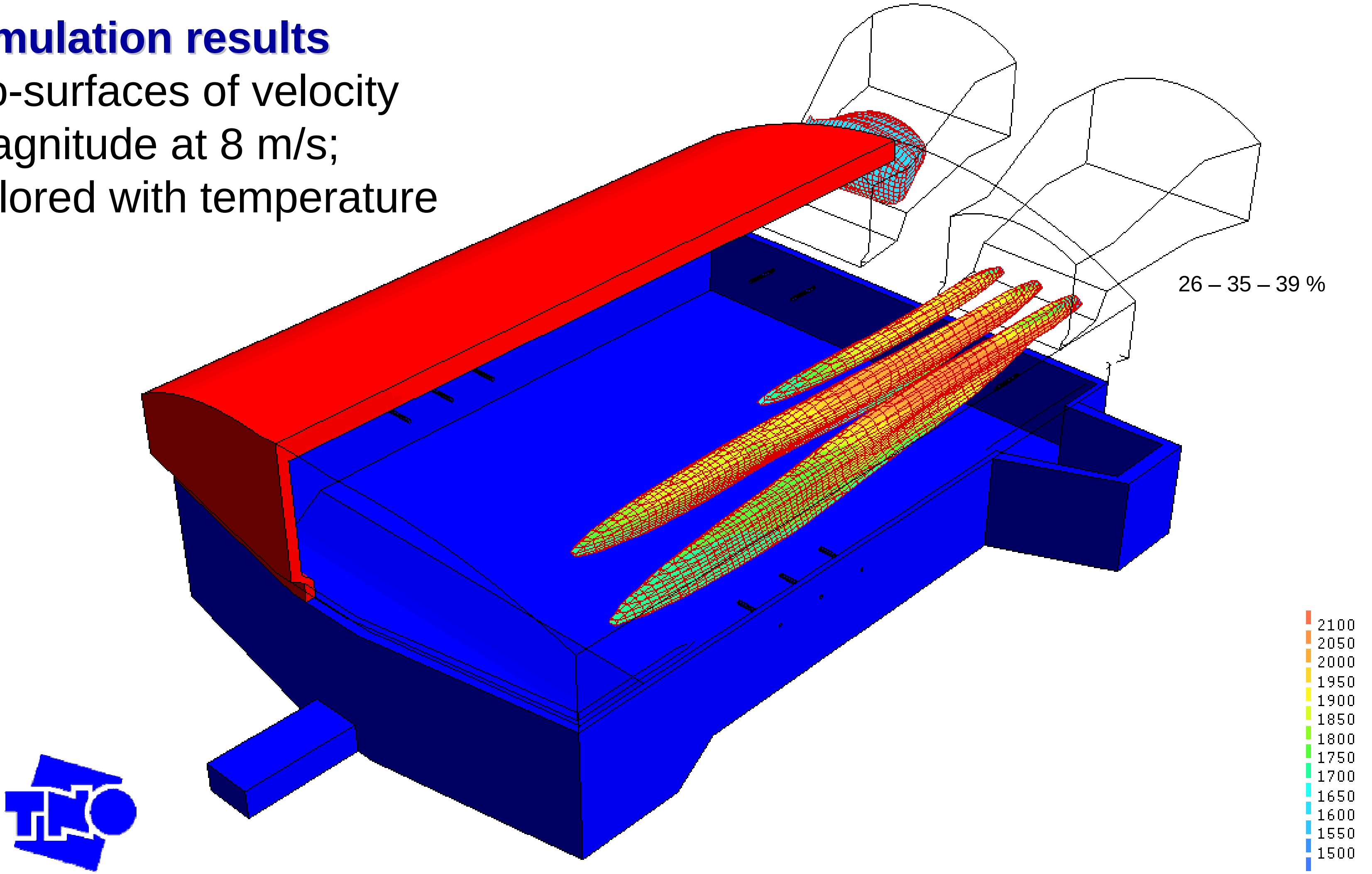


geometry and grid

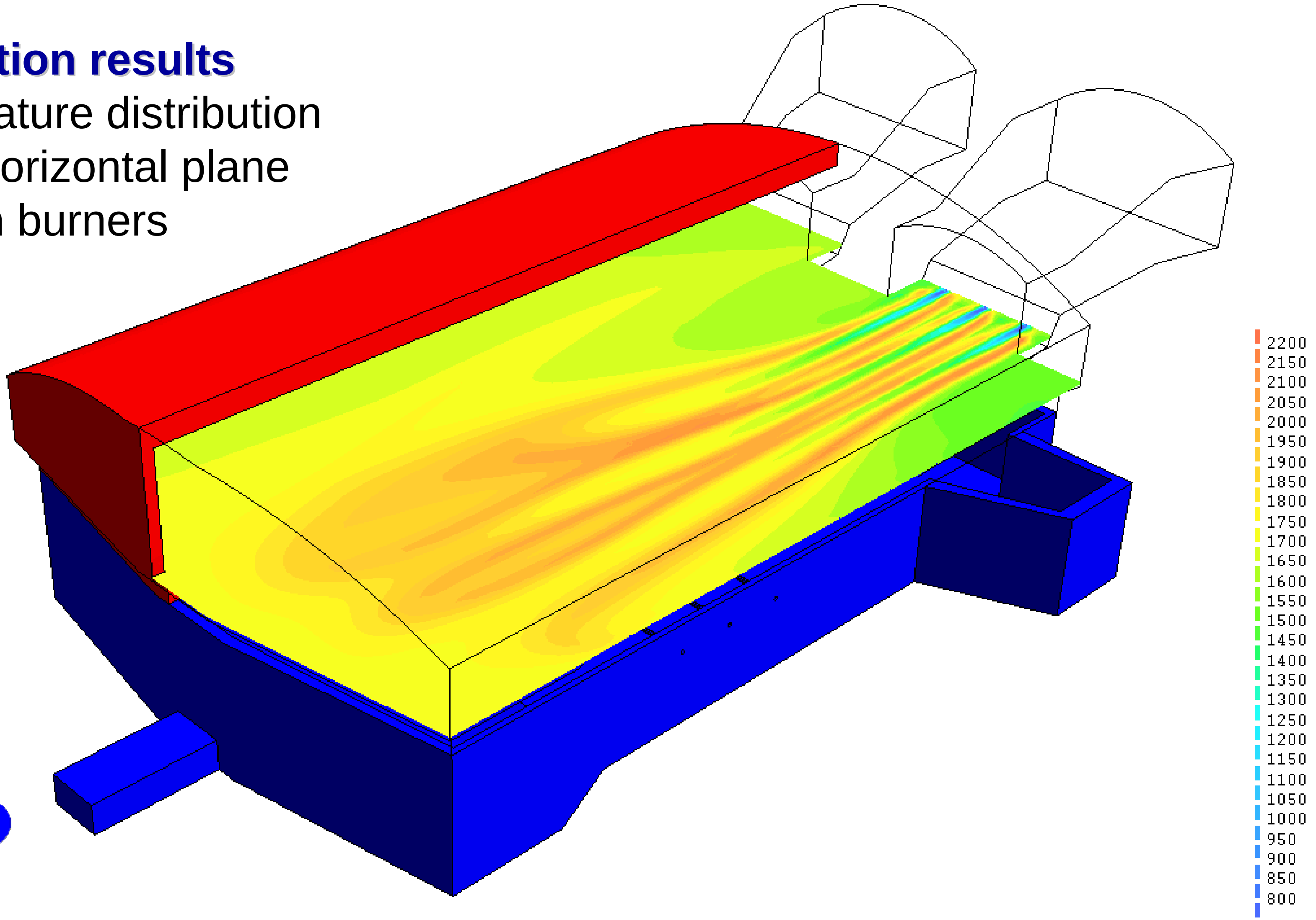


simulation results
iso-surfaces of velocity magnitude at 8 m/s; colored with temperature

