Firing Systems in the Focus of Energy Conversion

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Expectations on Firing Systems

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What are the expectations on Firing Systems as state-of-the-art?

- **Reliability**
- **Maintainability**
- **Availability**
- **Functionality**
- **Flexibility**
- **Effectivity**
  - **Minimized Heat Losses (Unburned Carbon)**
  - **Low Emission Values**
  - **High Degree of Fuel Flexibility**

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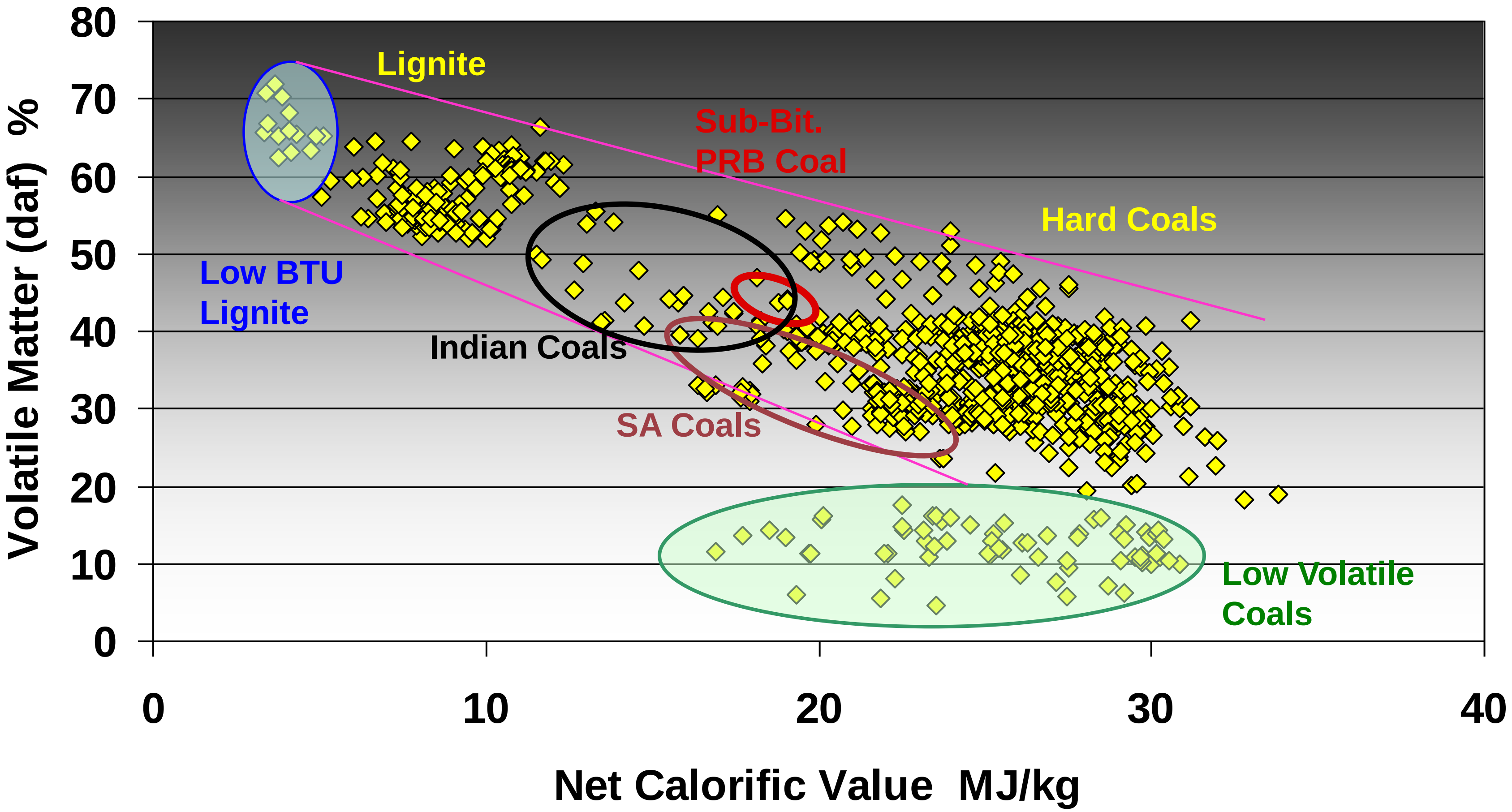
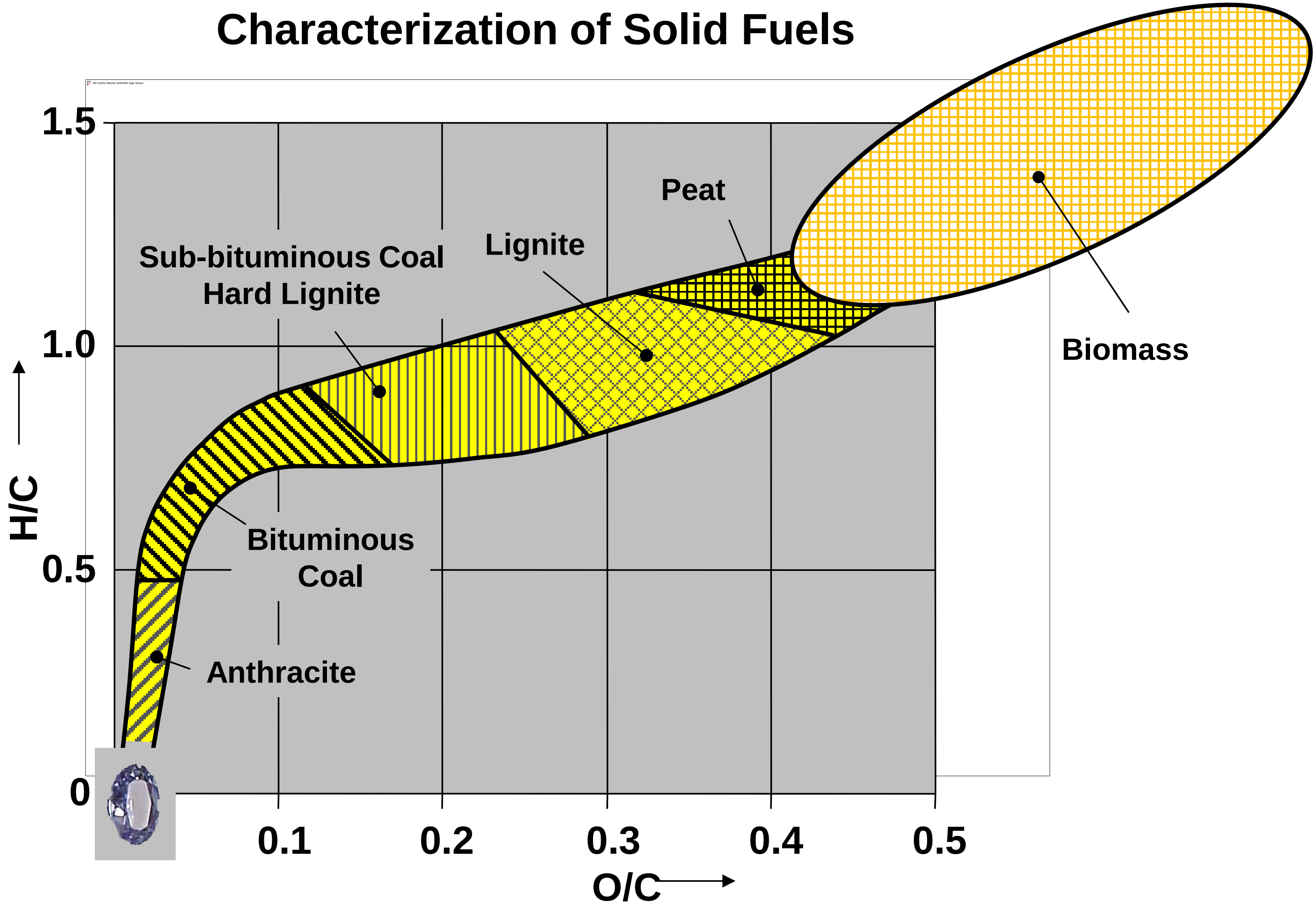
Wide Range of Coal Qualities



