Co-Feeding Fibrous Biomass and Coal into Entrained Flow Gasifiers

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ECN

Energy research Centre of the Netherlands

Gasification Asia Pacific

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Robin Zwart

GAP & Coal Chemicals Conference



荷兰能源研究中心

Gasification Asia Pacific

纤维生物质与煤炭在气流床气化炉中的联合供料

Robin Zwart

亚太气化与煤化学大会



Presentation overview

Energy research Centre of the Netherlands (ECN)

- Short introduction to ECN

Entrained Flow Gasification

- General process flow scheme illustrating the issues of co-feeding biomass

ECNs contribution to solving the issues

- Torrefaction technology development
- Quality control of the torrefied biomass
- Modelling slagging and fouling behaviour
- Simulating slagging and fouling behaviour as well as testing reactivity





Photography by Jasper Lensselink

概述

荷兰能源研究中心（ECN）

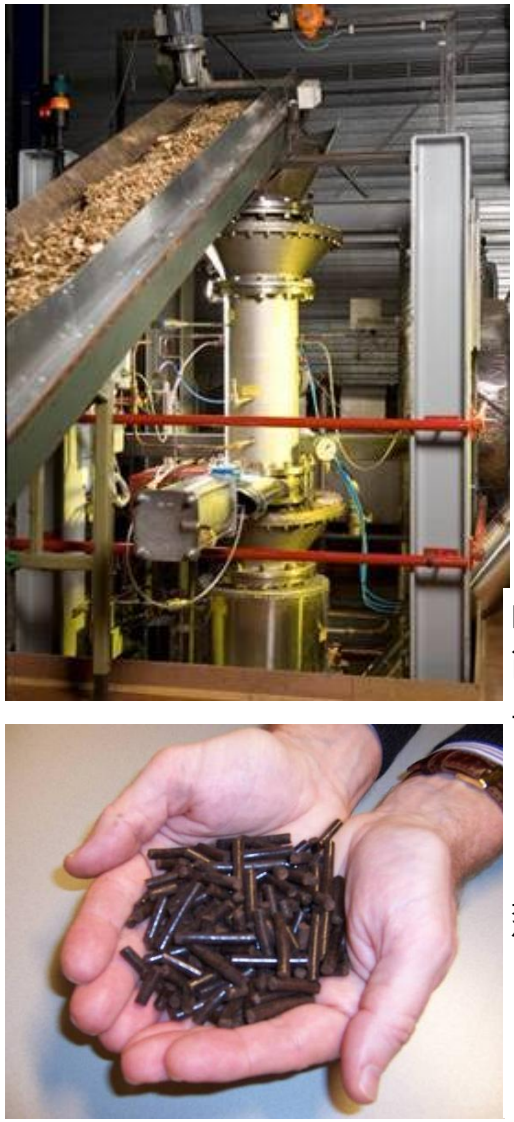
- ECN简介

气流床气化

- 通过一般工艺流程图说明生物质联供存在的问题

ECN对解决上述问题所作的贡献

- 开发烘焙技术
- 控制烘焙生物质的质量
- 结渣与积灰特性建模
- 结渣与积灰特性模拟试验与反应活性试验



图片由Jasper Lensselink 提供

The Energy research Centre of the Netherlands

Mission of ECN

develop high-quality knowledge and technology for the transition to sustainable energy management and introduce this knowledge and technology to the market

Focus of ECN

- energy conservation
- sustainable energy by means of wind, solar and biomass
- efficient and clean use of fossil fuels

Technology development at ECN

- gasification and tar removal for production of CHP
- torrefaction as pre-treatment step for EF gasification

荷兰能源研究中心

ECN的使命

为过渡到可持续能源管理阶段而开发高质量的知识和技术，并将其推向市场

ECN的工作重点

- *节约能源*
- *风能、太阳能、生物质能等可持续能源*
- *清洁有效地利用矿物燃料*

ECN的技术开发

- *用于热电联产的气化与除焦油技术*
- *针对气流床气化的烘焙预处理*

Entrained flow gasification



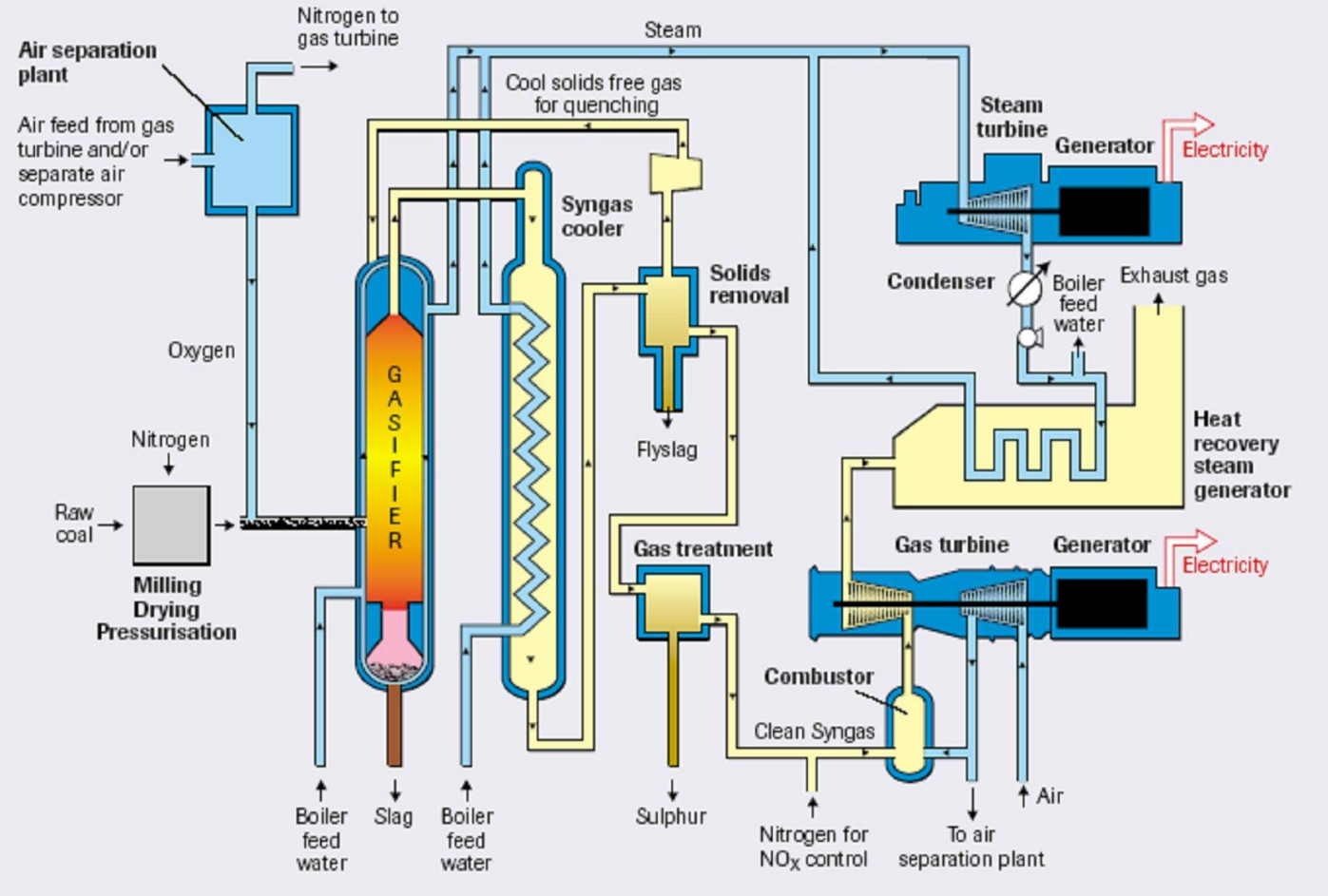
NUON Buggenum 250 MW_e IGCC based on Shell EF gasification technology

气流床气化



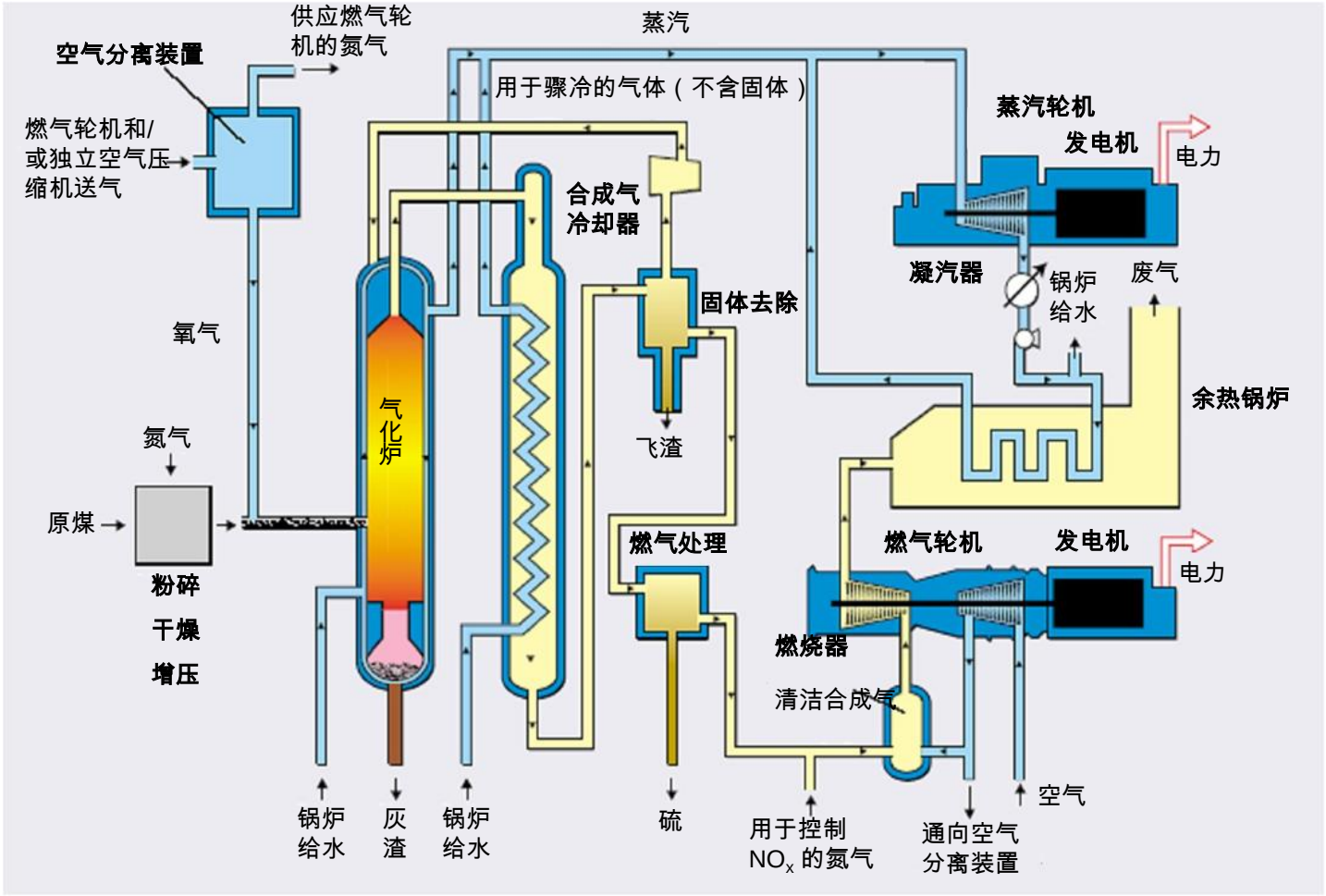
NUON Buggenum 250MW$_e$ 整体煤气化联合循环（IGCC）发电厂 （采用Shell气流床气化技术）

Entrained flow gasification



Scheme from Roads2HyCom site (www.roads2hy.com) hosted by RWTH, Aachen, Germany

气流床气化



德国亚琛工业大学主办的 Roads2HyCom (www.roads2hy.com) 现场方案

Torrefaction… as biomass is a difficult energy source

- … in view of:
  - End-use (gasification, but also combustion and chemical processing)
  - Logistics (feeding, as well as handling and transport)

- Difficult properties are:
  - Low energy density (LHV_{ar} = 10-17 MJ/kg) *(LHV_{coal} > 30 MJ/kg)*
  - Hydrophilic
  - Vulnerable to biodegradation
  - Tenacious and fibrous (grinding difficult)
  - Poor “flowability”
  - Heterogeneous



生物质能源材料难以处理，需要烘焙

- 目的
  - 最终用途（气化、燃烧和化学处理）
  - 物流（供料、处理和运输）

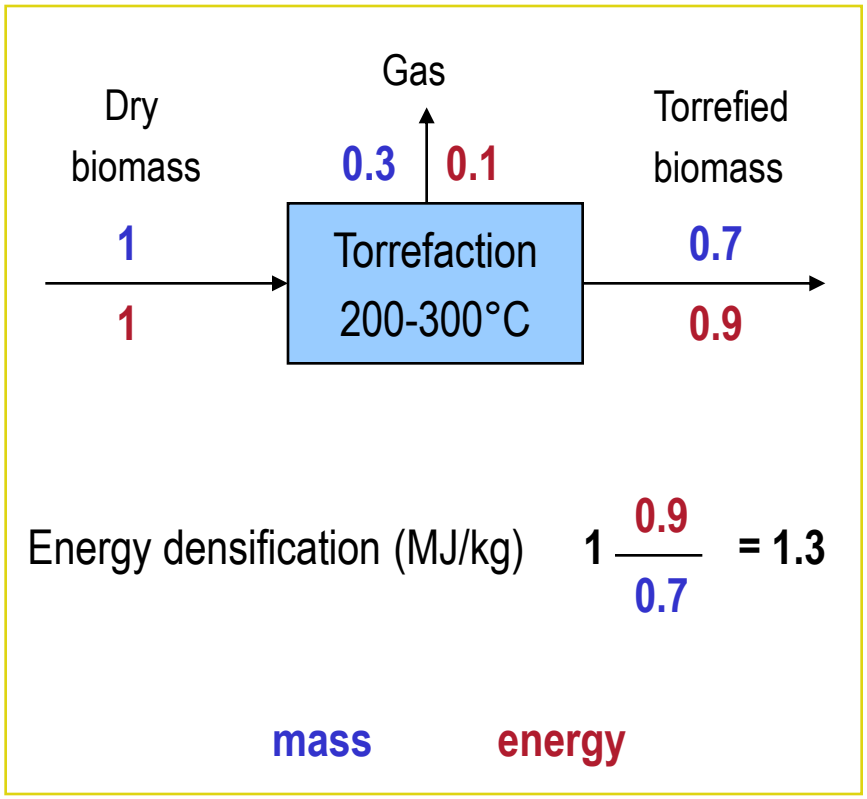
- 不利性质
  - 能量密度低（LHV_{ar} = 10-17 MJ/kg）
    （*$LHV_{煤}$ > 30 MJ/kg*）
  - 亲水
  - 易发生生物降解
  - 纤维质，有韧性（难以粉碎）
  - “流动性”差
  - 不均匀



Torrefaction...
for upgrading biomass

In short: the roasting of biomass





Process parameters

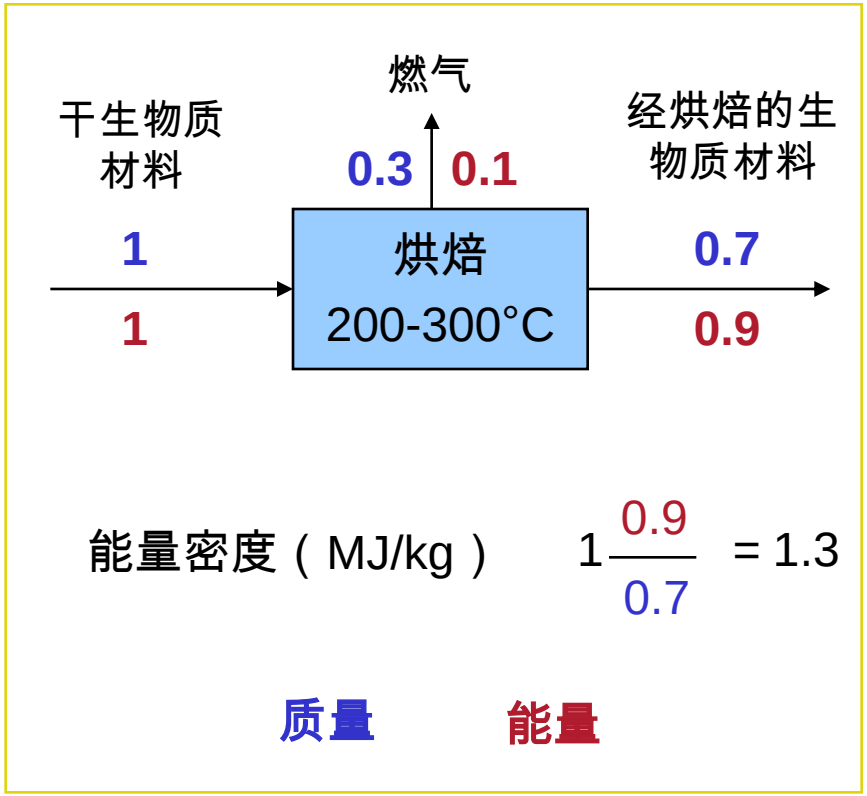
- Temperature: 200-300°C
- Residence time: 10-30 minutes
- Particle size: < 4 cm
- Absence of oxygen
- Pressure: near atmospheric

Lower temperatures than pyrolysis (i.e. less losses) & focusing on solid products!

