Continuous measurement of coal flow and air-fuel ratio for closed-loop control

Power-Gen Europe 2010

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Introduction

Introduction

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Why is coal and air flow control so important?

- Fuel and air flow parameters determine the quality of combustion
- Area in which the overall generation process is least perfect
- Process not directly monitored and controlled
- Increasing variability of coal quality
- Renewable energies impose increasingly dynamic load adaptation
- Boiler are usually not operated at their design point

Introduction

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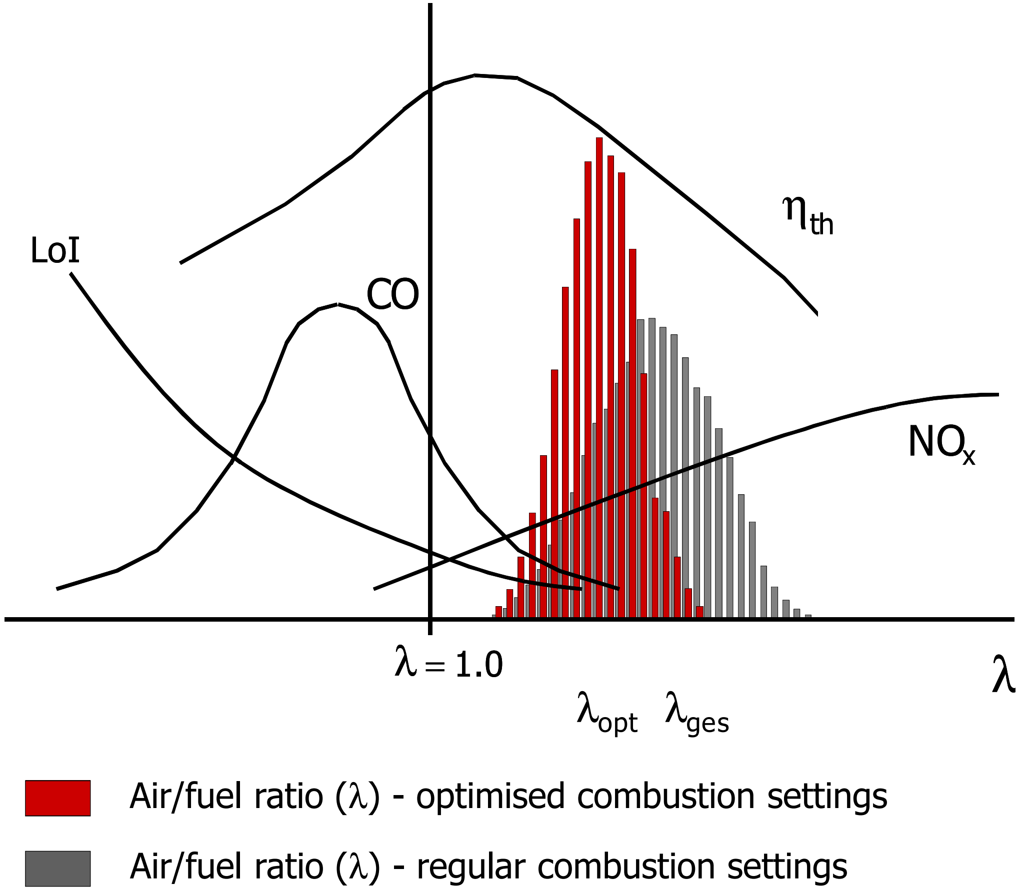
Air/fuel ratio and performance



Strategy

- Reduce process variability and shift operating point closer to the limits
- Individual adjustment of air and fuel flow at burner level
- Identify and utilize the intricate interplay of combustion parameters

- Continuous optimization
- Instantaneous adaptation to load changes

Why is coal and air flow control so important?