Fuels

Characterization of Solid Fuels



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Coal Properties and their Influence on Design of Combustion System:

- Ash, Moisture, Grindability → Mill Size / Fuel Capacity
- Ash Content → Size of De-Ashing System
- Heating Value → Combustion Air Amount (Fan / Duct) / Stoichiometric Figure
- Volatile Matter → Ignition Behaviour / NOx Emission
- Nitrogen, Sulphur → Emission Values
- Sulphur, Chlorine → Flue Gas Atmosphere / Corrosion Risk
- Swelling Index → Pyrolysis / Unburned Carbon of the First Kind
- Ash Properties → Furnace Size / Furnace Exit Gas Temperature / Slagging / Fouling

Furnace Design

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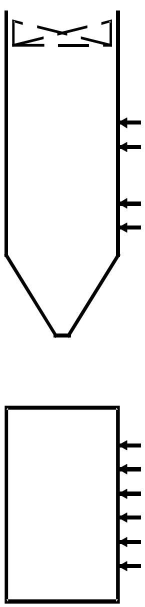
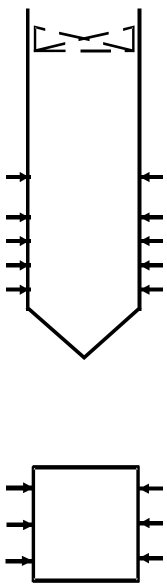
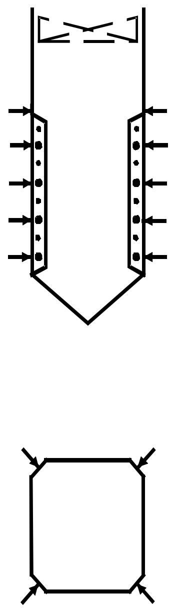
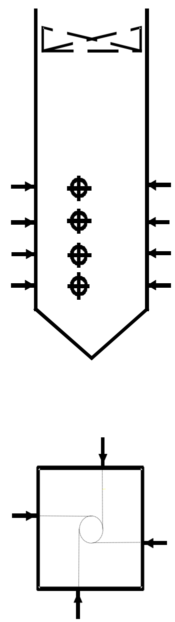
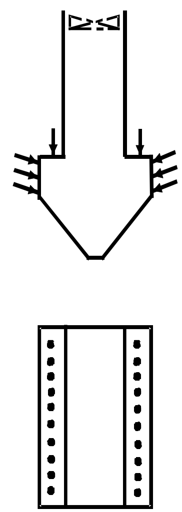
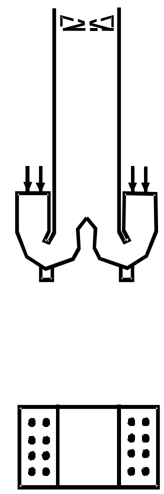
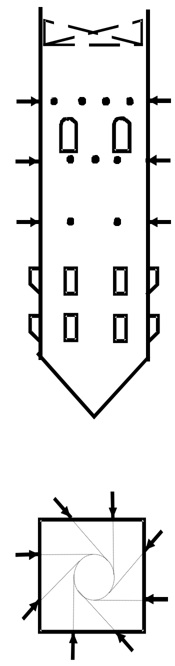
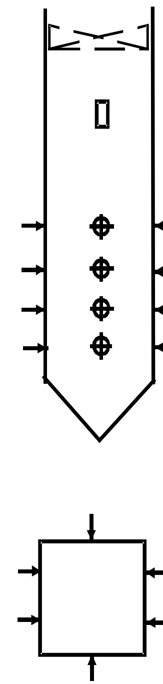
The term **Combustion Facility** describes the process and location where the proper events and reactions for the transfer of energy by oxidation of fuel products are initiated and executed.

This location is also known as the **Furnace**.

Aggregates and components such as Burners, Igniters, Coal Bunkers, Feeders and Mills, De-Ashing Facilities, Fans, Air-Heaters as well as Fuel Lines and Air and Flue Gas Ducts are sub-systems that are built up, together with the Furnace, to the **Combustion System**.

Furnace Design

Bituminous Coal						Lignite	
Front	Double Front / Opposed	Corner	All-Wall	Down Shot	Slag-Tap / U-Type	Tangential	All-Wall
							

Furnace Design

A well balanced Furnace Design has to consider the Fuel Properties in respect of the thermal requirements of the steam generator.

Therefor the Heat Release related to
- **the Furnace Cross Section,**
- **the Heating Surface in the Burner Belt Area and**
- **the Furnace Volume**

have to meet with the demand of highly efficient combustion system having regard to complete combustion and low emission values.

Important Design Tools used by HPE
- **PreFanal → First Combustion Calculation and Furnace Layout**
- **FANAL → Combustion Behaviour → Furnace Temperatures / Emission Values / Burnout Characteristics**
- **DAMAUS → Thermal Boiler Calculation**
- **CFD → Layout – Check and Optimization**