通过烘焙提高生物质材料质量

（主要为烘干）





处理参数

- 温度：200-300°C
- 滞留时间：10-30分钟
- 粒度：< 4 cm
- 无氧
- 压力：接近大气压

低于高温分解的温度（低损耗），注重固体产物的生成！

Torrefaction

Woody biomass



Agricultural residues



Friable and less fibrous
19 - 22 MJ/kg (LHV, ar)
Hydrophobic
Preserved
Homogeneous

Improved fuel properties:
- Transport, handling, storage
- Milling, **feeding**
- Gasification, combustion
- Broad feedstock range
- Commodity fuel

Mixed waste



Torrefaction and pulverisation



Fuel powder

Increasing density

Pelletisation



Fuel pellets

Tenacious and fibrous
10 - 17 MJ/kg (LHV, ar)
Hydrophilic
Vulnerable to biodegradation
Heterogeneous

Bulk density 650-750 kg/m^3
Bulk energy density 13-17 GJ/m^3

烘焙

木屑



农作物秸秆



易碎，纤维含量低
19 - 22 MJ/kg（LHV，ar）
疏水
防腐
均匀

燃料性质改善：

- 运输、处理、储存
- 粉碎、**供料**
- 气化、燃烧
- 原料来源广泛
- 商品燃料

混合废物



烘焙粉碎



燃料粉末

提高密度

粒化



燃料颗粒

纤维质，有韧性
10 - 17 MJ/kg（LHV，ar）
亲水
易发生生物降解
不均匀

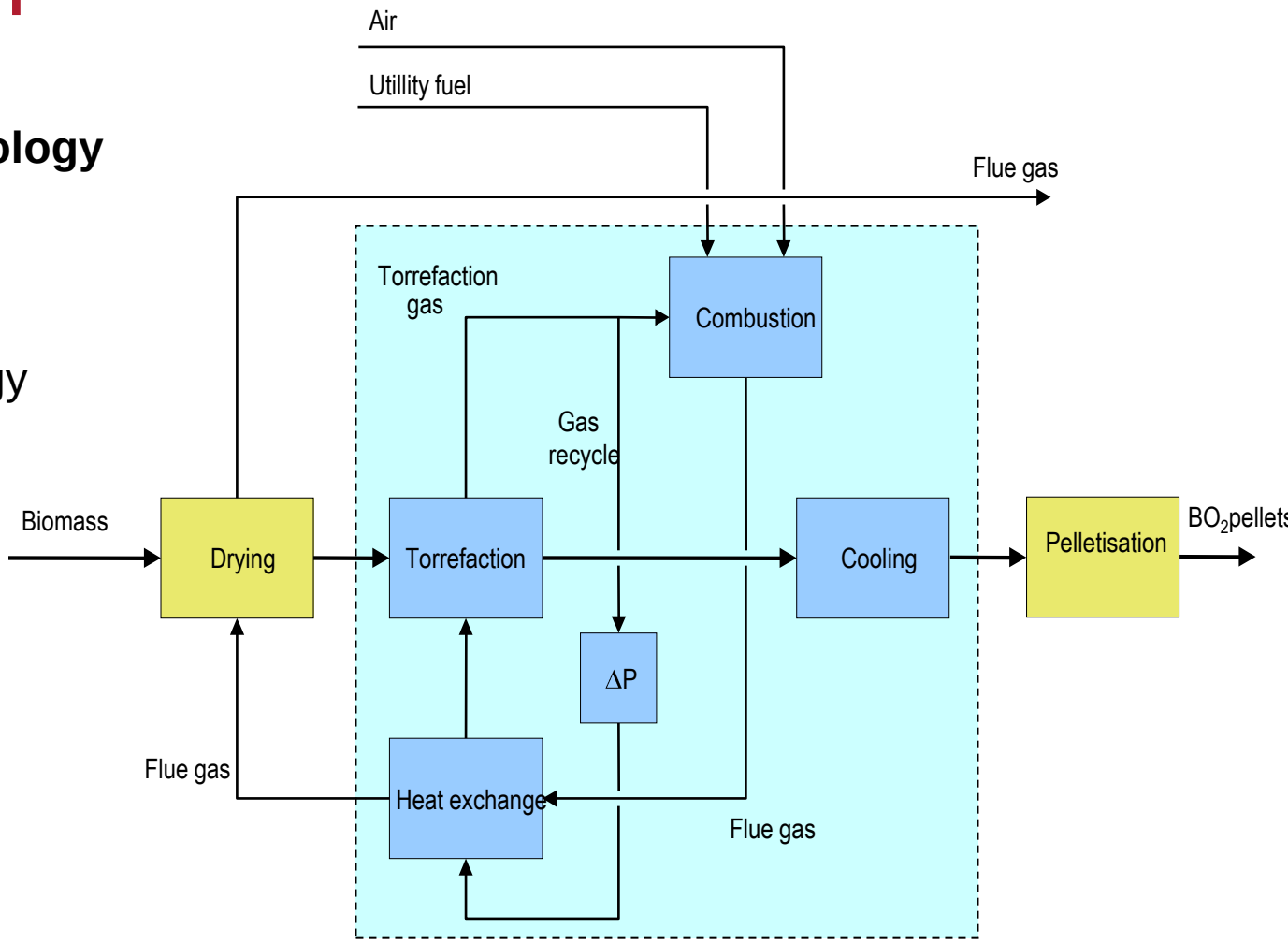
体积密度 650-750 kg/m^3
体积能量密度 13-17 GJ/m^3

Torrefaction

The ECN BO_2 technology

- Conventional drying and pelletisation
- Compact dedicated
- moving bed technology with direct heating
  (no moving parts)

- Heat integration
- High energy efficiency (> 90%)
- Cost effective
- IP is patent protected
- Over 1,000 hours of pilot scale production

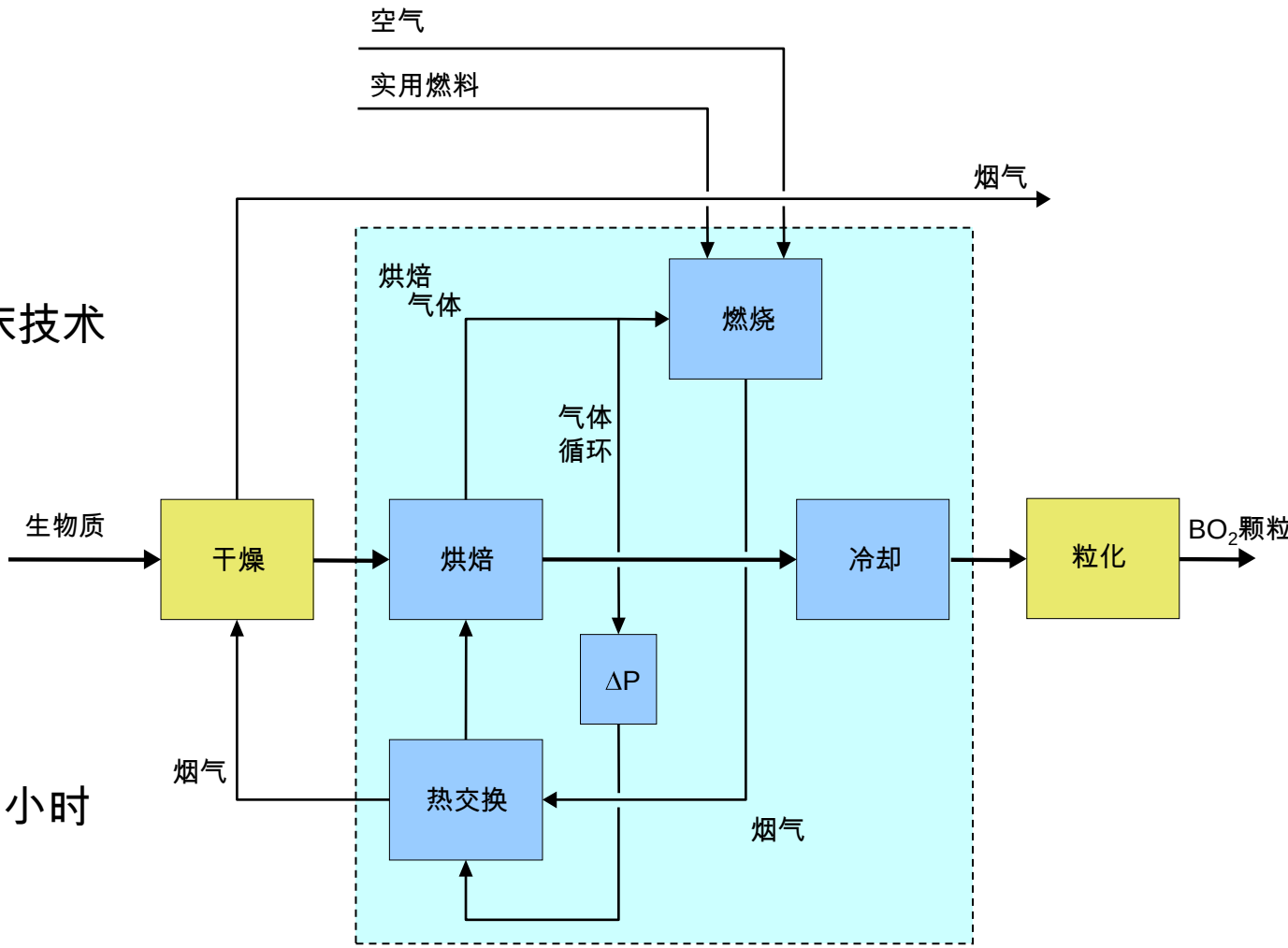


烘焙

ECN BO_2 技术

- 常规式干燥与粒化
- 致力于紧凑
- 可直接加热的移动床技术
  （无活动部件）

- 热量集成
- 高能效（> 90%）
- 性价比高
- IP受专利保护
- 试验生产超过1,000 小时



Torrefaction













烘焙













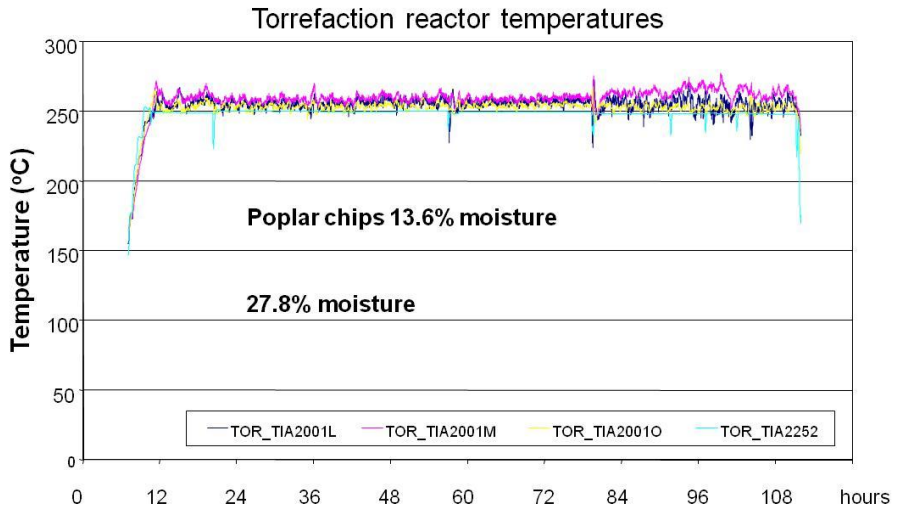
Quality control

Aiming for optimal…

- Heating value
- Overall energy efficiency
- Pellet durability
- Hydrophobicity
- Pellet density
- Grindability
- Reactivity

Parameters available…

- Torrefaction temperature (including good control)
- Torrefaction residence time
- Product cooling
- Densification procedure



Temperature control to avoid hotspots and handle exothermic behaviour of the process



Temperature of torrefaction and densification in order to reduce or avoid utilization of binders