Controllable O&M variable	$\Delta\eta_{th}$
Coal fineness	0.1 - 0.3%
Primary air-flow	0.1 - 0.2%
Fuel line balance	0.1 - 0.3%
Particulate-air ratio	0.1 - 0.3%
Carbon-in-ash (LoI)	0.1 - 0.3%
Excess oxygen	0.1 - 0.3%
Total*	**0.6 – 1.7%**

*** These benefits do not add up synergistically. Typically, an overall improvement in net efficiency will be around 0.3 – 1.0%**

Benefits quantified

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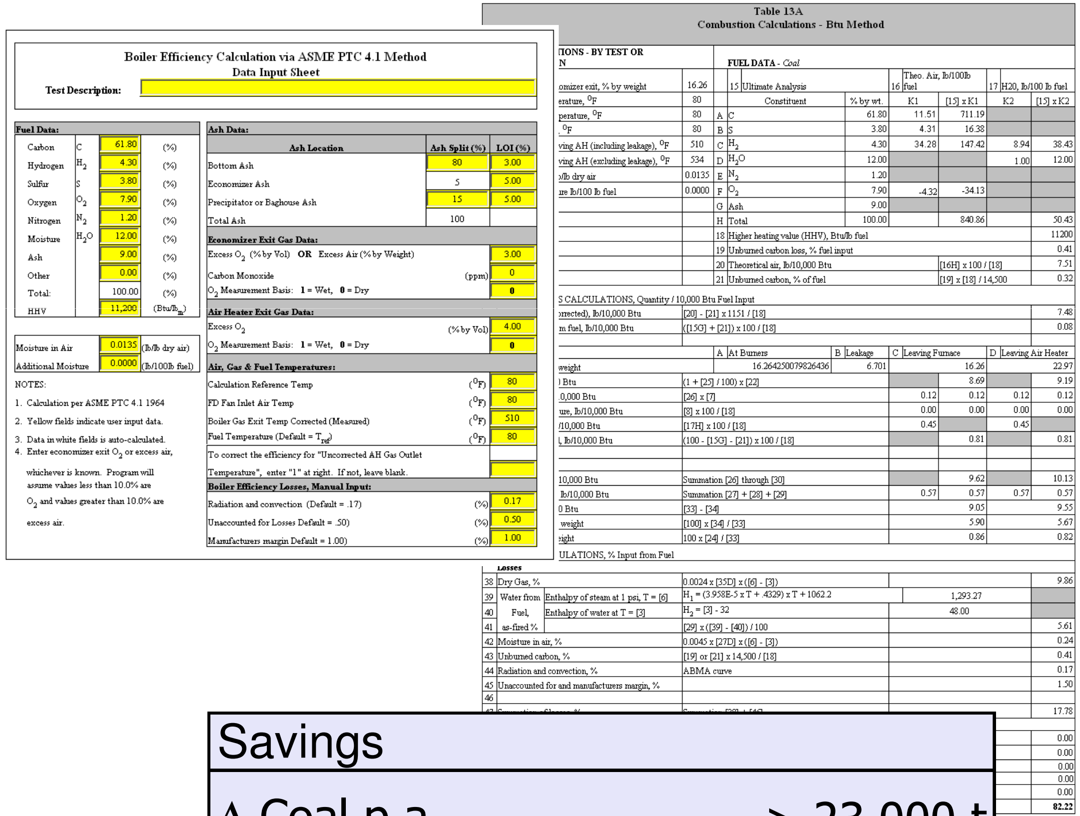
Plant	
Unit size	630 MW
Lignite LHV	10,300 kJ/kg
PLF	88.5 %

Reference	
Coal flow	660 t/h
O_2 excess	4.0 %
LoI_{ref}	2.9 %
$T_{BoilerExit, ref}$	199 °C
$\eta_{Boiler, ref}$	86.66 %

Optimisation	
Coal flow	655 - 657 t/h
O_2 excess	3.2 %
LoI_{opt}	1.8 %
$T_{BoilerExit, opt}$	191 °C
$\eta_{Boiler, opt}$	87.10 %