Components of Coal Firing System

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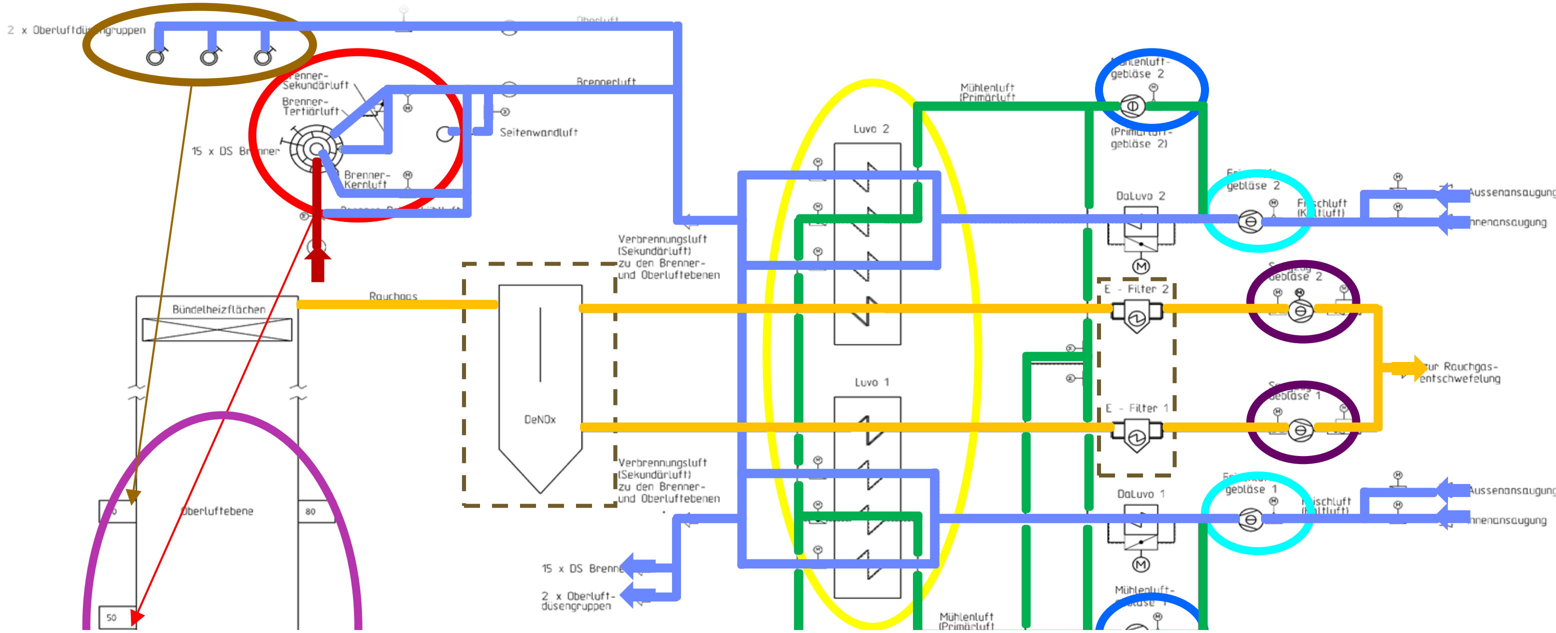
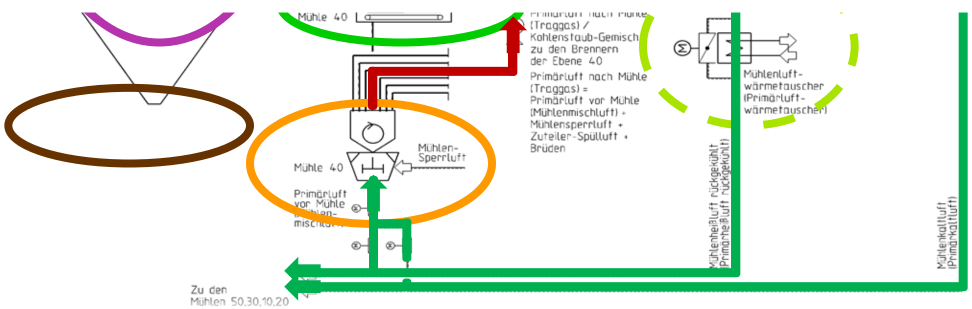


All components of the firing system have to be coordinated to reach optimized operating results.



Low NOx Coal Combustion

Development of Low NOx Burners

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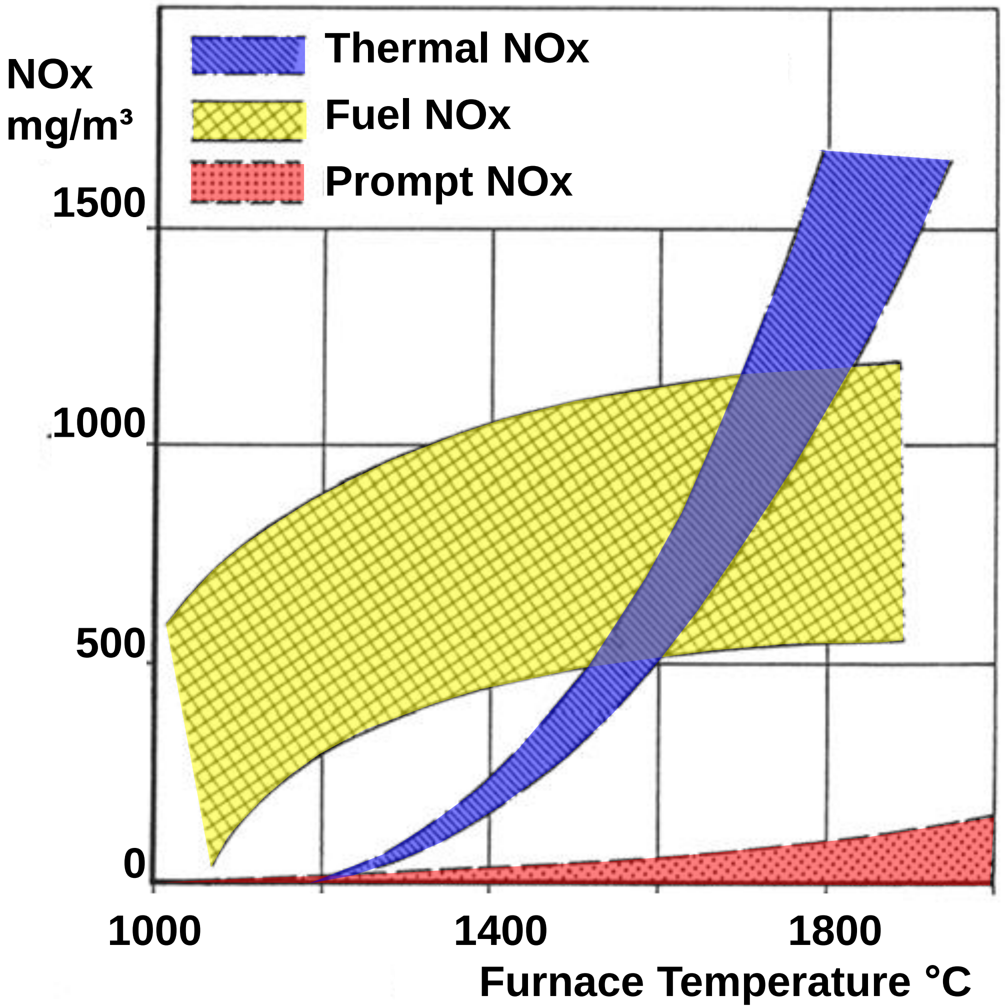
The development of high efficient combustion systems was significantly affected by the processing of Low NOx Combustion in the past three decades.

Learning from chemical processes, Low NOx Burners of today are focused on ignition of fuel products and the localisation and timely definition of the ignition point.

NOx Emission

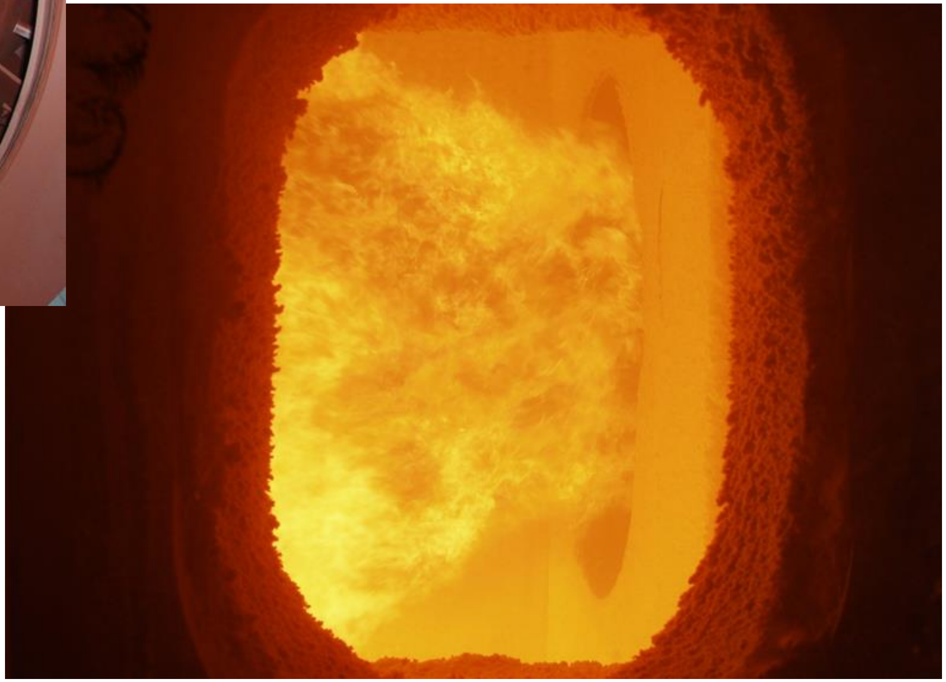
NOx Sources



Burner Design

DS® Burner

Ignition



The First Theorem of Combustion:

- Everything that is supposed to be burned must be ignited. Ignition is the Initiation of all combustion processes.
- That's why Initiation and the Course of Ignition is in the Focus of Combustion Technology.