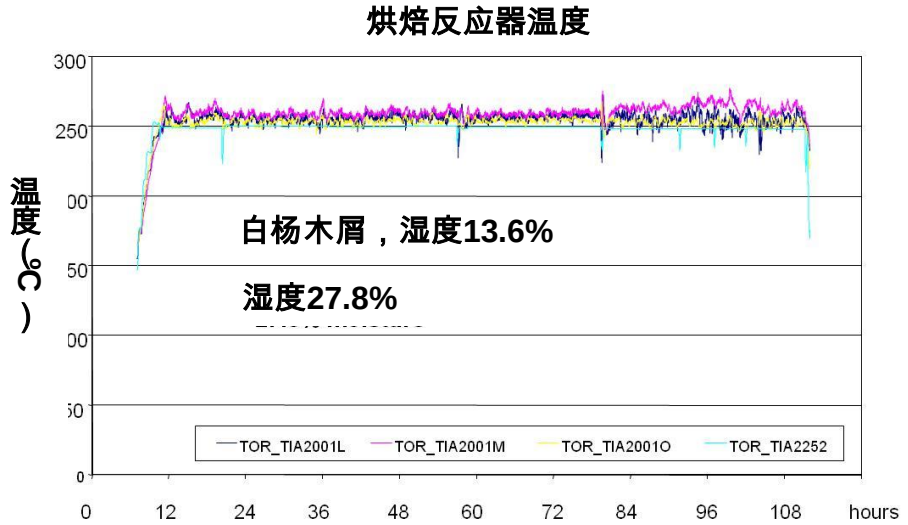
质量控制

力求最优：

- 热值
- 总能效
- 颗粒耐久性
- 疏水性
- 颗粒密度
- 可粉碎性
- 反应性

可用参数：

- 烘焙温度（包括良好的控制）
- 烘焙滞留时间
- 产物冷却
- 密实化程序

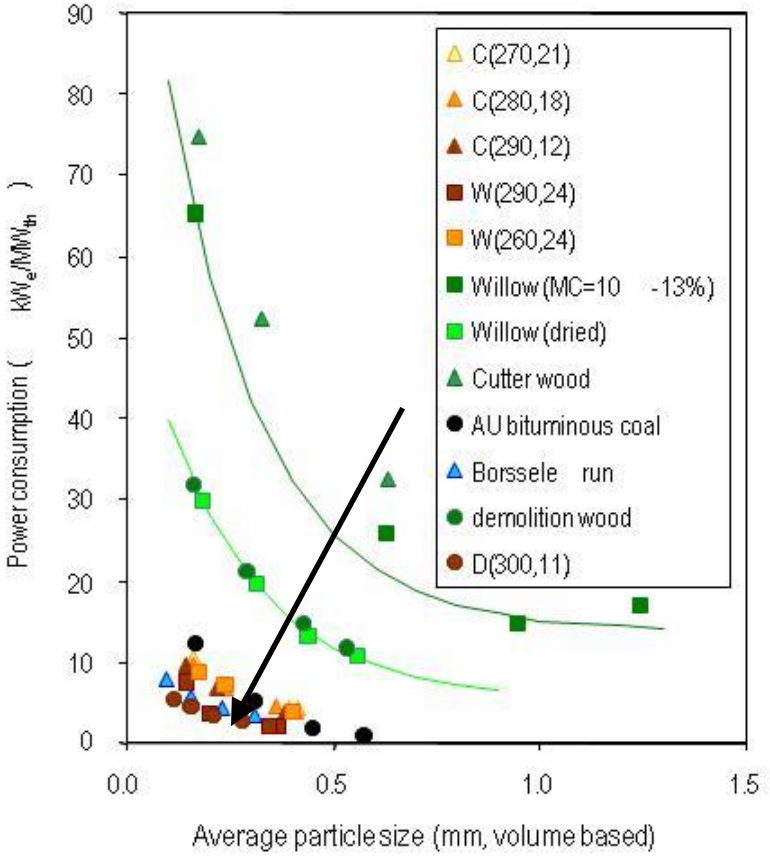


控制温度以避免产生热点，处理加工过程中的发热状况

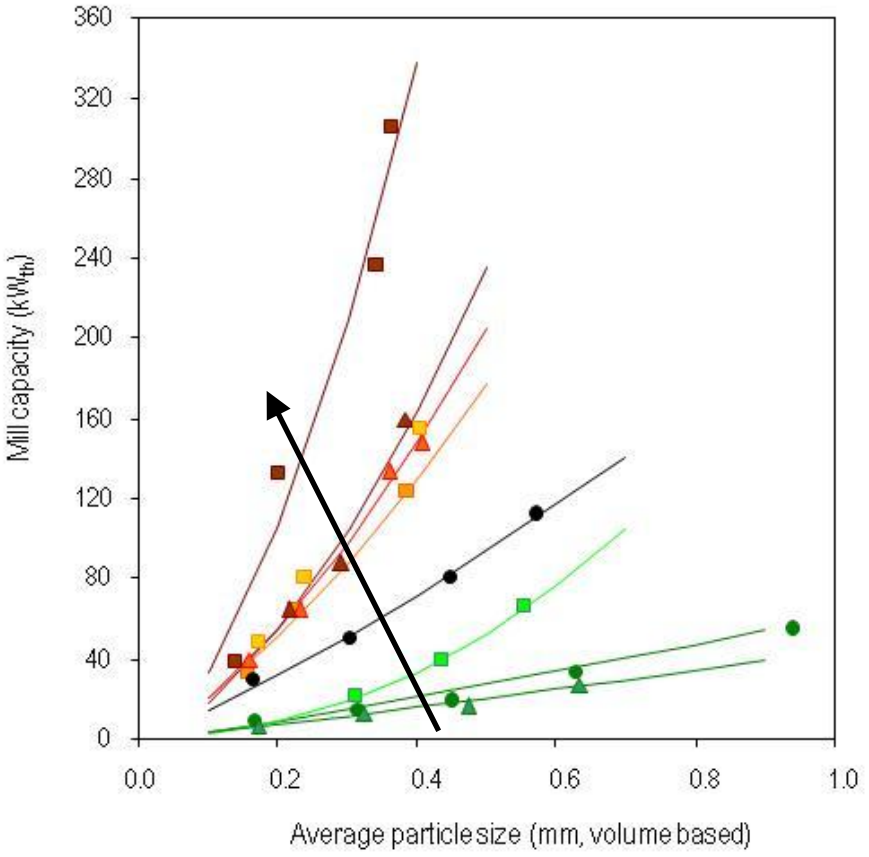


控制烘焙与密实化的温度，以减少或避免使用粘结剂

Quality control

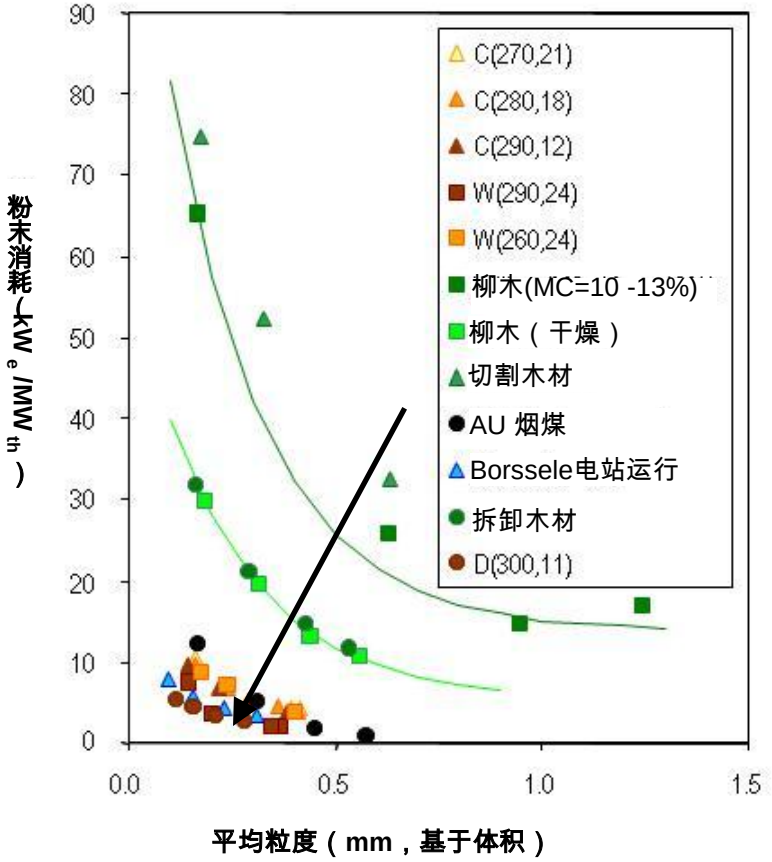


Grindability

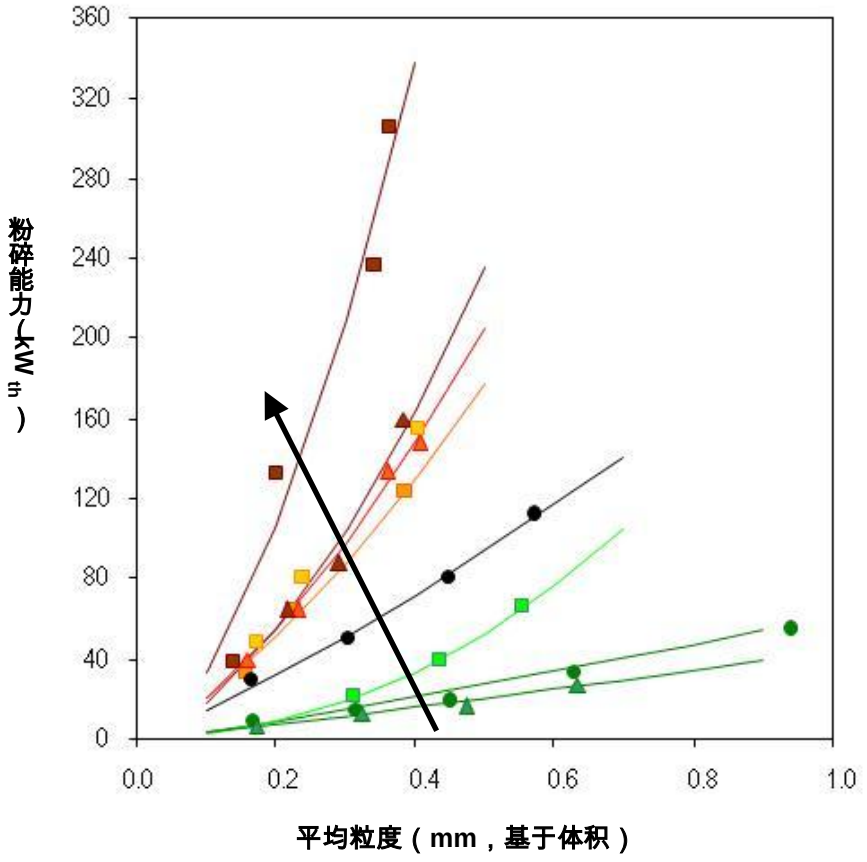


*Torrefaction leads to a decrease in milling power required and increase in milling capacity and as such **allows co-feeding of biomass and coal** in existing mills*