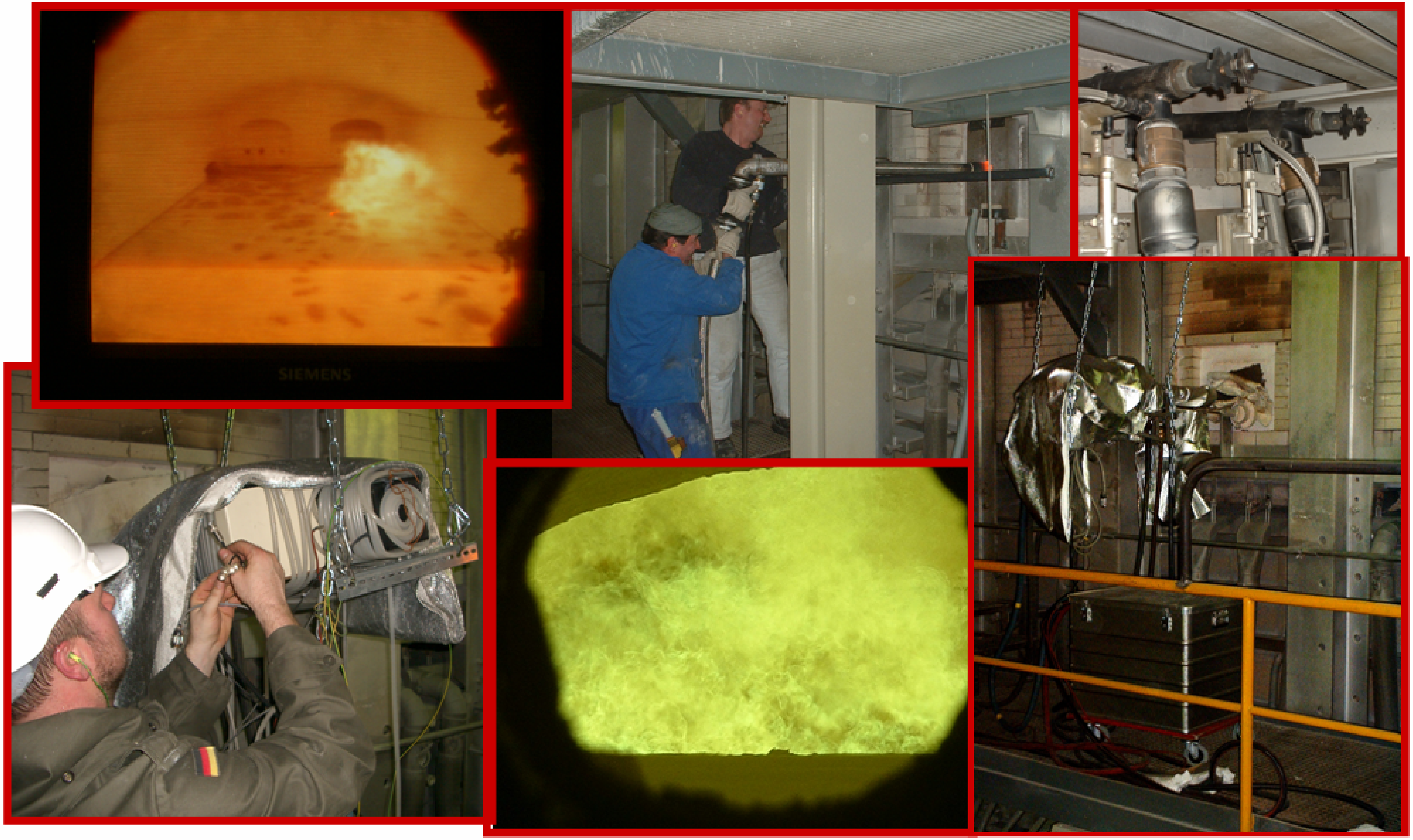


simulation results

temperature distribution
in the horizontal plane
through burners

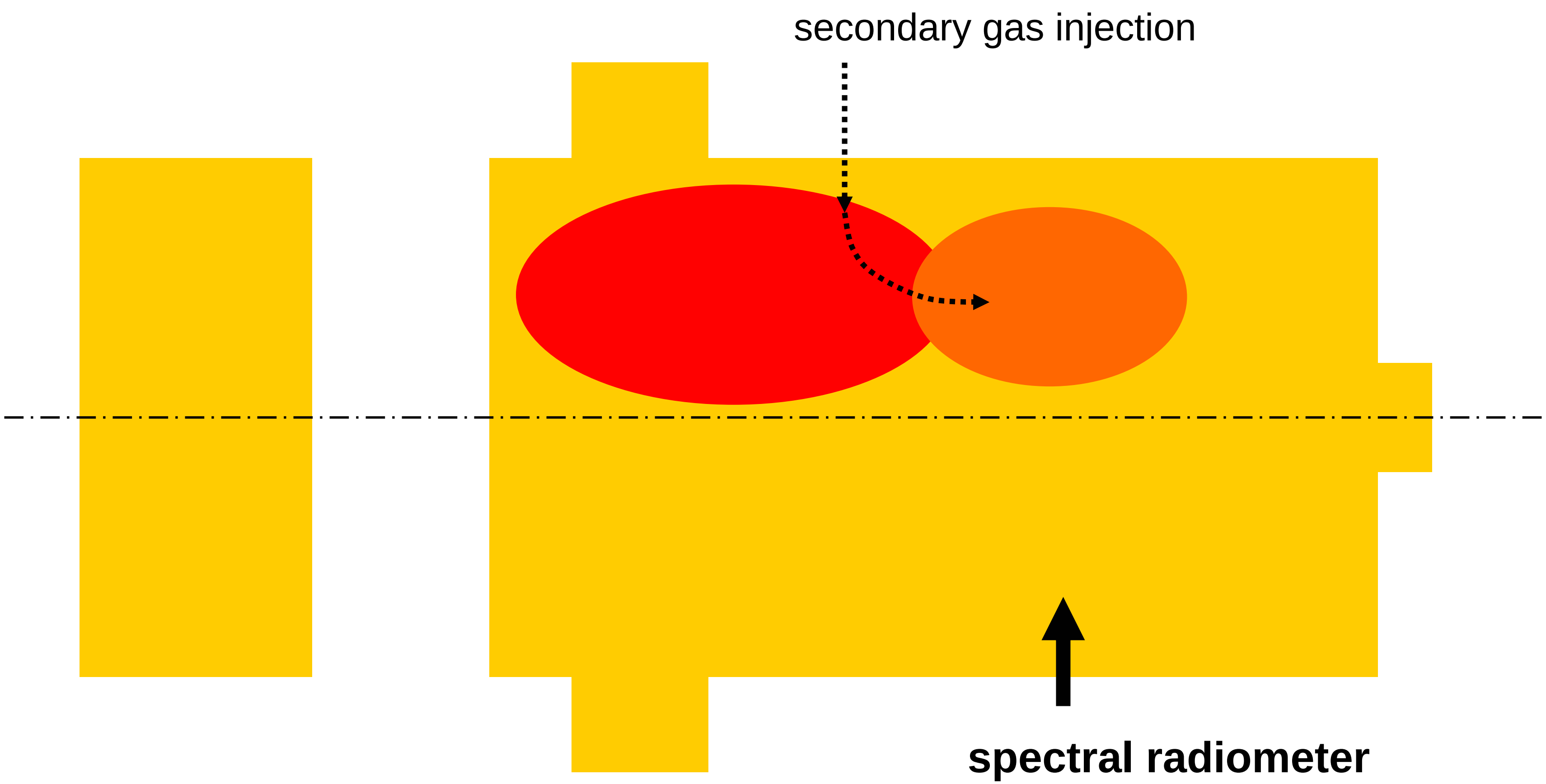


realisation at an industrial furnace



flue gas analysis at regenerator head

burner settings		$O_{2,\ flue}$ [%]	CO [mg/m_N^3] 8% O_2	NO_x [mg/m_N^3] 8% O_2
standard	flame right	2,5	29	100 %
	flame left	2,3	30	
covered jet	flame right	2,3	55	113 %
	flame left	2,3	70	
second. gas inj.	flame right	2,9	64	62 %
	flame left	2,8	55	


secondary gas injection
spectral radiometer

conclusion regenerative furnaces

covered jet

- small assembling amount
- no changes regarding NOx
- more energy in the rear part of flame

secondary gas injection

- slightly higher assembling amount
- clear decrease in NOx emissions
- more energy in the rear part of flame