The Second Theorem of Combustion:

The Definition of Ignition

- Ignition = Pyrolysis + Oxidation

DS® Burner Development / Pyrolysis

- **Pyrolysis describes the thermo-chemical split of organic compounds by means of which high temperature forces the breaking of bigger molecules into smaller ones.**
- **The changing of coal happens under influence of heat without any additional oxygen supply.**
- **Beside the coking coal production, tar and combustible gases, namely the volatiles, are the main products of the pyrolysis process.**
- **The release of volatiles mainly depends on coal type, particle size, temperature, time for reaction and heat-up range.**
- **The younger the respective coal quality, the lower the rate of carbonisation. That leads to higher amount of volatiles available and better conditions for accelerated de-volatilization.**
- **Pyrolysis starts at particle temperatures between 250° C and 400° C depending on coal quality.**

Ignition = Pyrolysis + Oxidation

- **Conditions of Pyrolysis:**
  - Fuel Concentration
  - Heat Transfer
  - Time for Reaction

- **Conditions of Oxidation:**
  - Primary Oxygen Content
  - Oxygen Quotient ω

$$\omega = \frac{O_2 \text{ primary (actual value)}}{O_2 \text{ Demand of Volatiles}}$$

NOx Emission / Burner Pyrolysis Model

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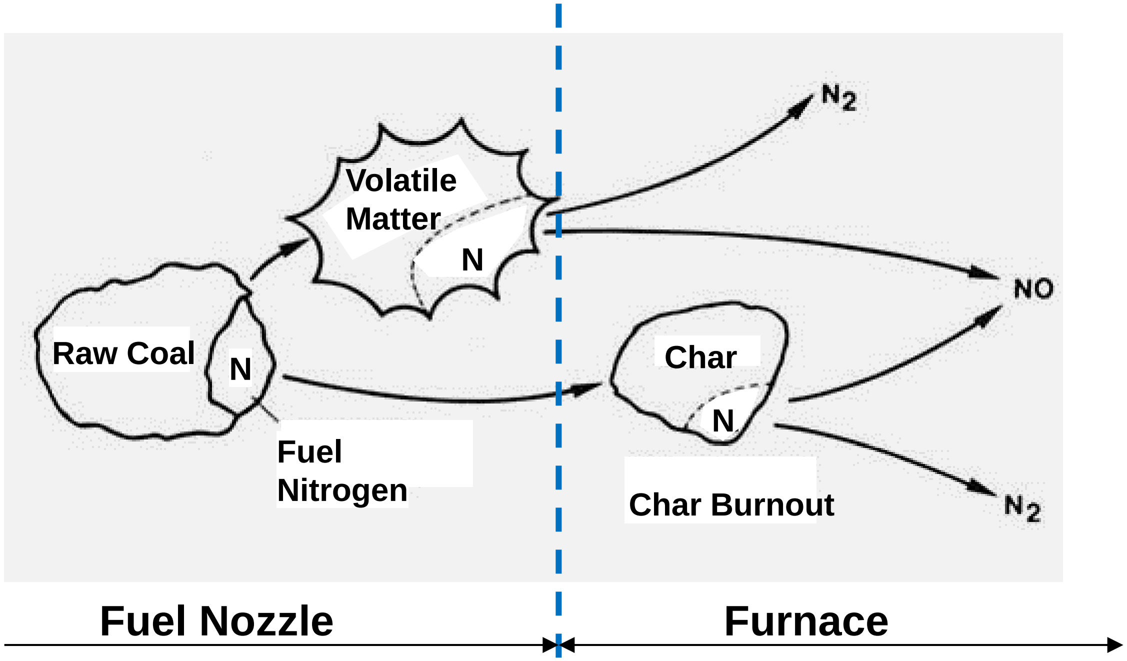
Nitrogen Distribution during Pyrolysis



During coal pyrolysis, the fuel nitrogen is split into the portions of the char and volatiles.

Thus, it is also determined whether the HCN or NH_3 branch of NO formation becomes relevant or influences the decomposition reaction

Objective of the optimized pyrolysis: Release of the maximum possible amount of volatiles and nitrogen in volatiles to accelerate the mechanisms of reduction.

NOx Emission / Burner Pyrolysis Model

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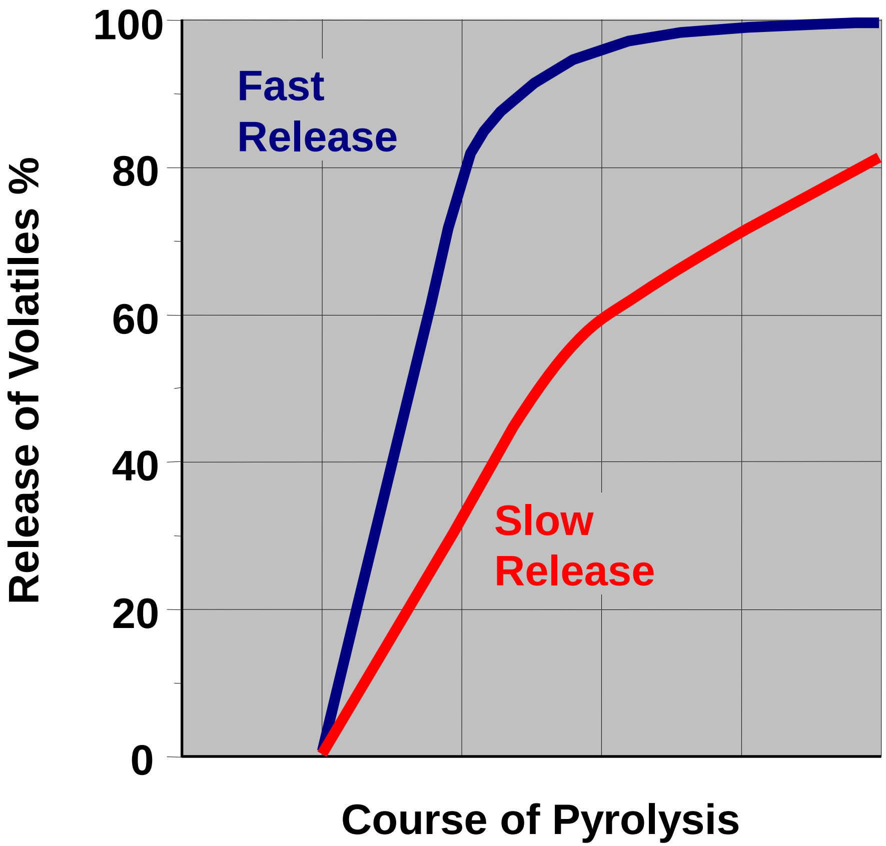
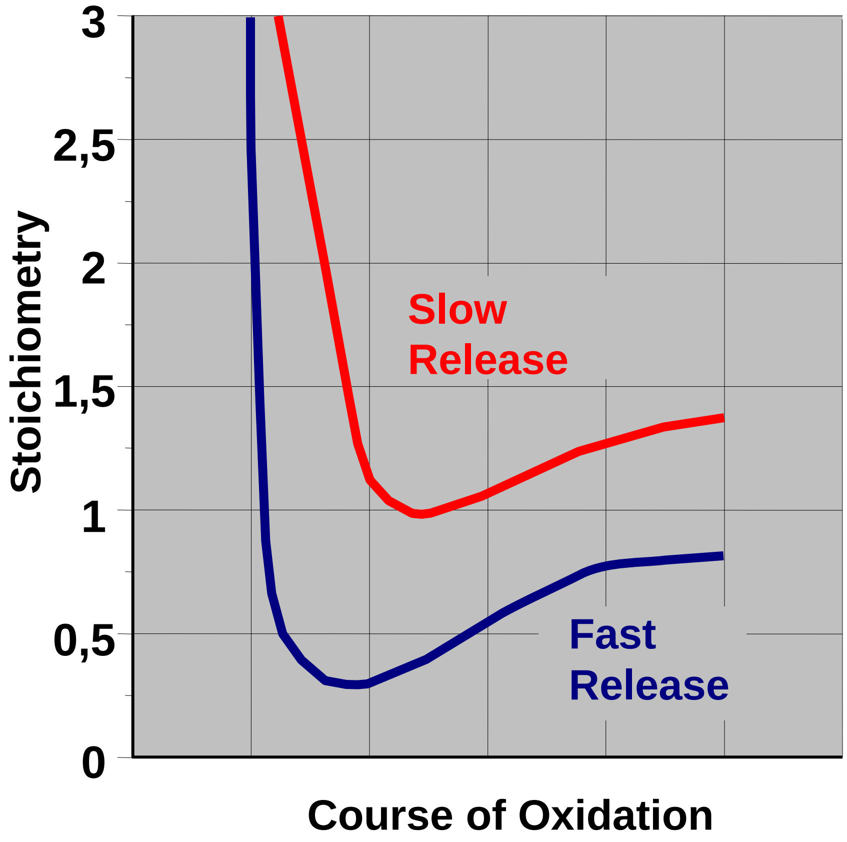
Proceedings during Pyrolysis and Oxidation