质量控制



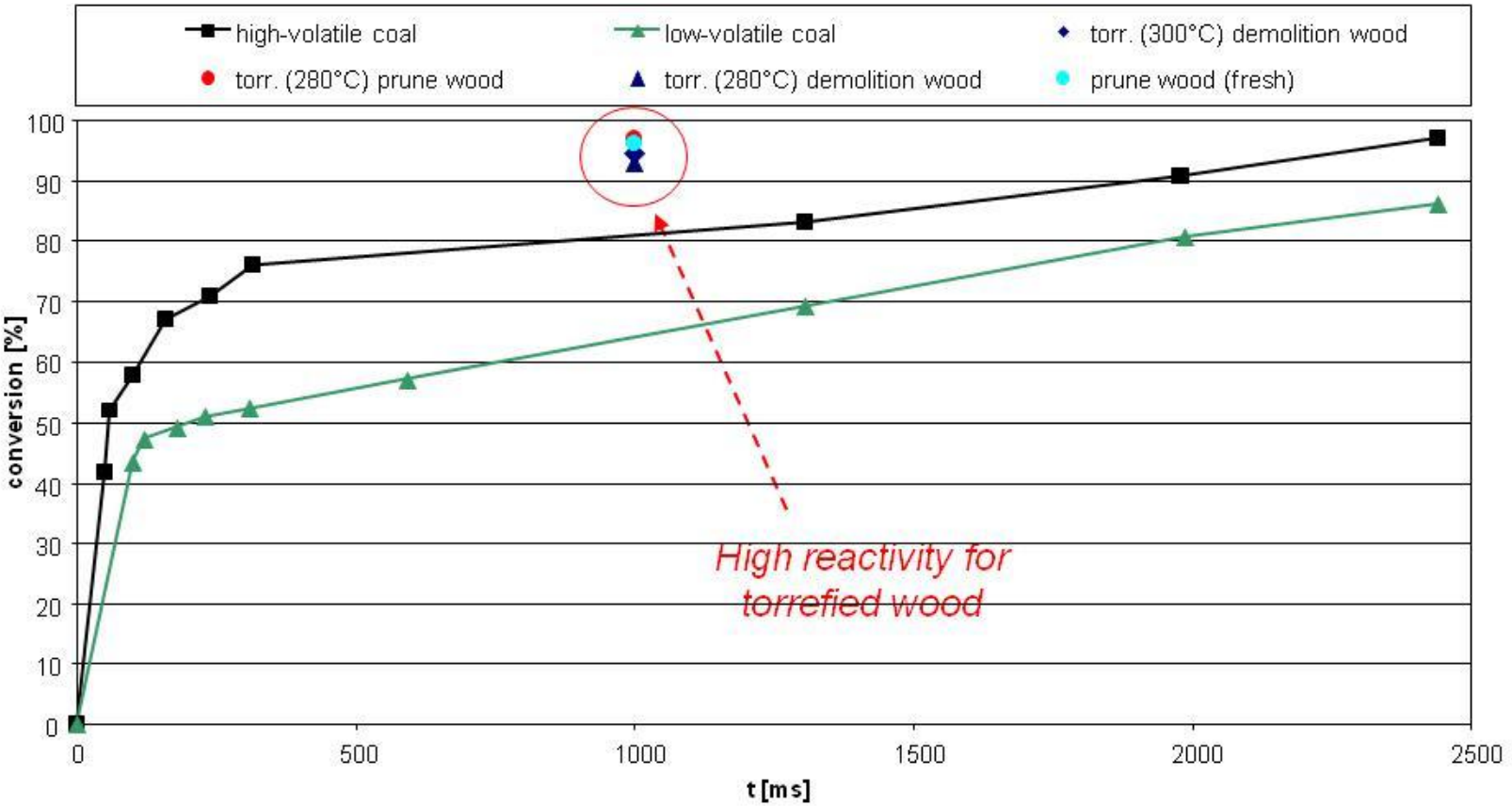
可粉碎性



烘焙可以降低所需粉碎功率，提高粉碎能力，在现有磨煤机上实现生物质和燃煤的同时供料

Quality control

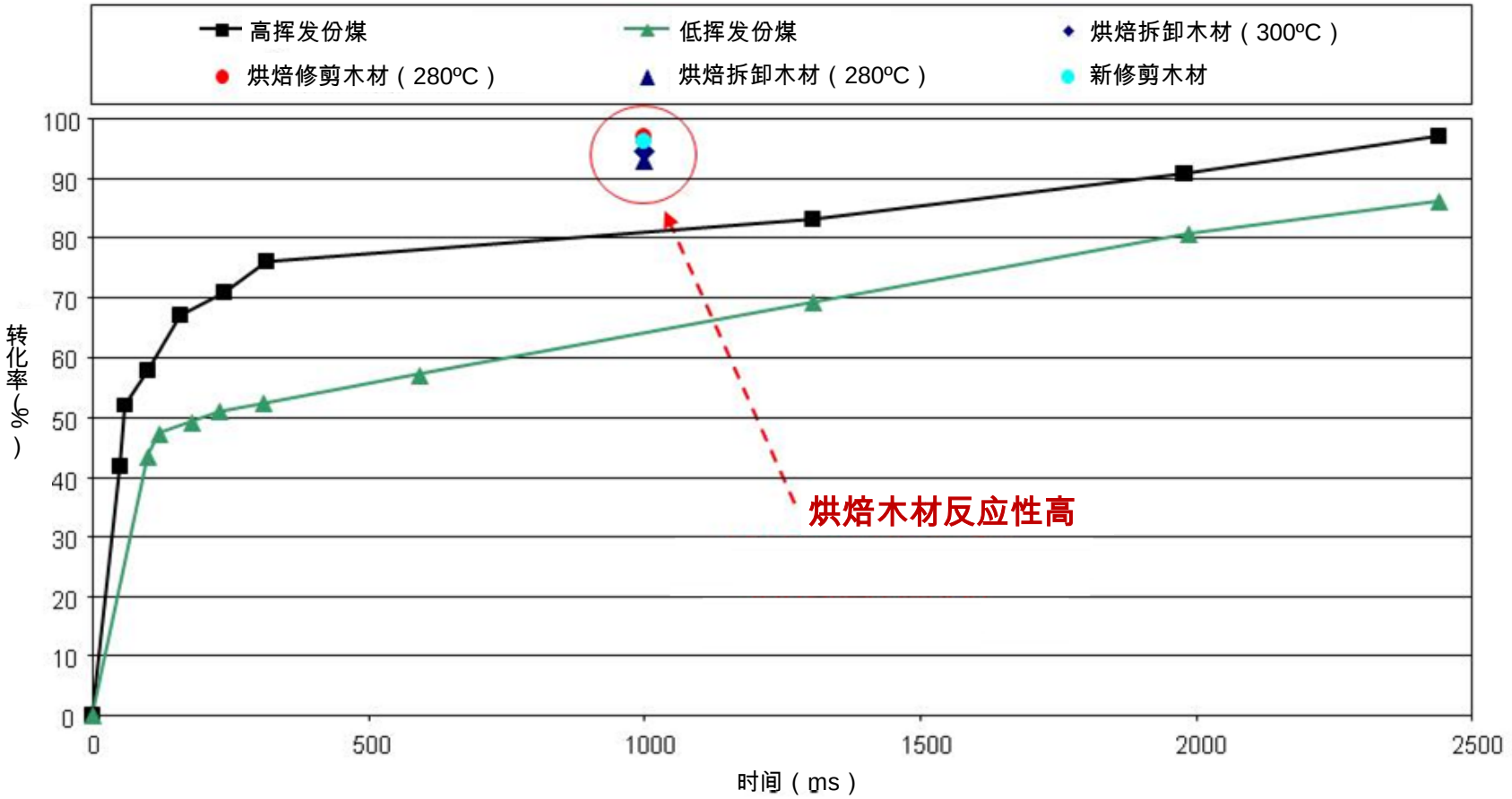
Reactivity



Torrefaction material will convert faster than coal
*and as such **allows co-firing of biomass and coal** in existing plants*

质量控制

反应性



烘焙材料的转化速度比燃煤高，可以在现有电厂中实现生物质和燃煤的同步转化

Modelling slagging and fouling behaviour

FACTSage program for computational thermo chemistry

- Thermodynamic modeling used to investigate slagging behavior and determine fluxing strategy for torrefied wood types
- Investigate potential fate of inorganic components as function of gasification temperature
- Measure ash fusion temperatures of mixtures of coal/torrefied wood/fluxing agent
- Determine the ideal mixture of biomass and coal which will results in better performance than coal or biomass alone

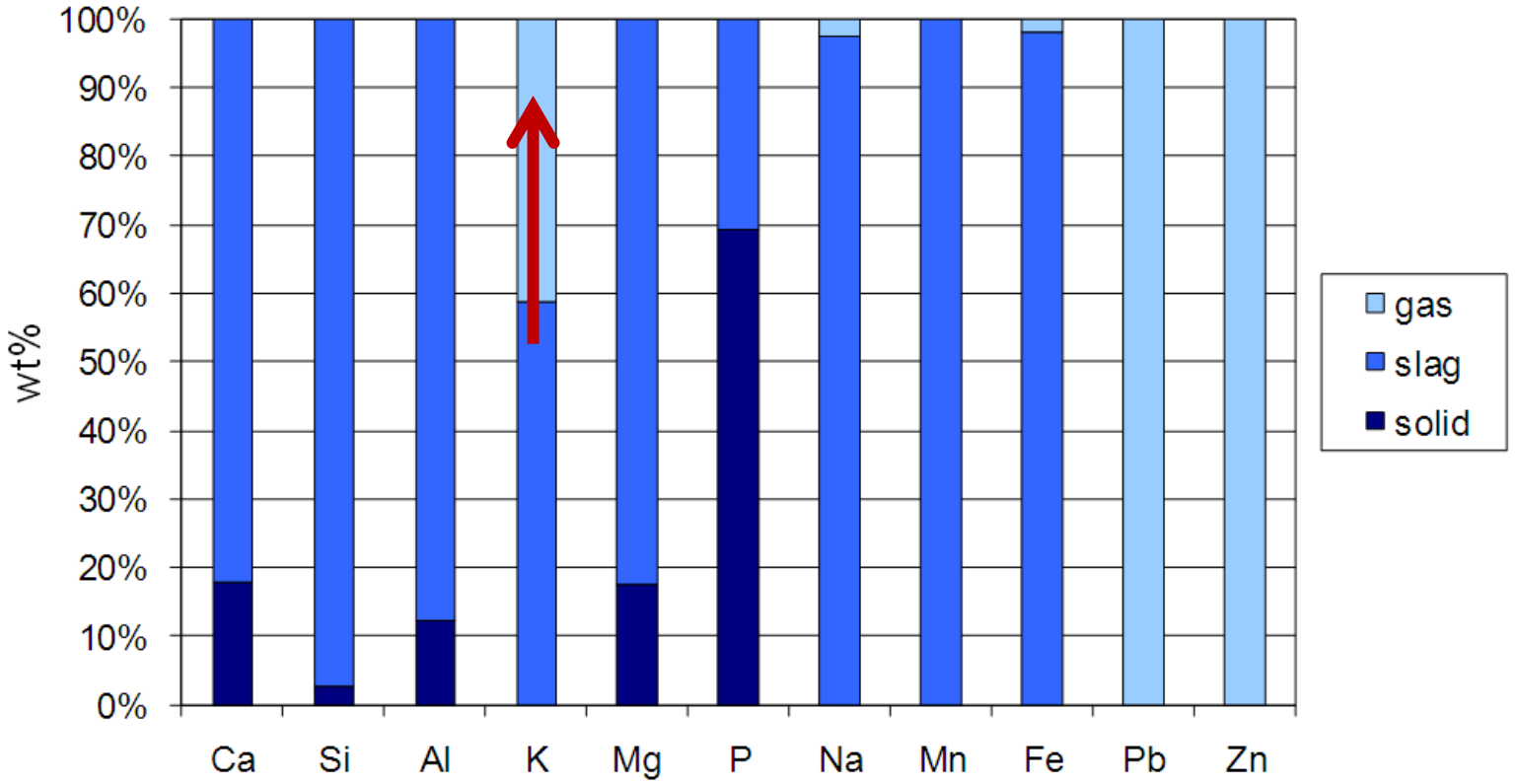
结渣与积灰特性建模

通过FACTSage程序进行热化学计算

- 通过热力学建模来研究结渣特性，并针对烘焙的木材类型确定稀释方法
- 研究无机成分随气化温度发生变化结果
- 测定煤混合物/烘焙木材/稀释剂的灰熔化温度
- 确定生物质与煤的理想混合状态（优于单独使用煤或生物质时的性能）

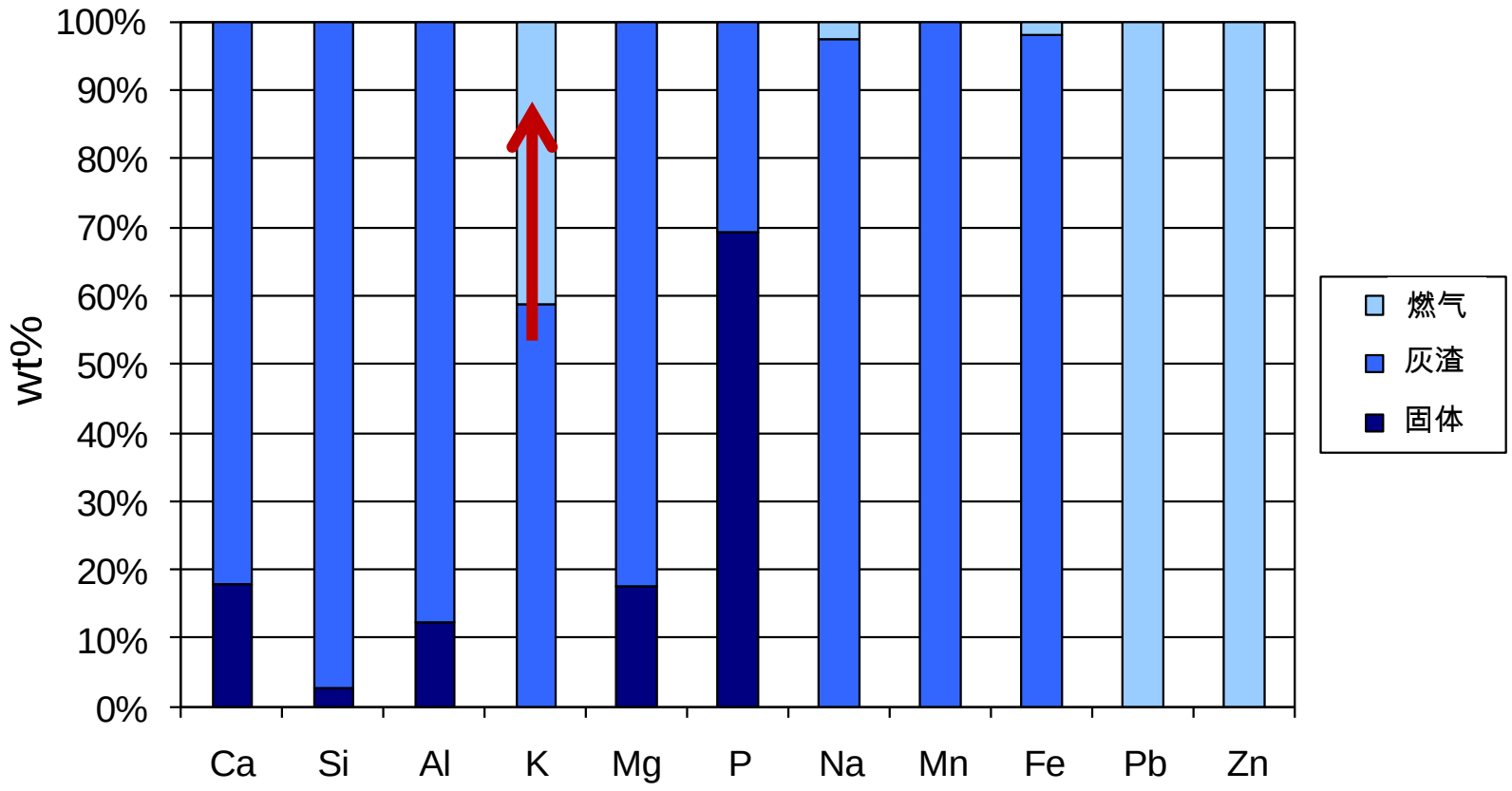
Modelling slagging and fouling behaviour

Phase distribution (example 1300°C)



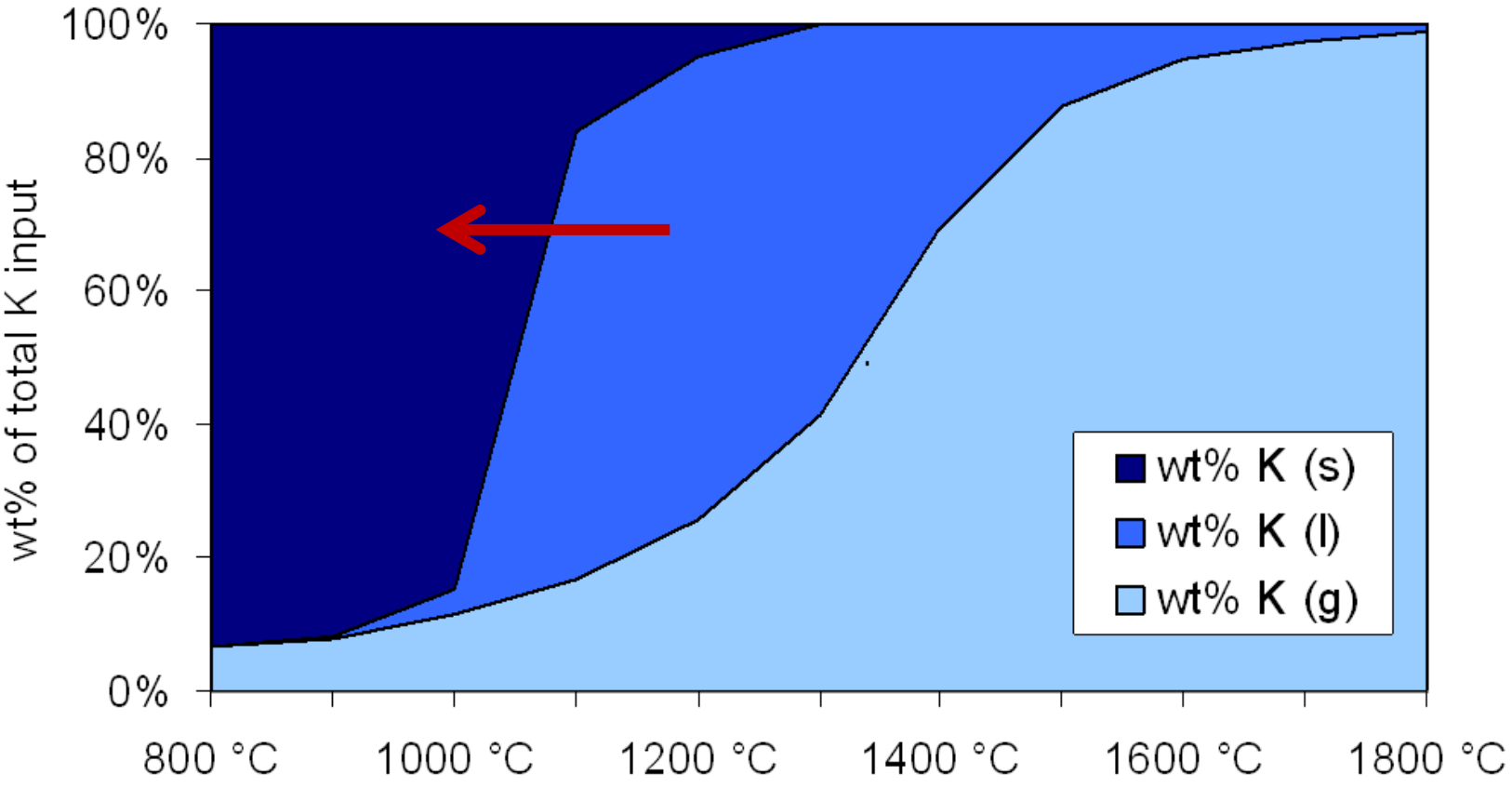
结渣与积灰特性建模

相分布（示例温度1300°C）



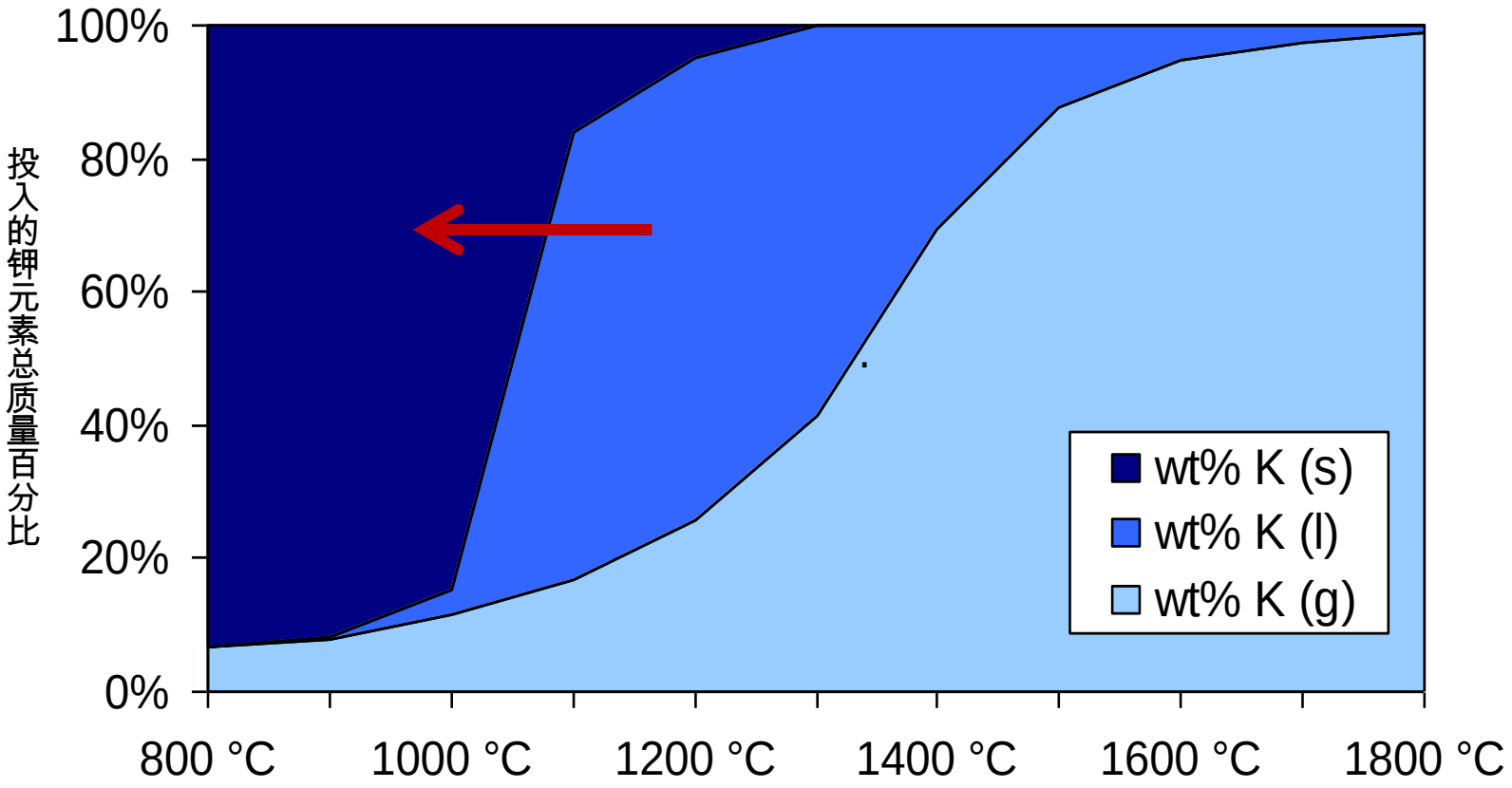
Modelling slagging and fouling behaviour

Alkali distribution



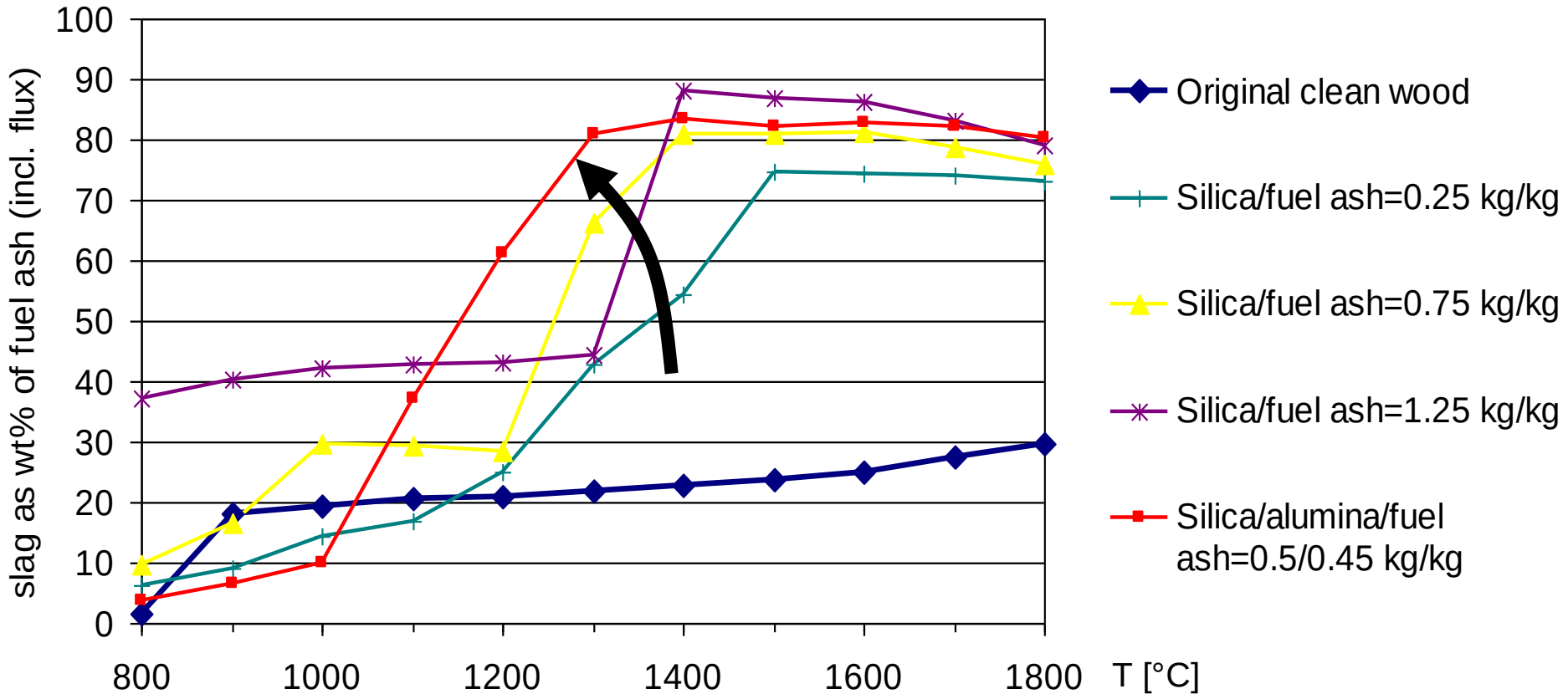
结渣与积灰特性建模

碱分布

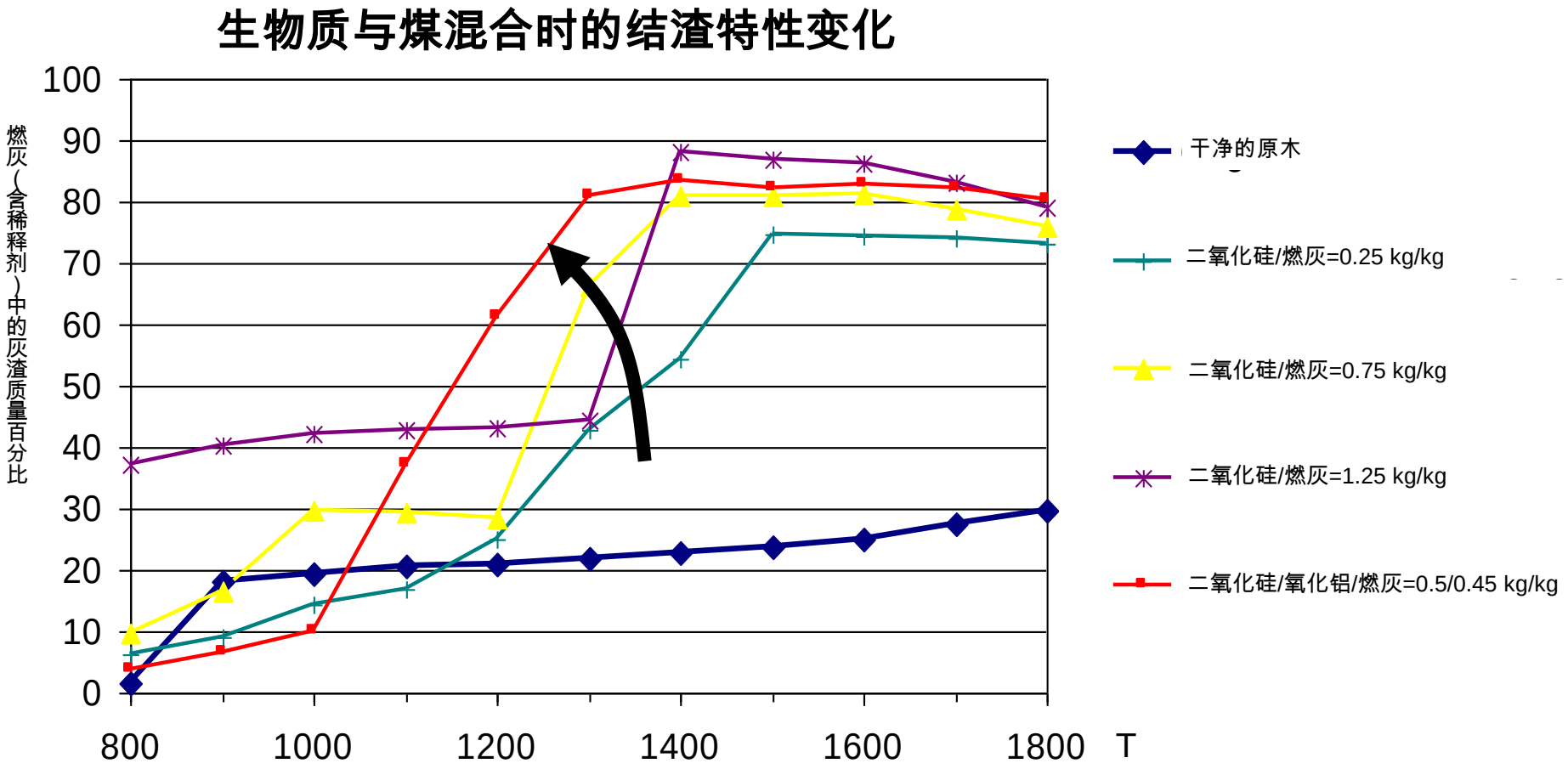


Modelling slagging and fouling behaviour

Slagging behavior as function of mixing biomass and coal

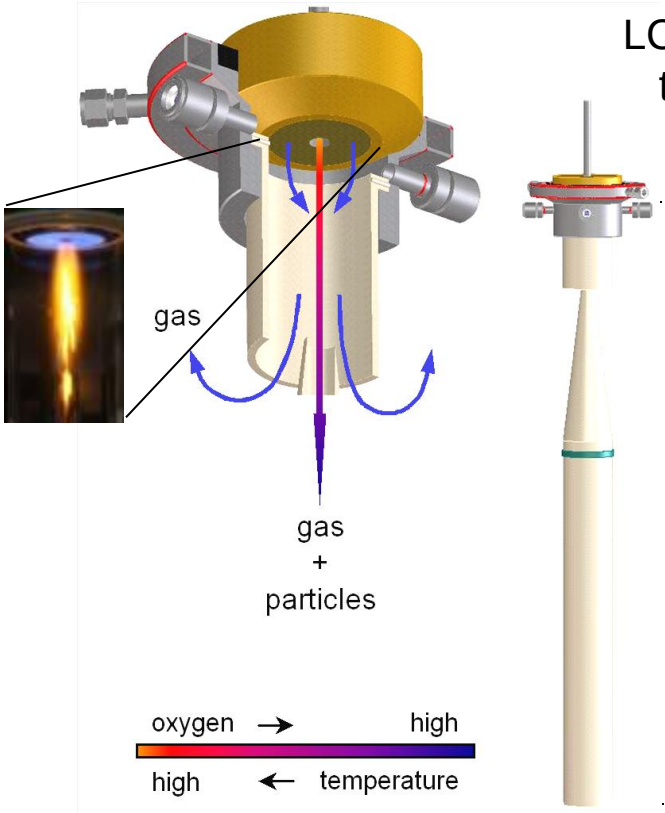


结渣与积灰特性建模

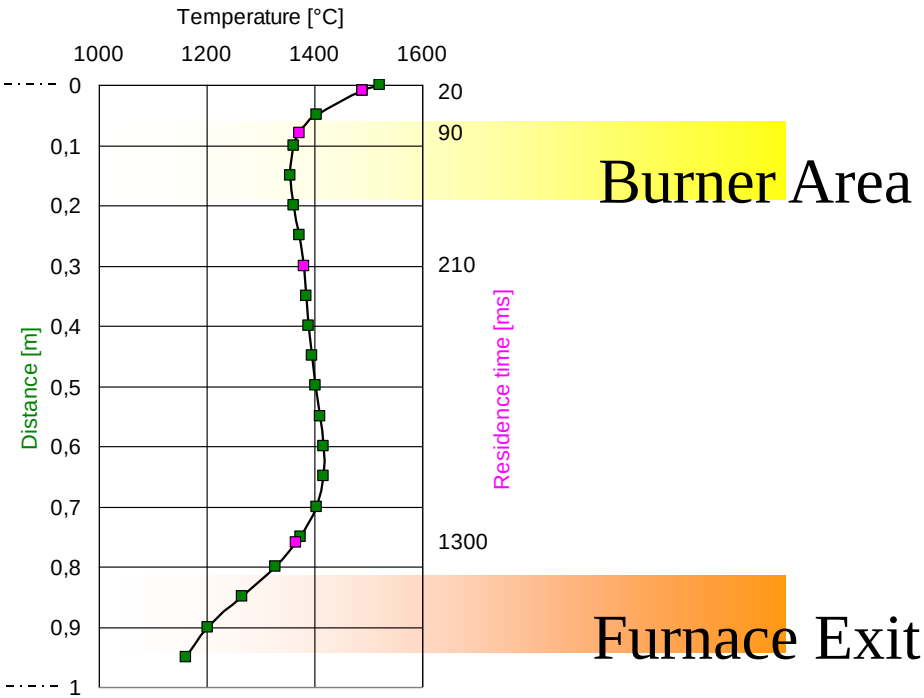

生物质与煤混合时的结渣特性变化
燃灰（含稀释剂）中的灰渣质量百分比
100
90
80
70
60
50
40
30
20
10
0
800
1000
1200
1400
1600
1800
T
干净的原木
二氧化硅/燃灰=0.25 kg/kg
二氧化硅/燃灰=0.75 kg/kg
二氧化硅/燃灰=1.25 kg/kg
二氧化硅/氧化铝/燃灰=0.5/0.45 kg/kg

Labscale Combustion & gasification simulator (LCS)

Residence time/temperature profile (example)