Expectations and Requirements on Coal Burners

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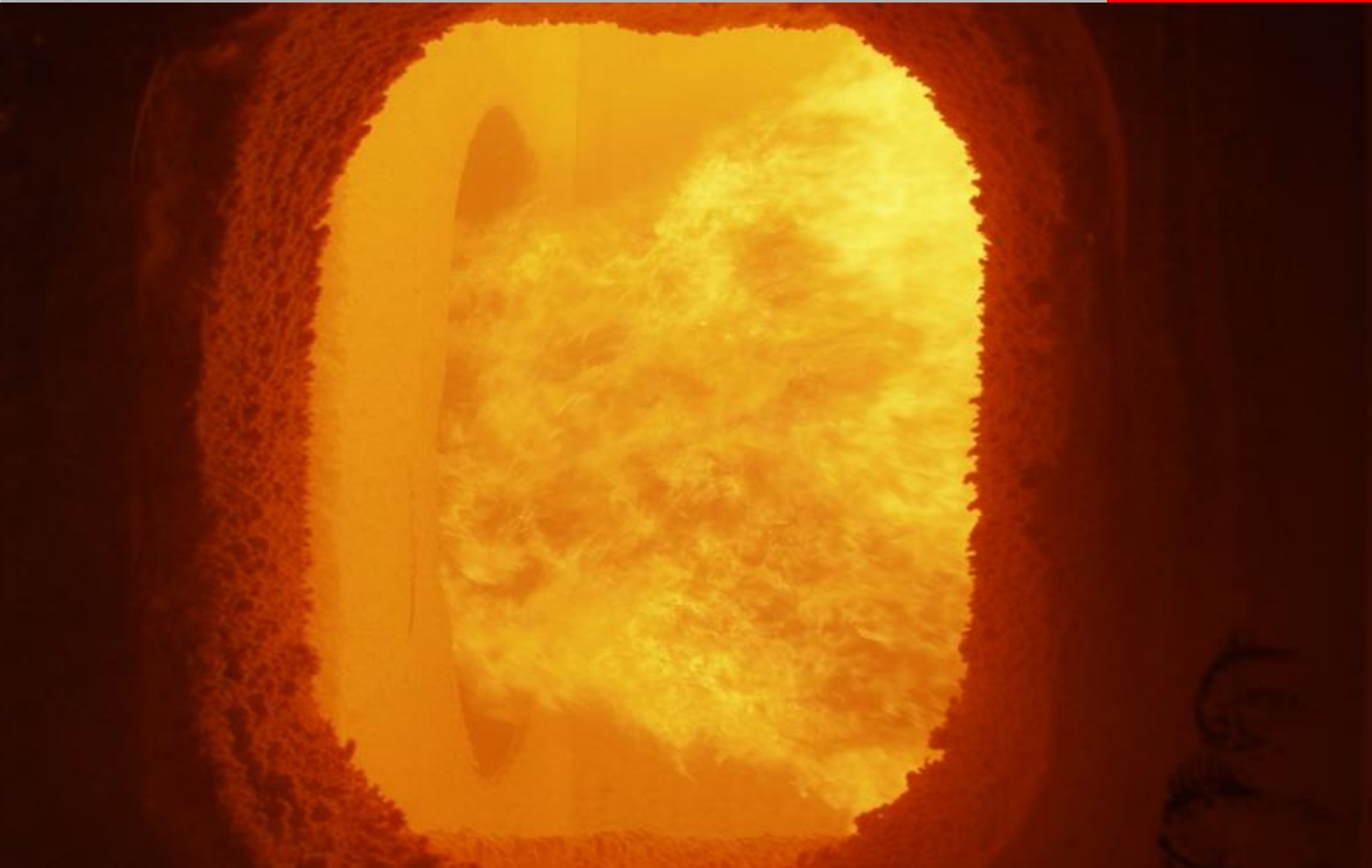
- Stable Ignition at the Burner Tip
- High Turn-down Rate
- Low NOx-Emission
- Operational Independence at Varying Coal Properties

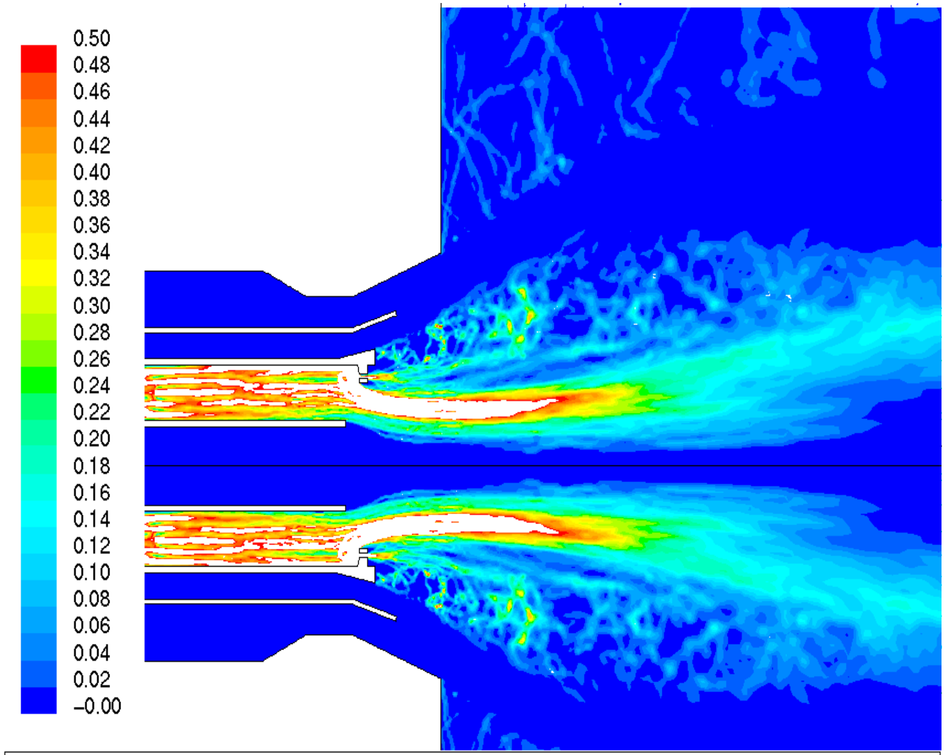
What's of Importance…

- Homogeneous PC Distribution at the Fuel Nozzle
- Definition of Ignition Conditions at the Fuel Nozzle
- Intensive Swirl on the PC and Combustion Air Side
- Residence Time High Enough at High Temperature and Low Oxygen Content
- Delayed Oxygen Mixing Towards the Initial Flame during Pyrolysis

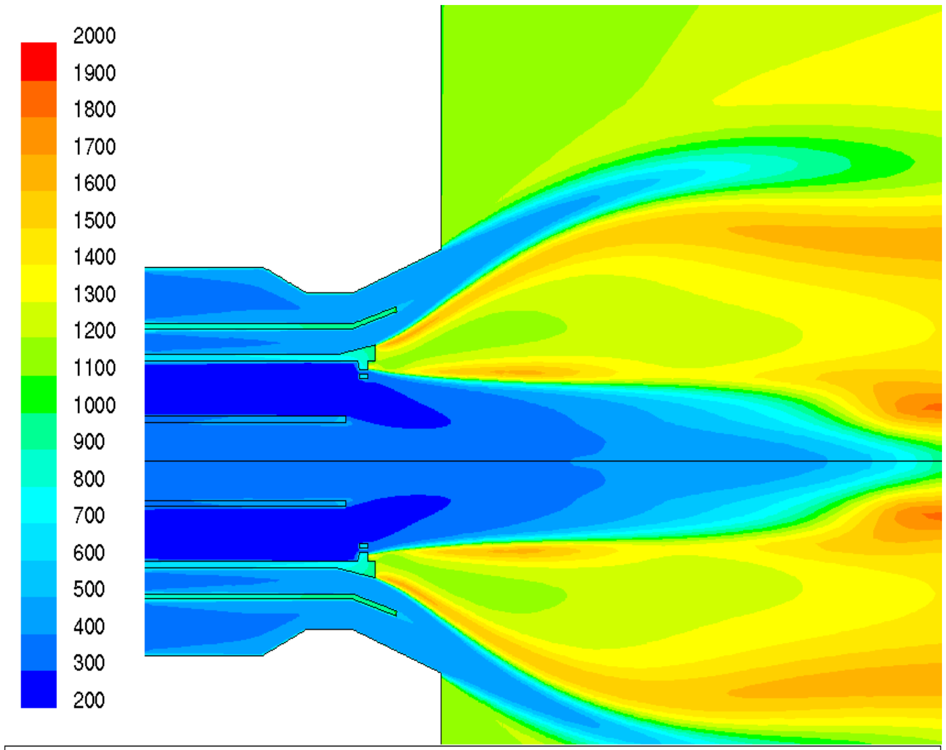
DS® Burner Today



DS® Burner Development, CFD Calculation

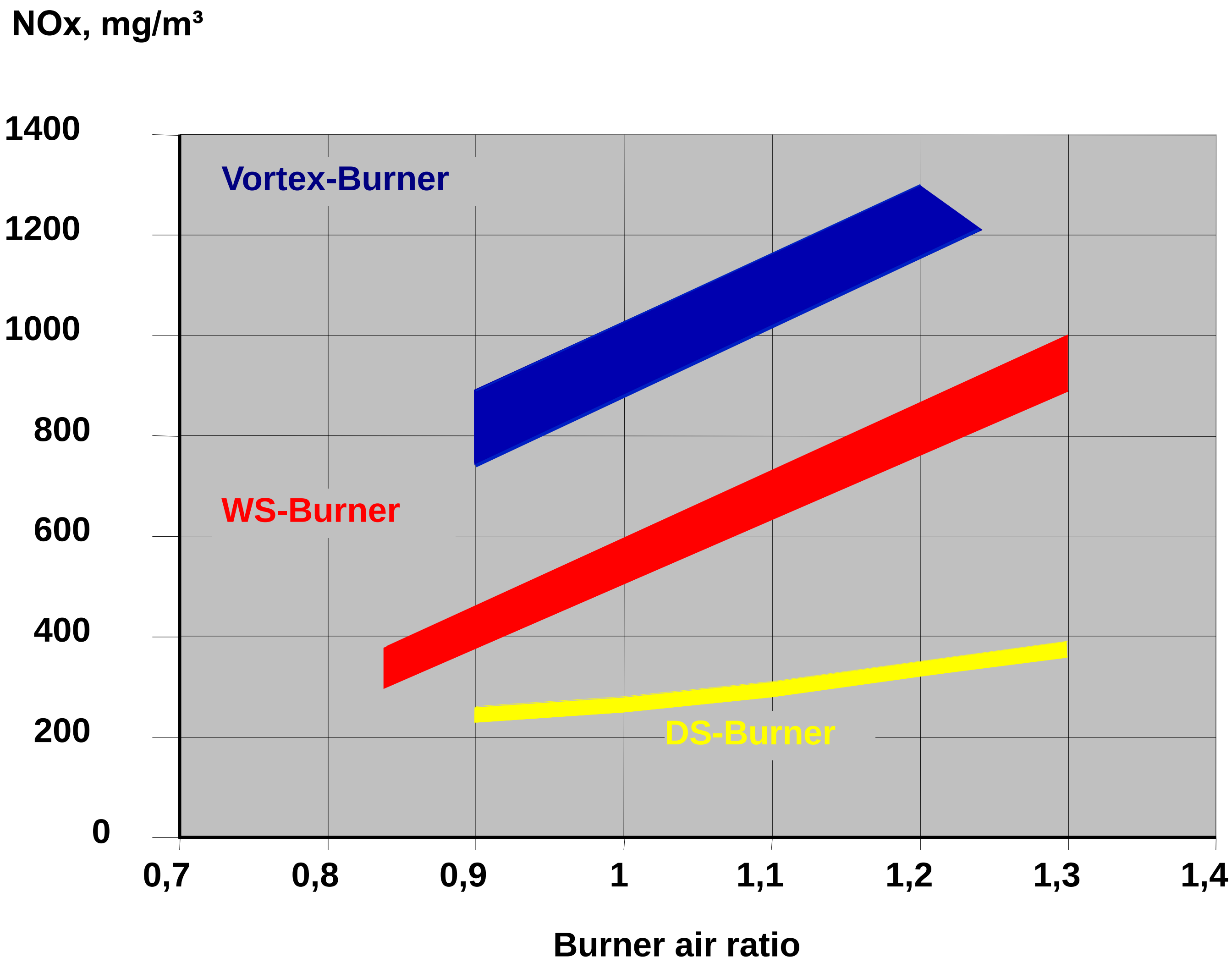


LaRobla DS-Brenner
Contours of DPM Concentration (kg/m3)
Mar 24, 2004
FLUENT 6.1 (axi, swirl, segregated, spe6, ske)