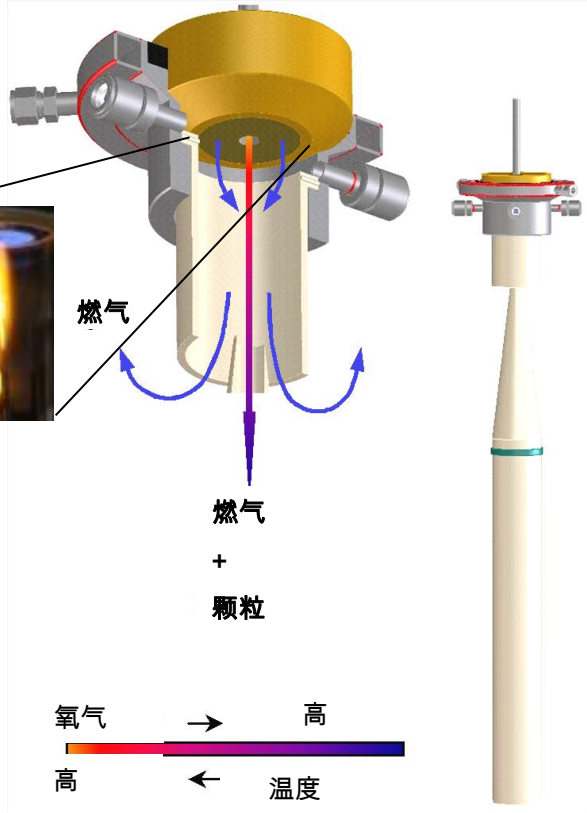


LCS PF facility (controlled conditions, 5 ms up to 2500ms, 600-1550°C, gas composition)

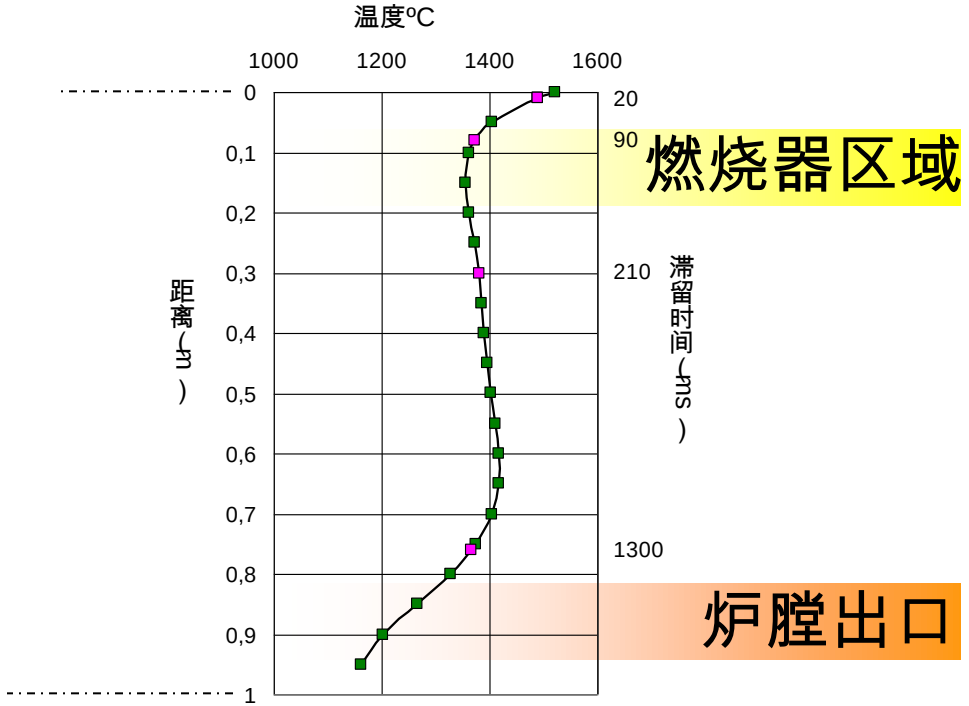


实验室燃烧与气化模拟器（LCS）

滞留时间/温度曲线（示例）



LCS PF设备（受控条件，5 ms-2500 ms, 600-1550°C，气体成分）



Labscale Combustion & gasification simulator (LCS)

LCS gasification experiments investigating:

- Conversion
- Slagging behavior
- Particle sintering on top syngas cooler (800-850°C)
- Particle deposition in economizer (400-600°C)
- Particle sampling (fate of inorganic components)
- Analysis of all samples

实验室燃烧与气化模拟器（LCS）

LCS气化实验可以研究：

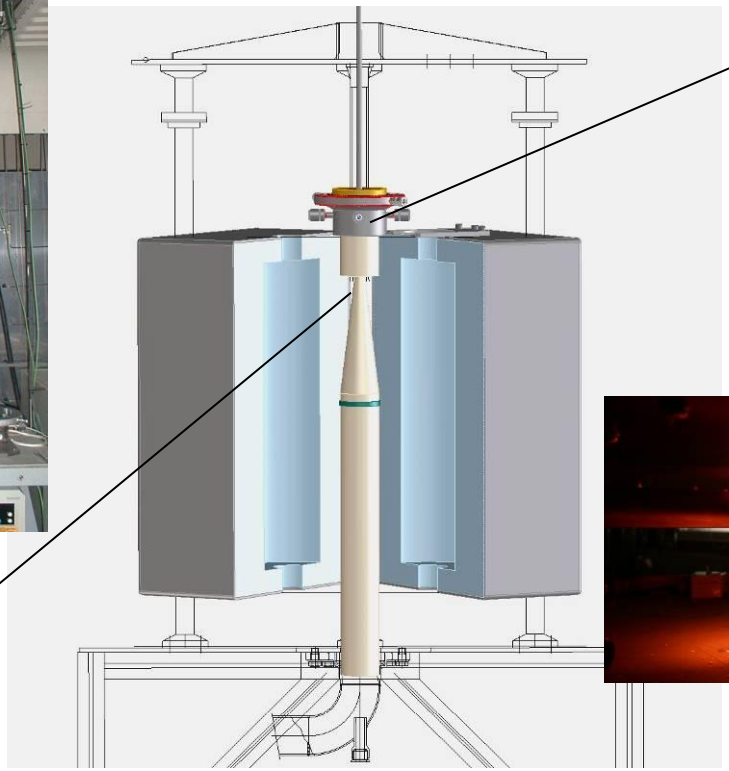
- 转化率
- 结渣特性
- 合成气冷却器顶部的颗粒烧结（800 – 850 °C）
- 省煤器中的颗粒沉积（400 – 600 °C）
- 颗粒取样（无机成分的变化结果）
- 所有样本的分析

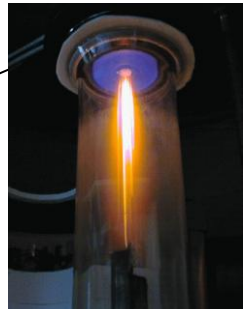
Lab-scale Combustion Simulator (LCS)

Lab-scale facility to mimic pulverised-fuel combustion and high-temperature gasification conditions



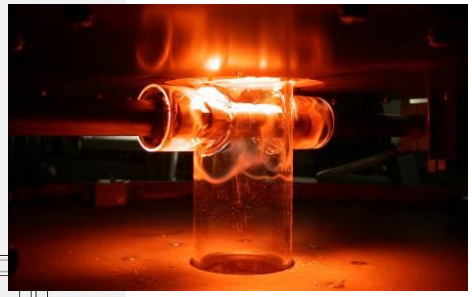






Staged gas burner: high heating rate + proper gas atmosphere

Special reactor design: 1-2s residence times with only limited total reactor length



Fouling probe



Particle sampling probe

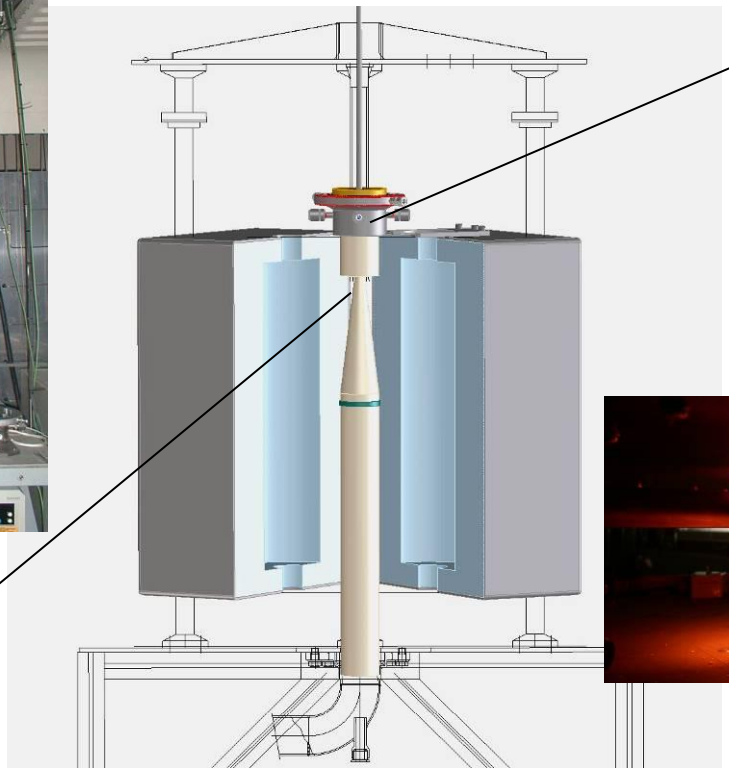
实验室燃烧模拟器（LCS）

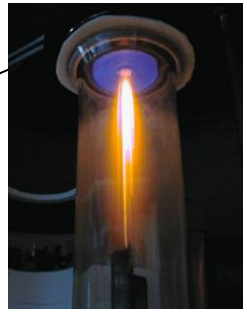
用实验室设备模拟粉煤燃烧与高温气化的条件



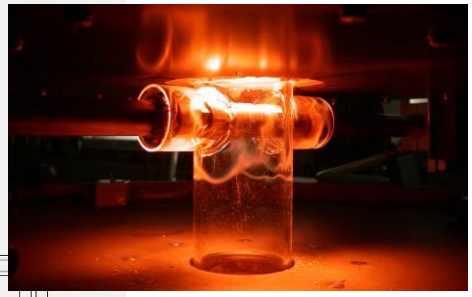


特制反应器：
滞留时间为1-2s
反应器总长度有限





多级煤气燃烧器：
升温速率高，正确的煤气气氛



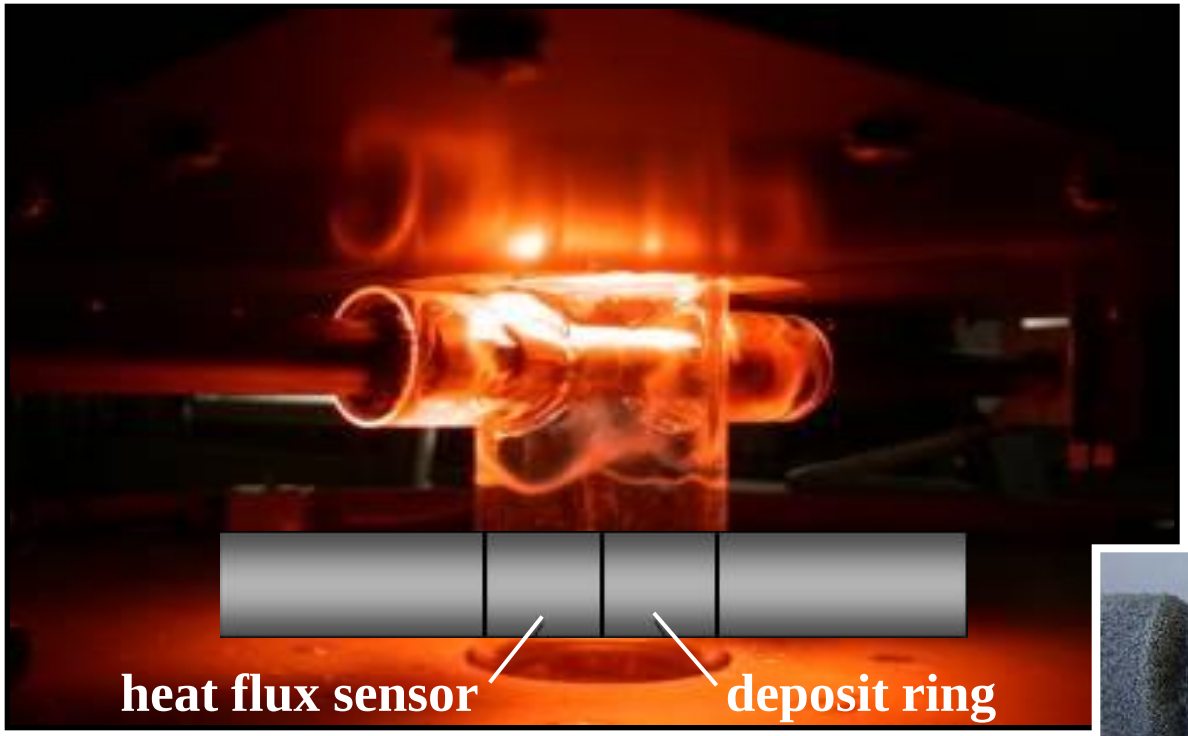
积灰探针



颗粒取样探针

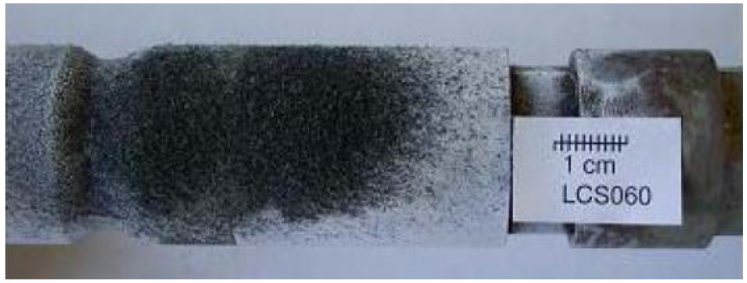
Labscale Combustion & gasification simulator (LCS)

Fouling



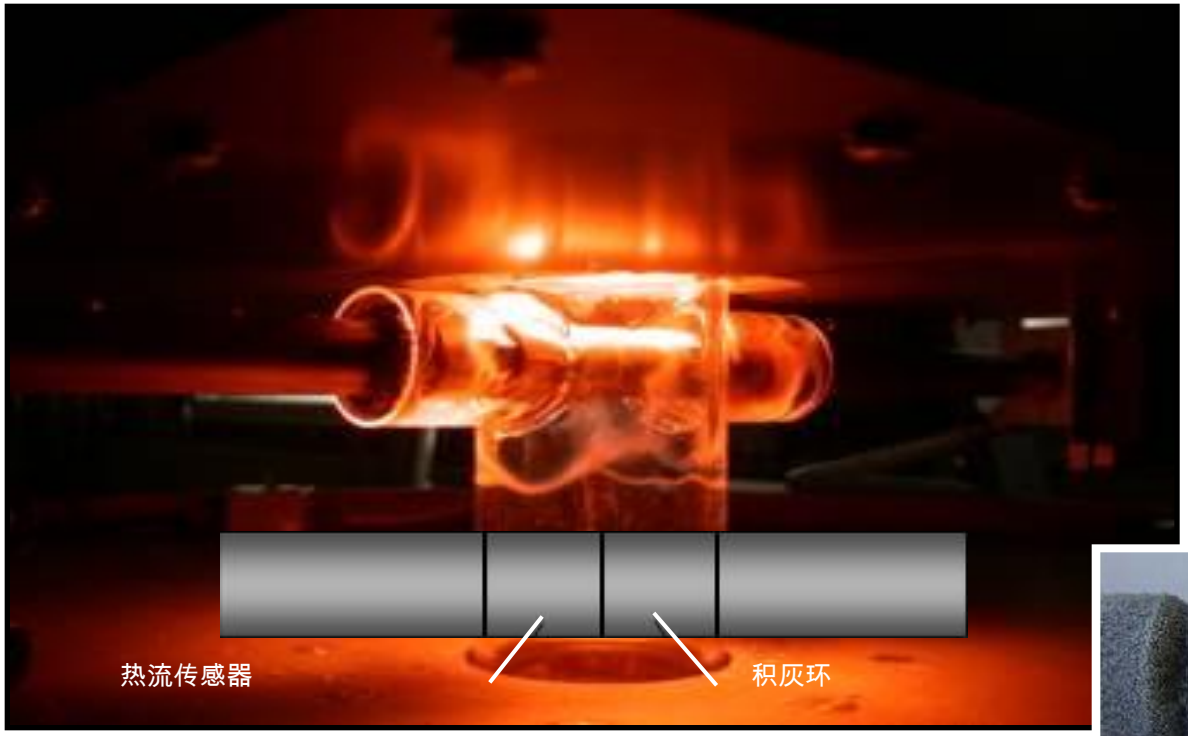
Investigate fouling:

- Transfer duct
- Influence on heat transfer



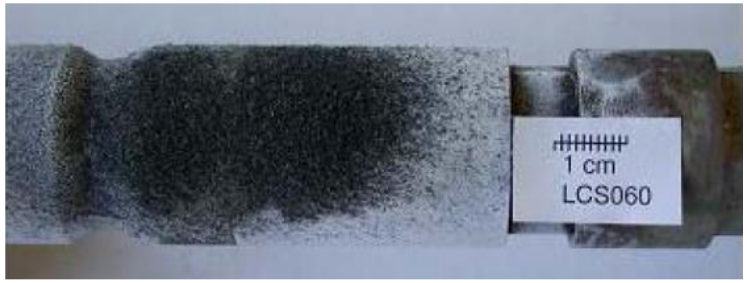
实验室燃烧与气化模拟器（LCS）

积灰



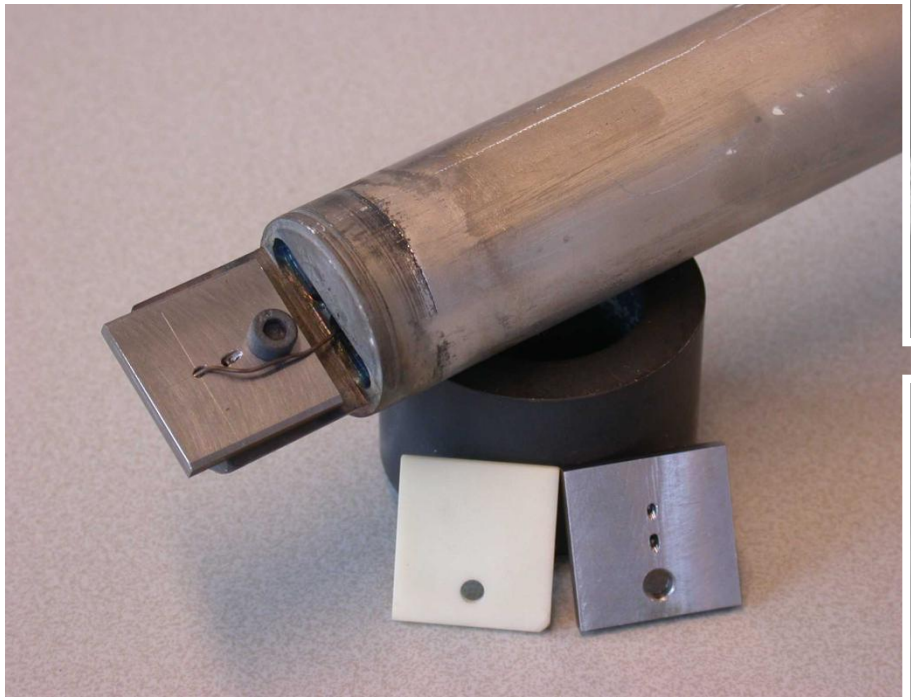
积灰研究：

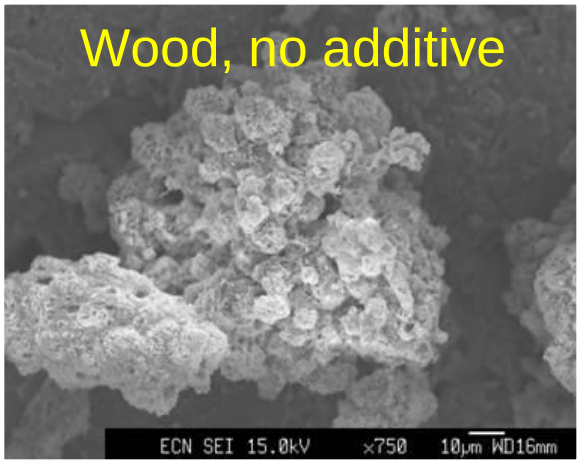
- 输气管
- 对热交换的影响

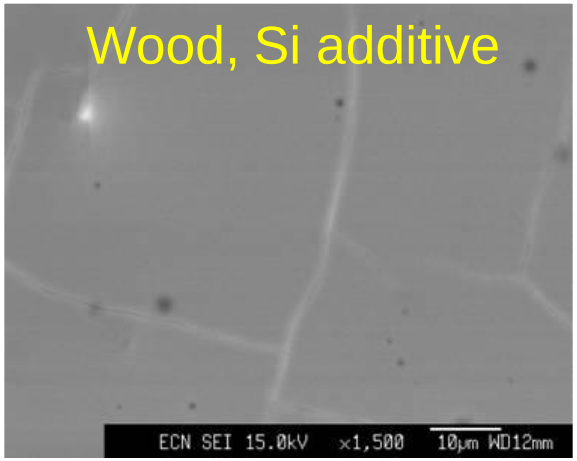


Labscale Combustion & gasification simulator (LCS)

Deposition (example 1300°C)

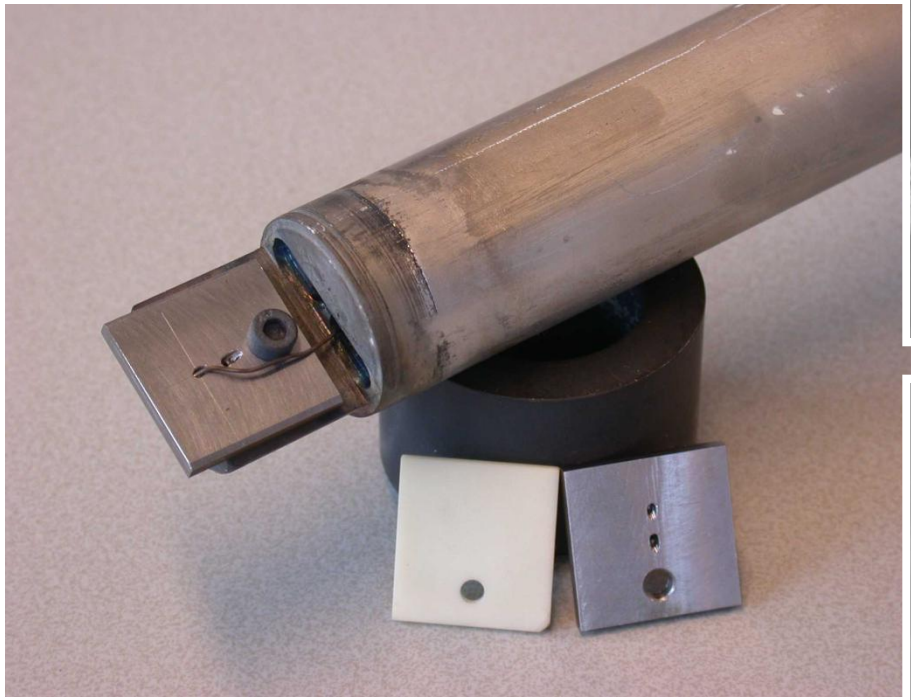


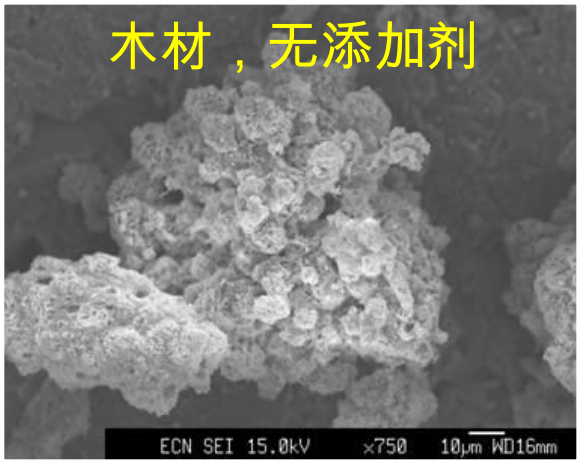


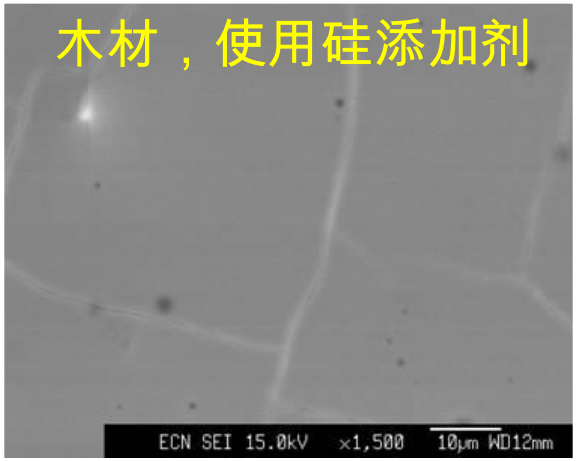


实验室燃烧与气化模拟器（LCS）

沉积（示例温度1300°C）

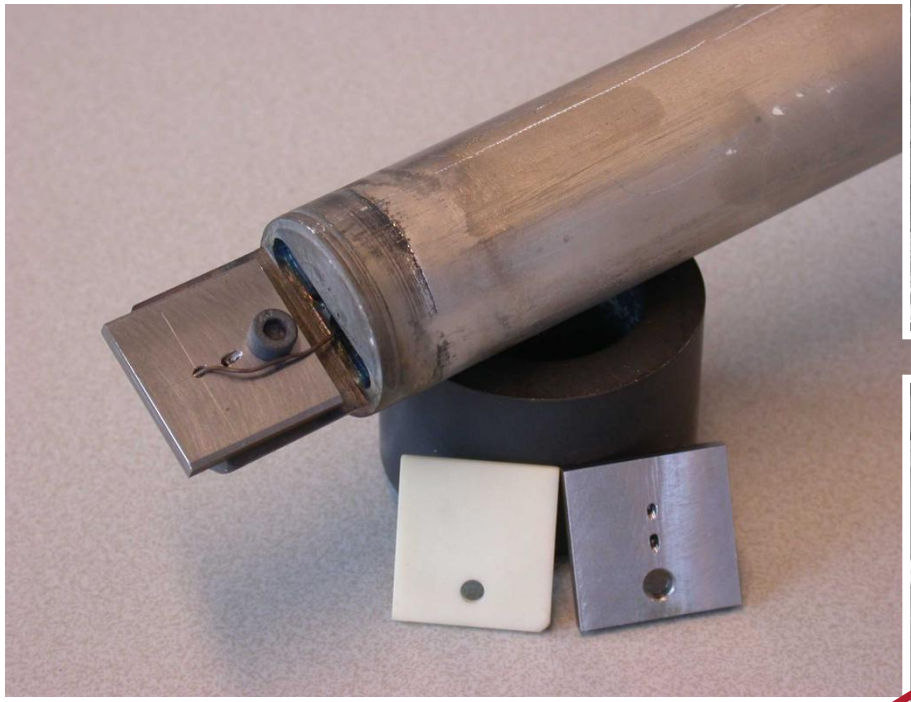


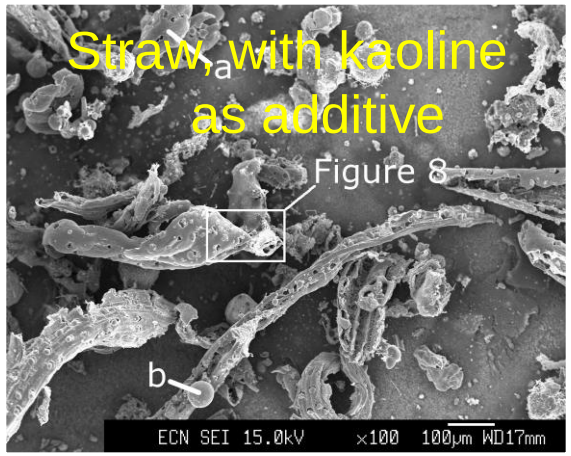


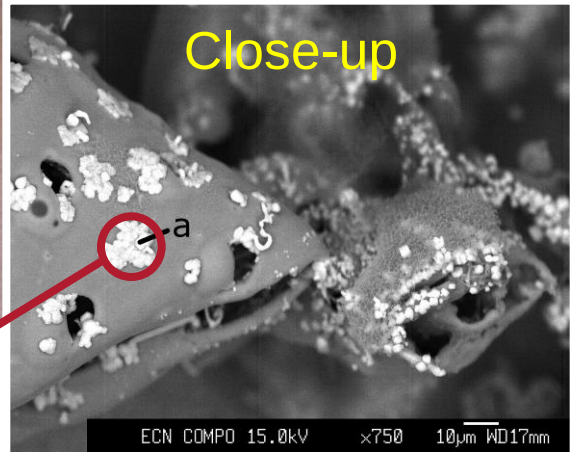


Labscale Combustion & gasification simulator (LCS)

Deposition (example 600°C)