LaRobla DS-Brenner
Contours of temperature-c
Mar 24, 2004
FLUENT 6.1 (axi, swirl, segregated, spe6, ske)

DS® Burner / NOx Characteristic

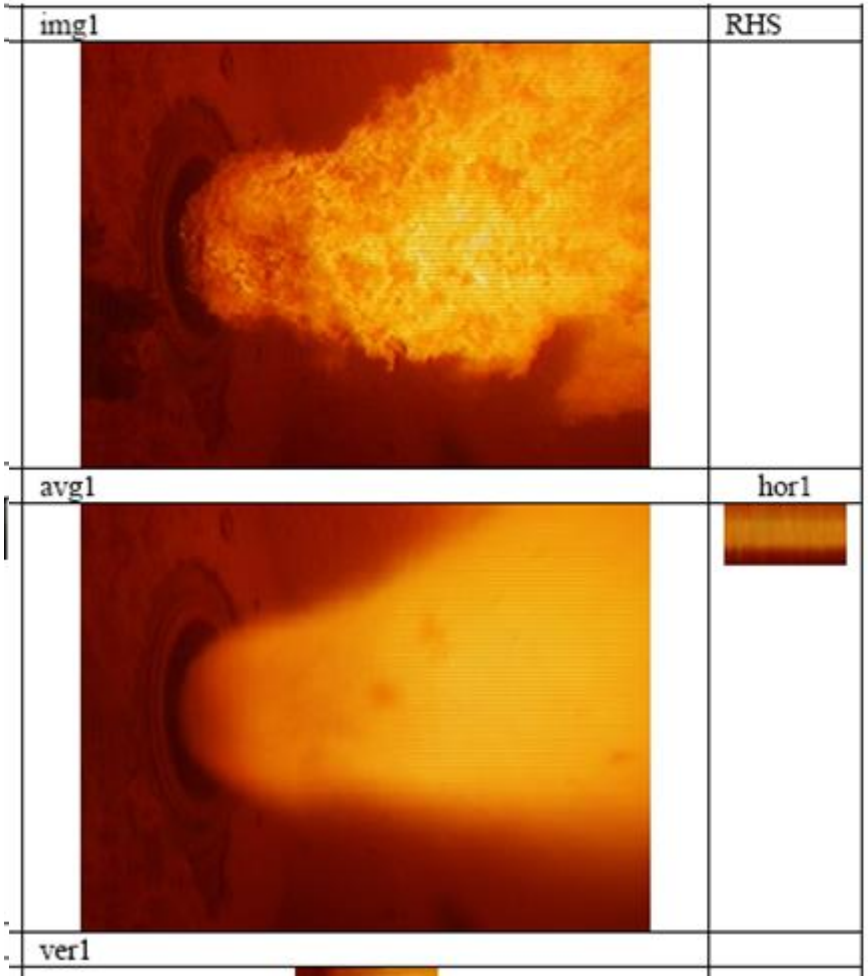


What makes the Burner being a functional unit?

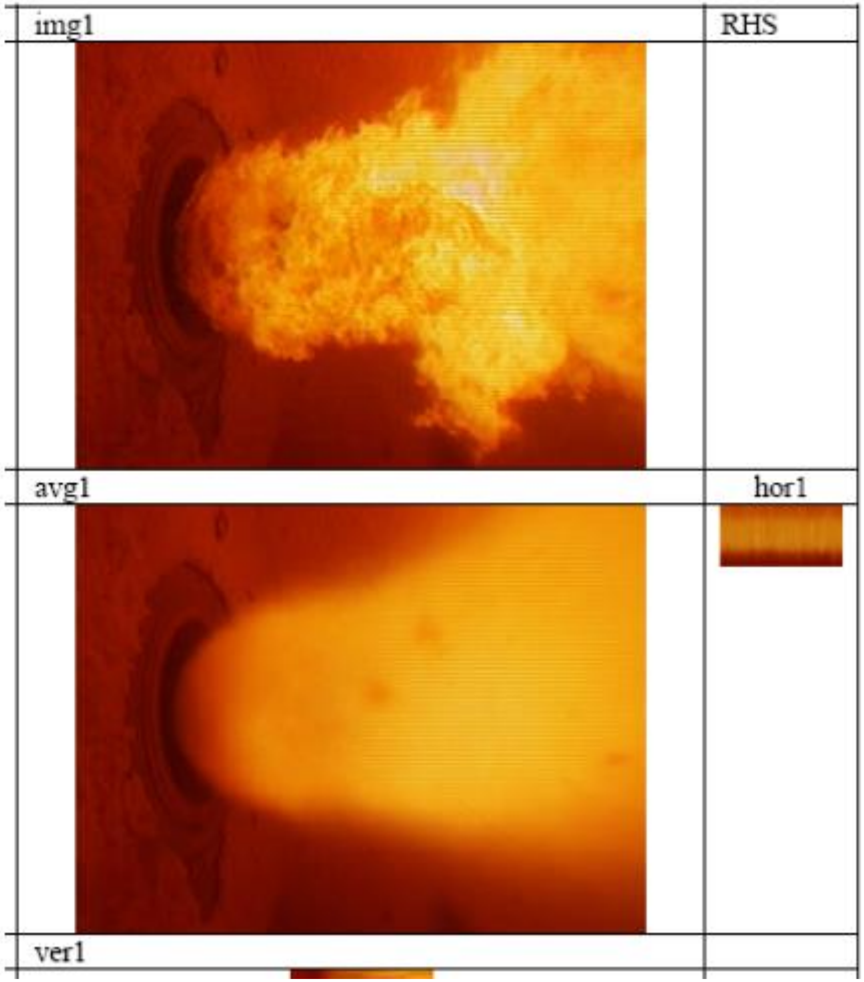
Results of DS® Burner Testing

Influence of Burner Swirl Settings on the Flame Shape

Burner Swirl: PA 35°/ SA 45°/ TA 45°



Burner Swirl: PA 35°/ SA 45°/ TA 60°



Influence on the Flame Shape

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Different Swirl Settings

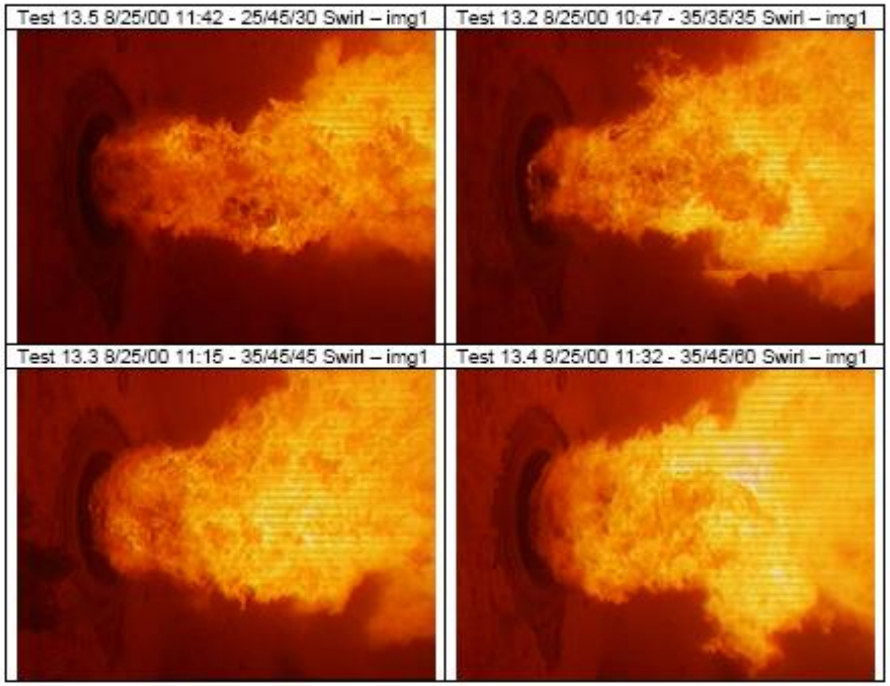


Figure 3-30 Comparison of Flame Video Images for Changes in Swirl Register Settings During DS Burner Tests with Flame Stabilizer Ring No. 2.1 (21 mm step, 9.6 mm teeth-20)