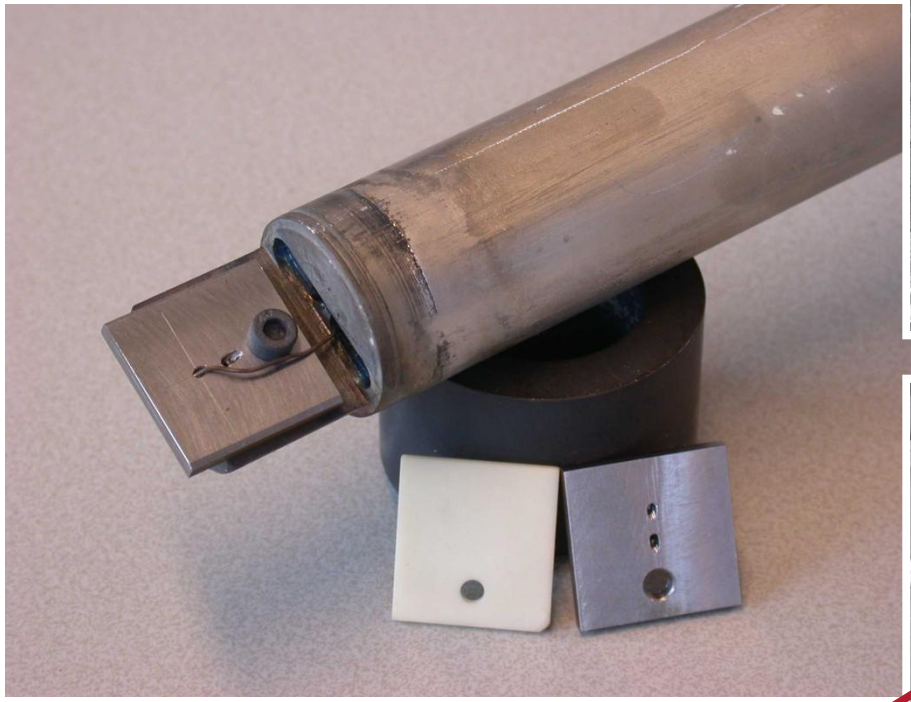


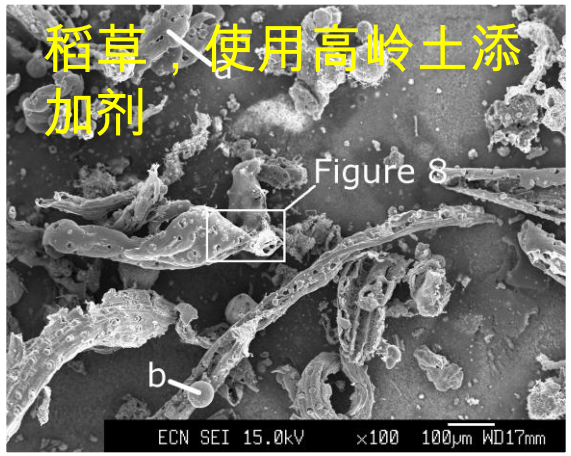


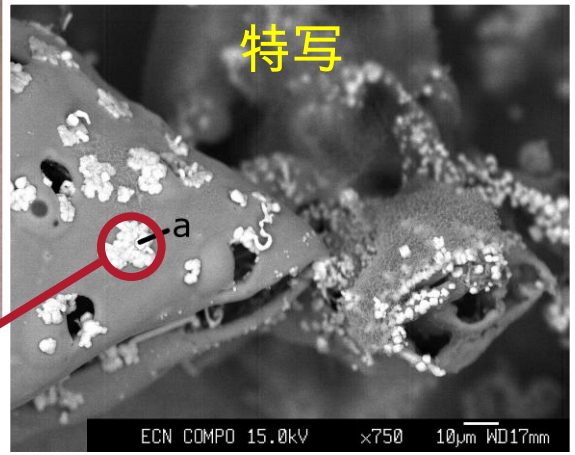
KCl

实验室燃烧与气化模拟器（LCS）

沉积（示例温度600°C ）



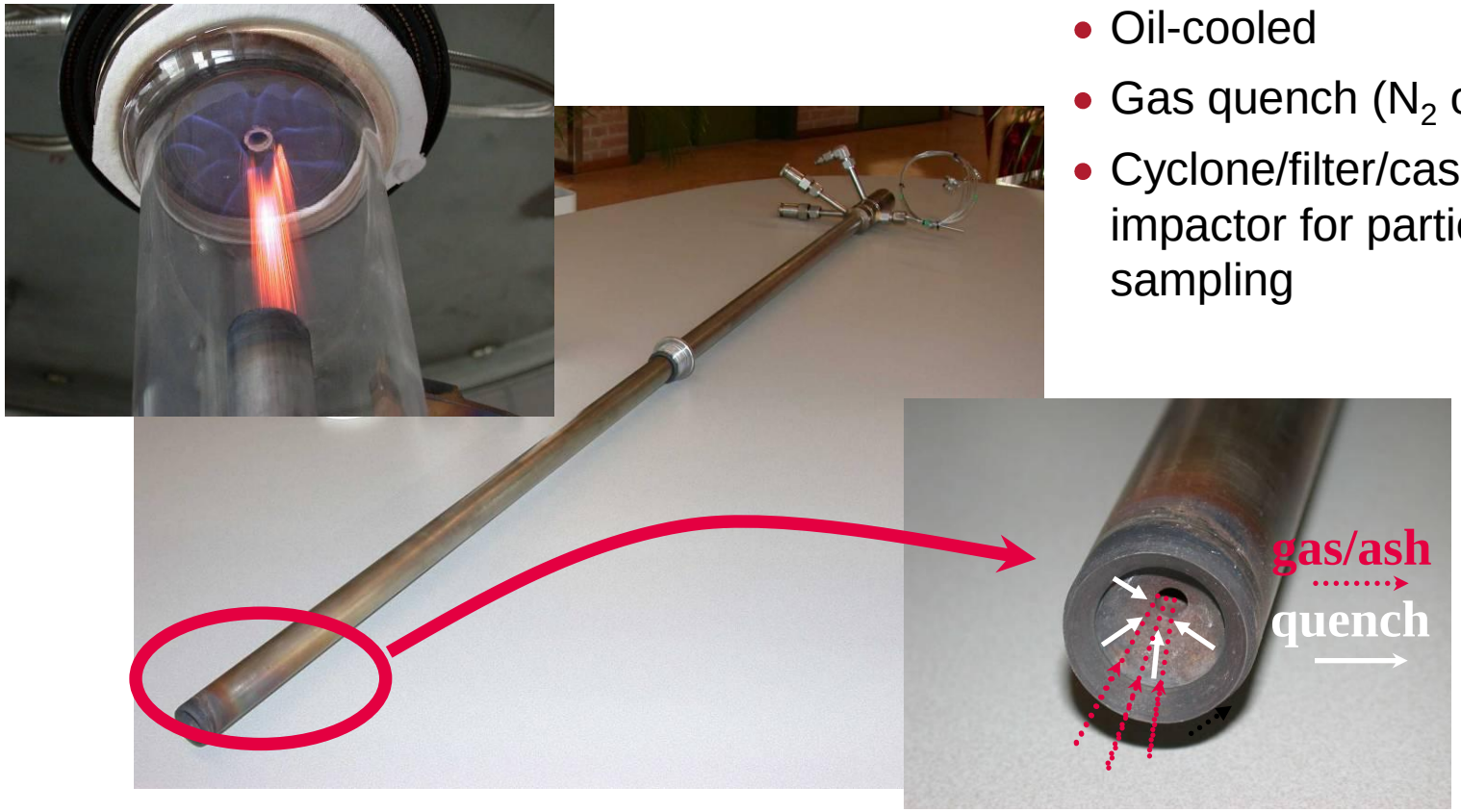




KCl

Labscale Combustion & gasification simulator (LCS)

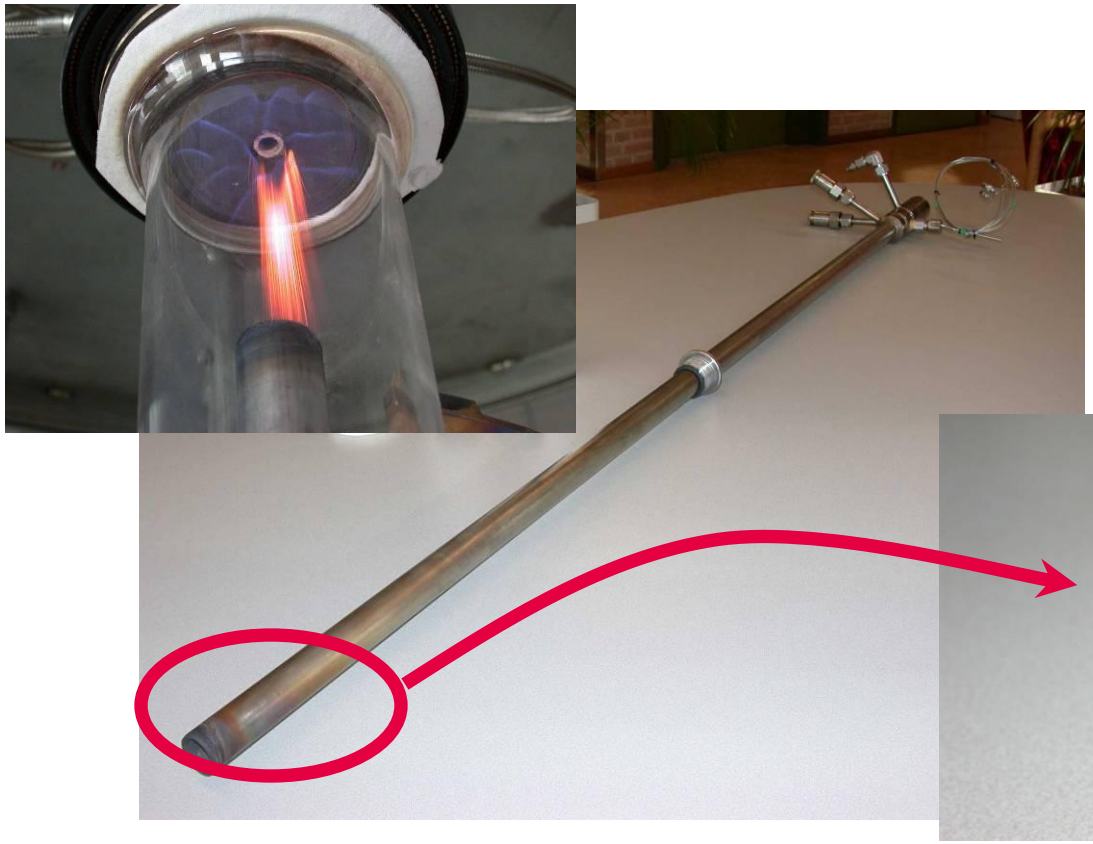
Particle sampling



- Oil-cooled
- Gas quench (N_2 or He)
- Cyclone/filter/cascade impactor for particle sampling

实验室燃烧与气化模拟器（LCS）

颗粒取样



- 油冷
- 气体骤冷（氮气或氦气）
- 用于颗粒取样的旋风分离器/过滤器/多级冲击采样器

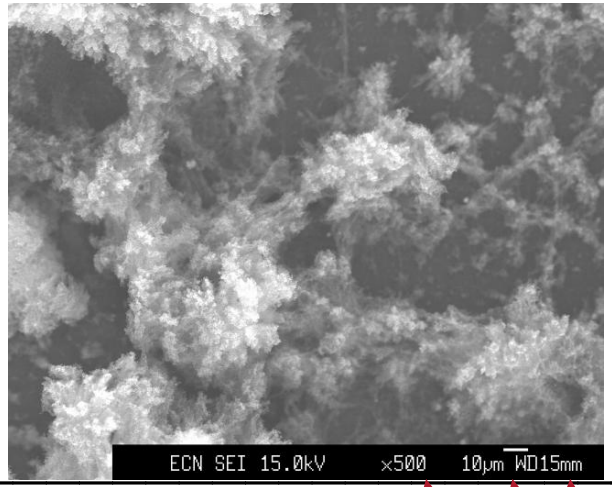
Labscale Combustion & gasification simulator (LCS)

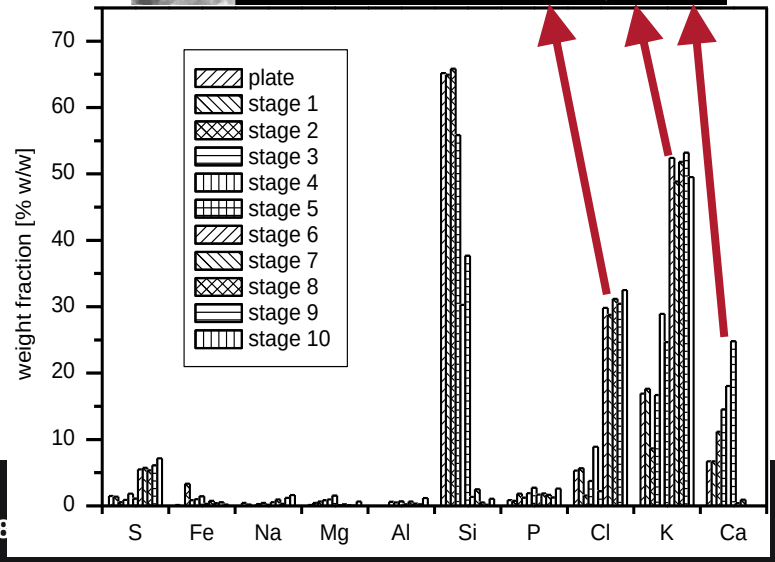


Particle sampling

Fractionated samples (lab- & full-scale) obtained with cascade impactors (CI):

- Study release inorganics and aerosol formation
- Provides composition and morphology of each size fraction
- In short: particle sampling allows investigation of all inorganic particles that enter syngas cooler





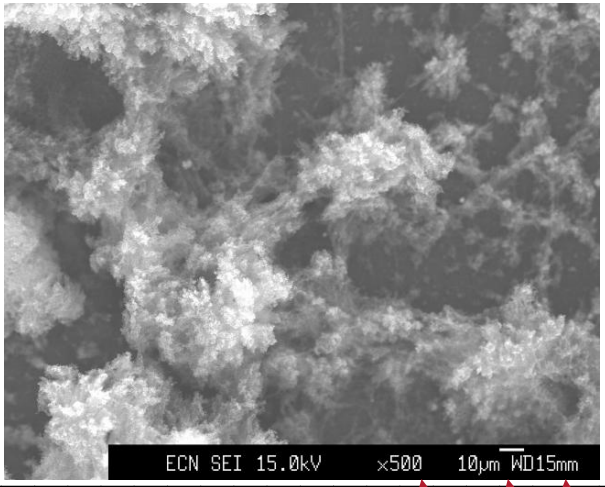
实验室燃烧与气化模拟器（LCS）

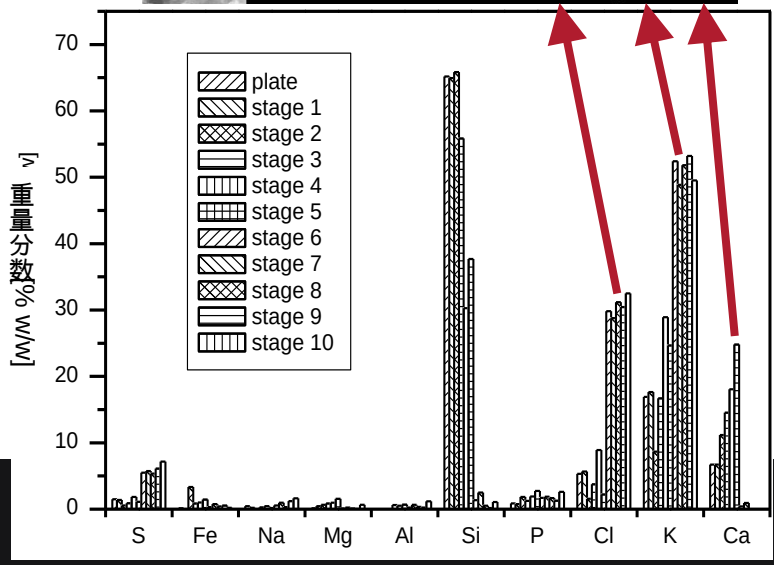


颗粒取样

使用多级冲击采样器（CI）进行分级取样（实验室取样和全面取样）：

- 研究释放的无机物和气溶胶的形成
- 确定各粒级的成分和形态
- 简而言之：通过颗粒取样可以研究进入合成气冷却器的所有无机颗粒





Thank you for your attention...

For more information,
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e-mail zwart@ecn.nl
internet www.ecn.nl









感谢您的关注！

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