Different Burner Capacities

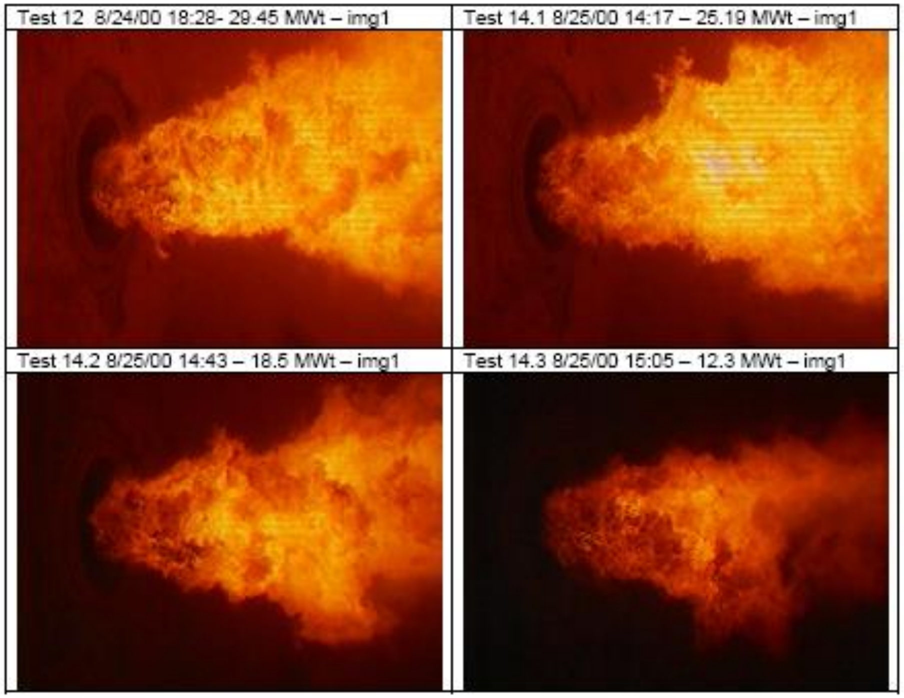


Figure 3-31 Comparison of Flame Video Images for Changes in Load During DS Burner Tests with Flame Stabilizer Ring No. 2.1 (21 mm step, 9.6 mm teeth-20)

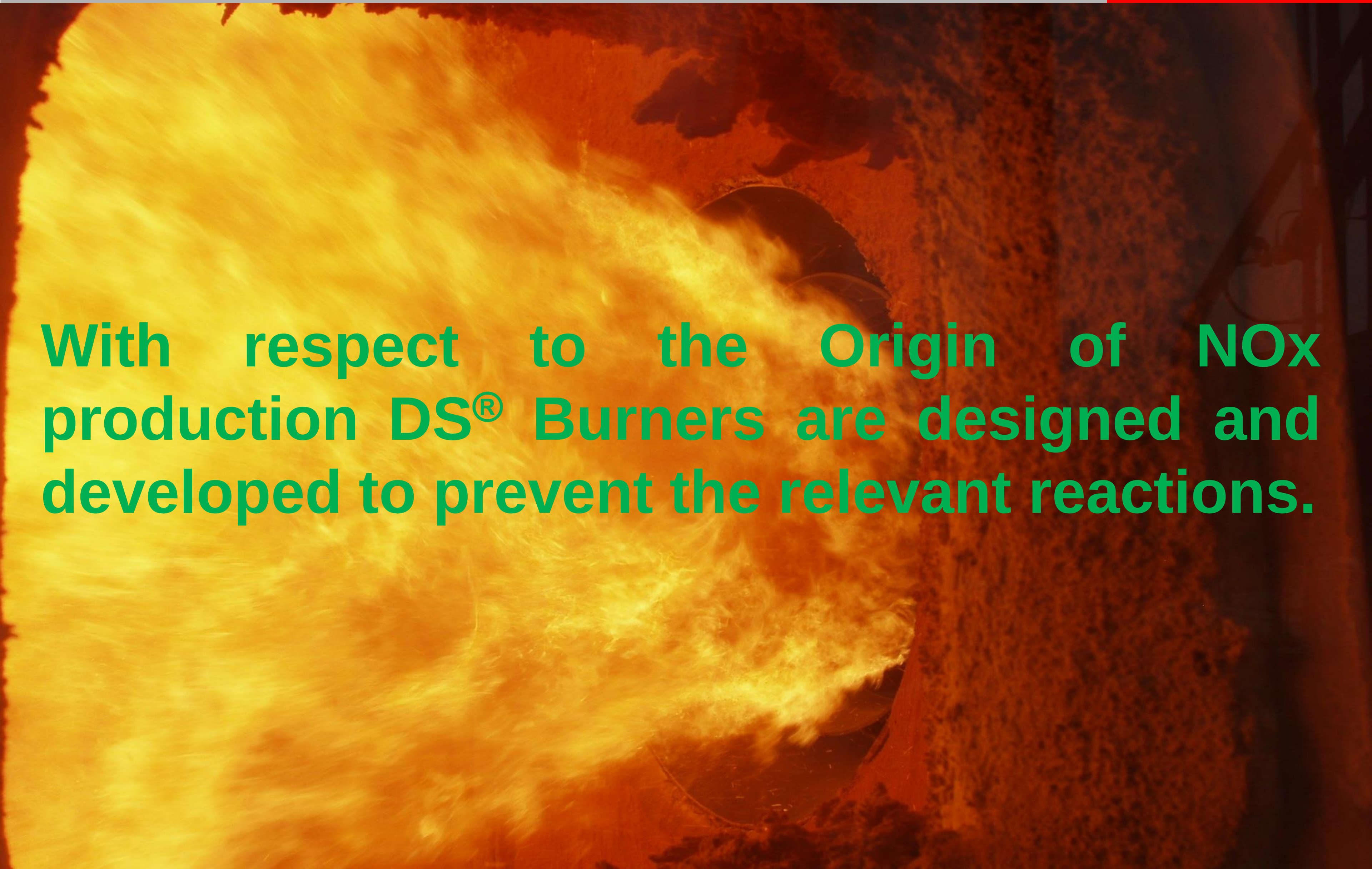
DS® Burner, Flame Pattern

DS® B … ad

DS® Burner, KK Coal (60%) + Sawdust (40%), 100% load

DS® Burner, Sawdust (91%) + NG (9%), 100% load

DS® - Burner, Flame Pattern



With respect to the Origin of NOx production DS® Burners are designed and developed to prevent the relevant reactions.

Thanks for Attention