Savings	
Δ Coal p.a.	> 23,000 t
Cost per tonne*	26 EUR
Annual savings	~ 600,000 EUR
Δ CO_2 p.a.	> 27,300 t
CO2 Certificate	20 EUR/t
´Carbon benefit´	~ 550,000 EUR
Total benefit p.a.	1,150,000 EUR

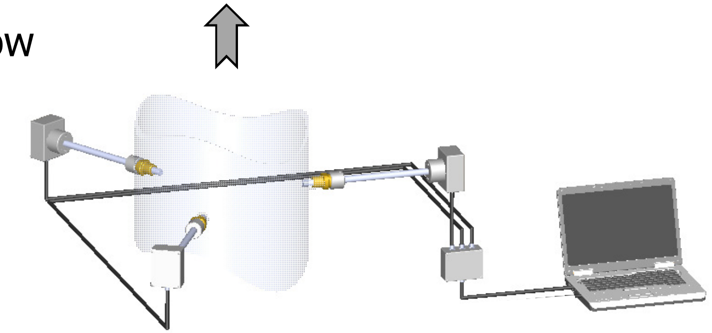
Monitoring – Controlling - Optimizing

Monitoring – Controlling - Optimizing

The Basic Idea

Measure

If you can't measure,
you can't control.



The Basic Idea

Measure
If you can't measure,
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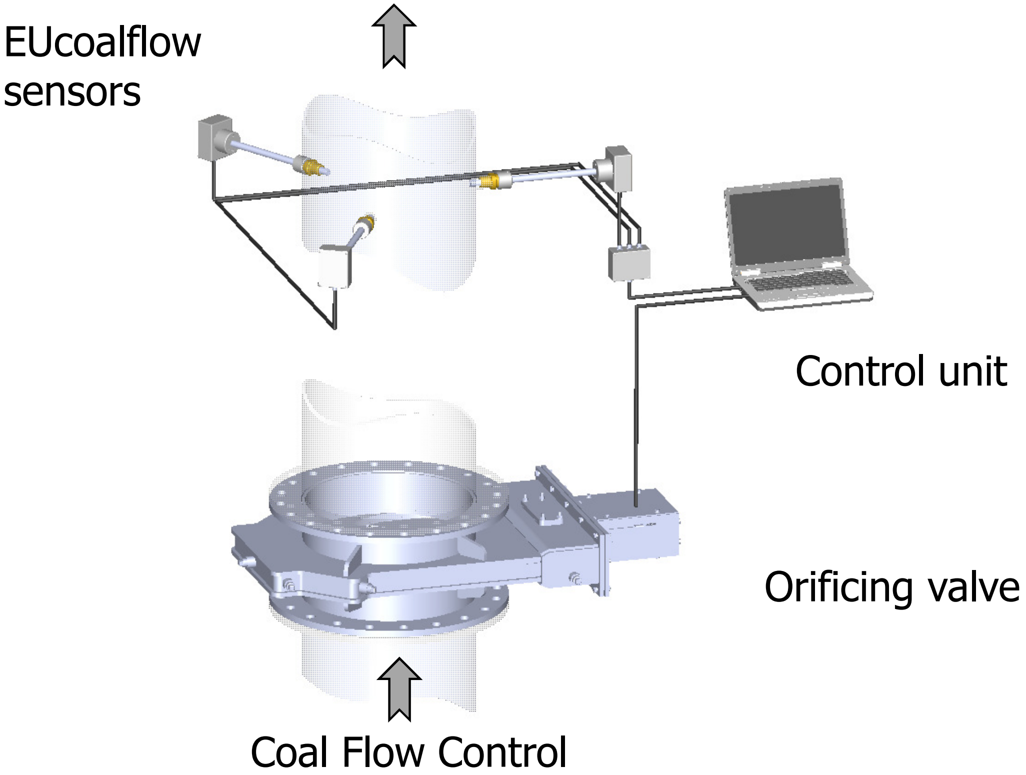
Control
If you can't control,
you can't optimize.



The Basic Idea

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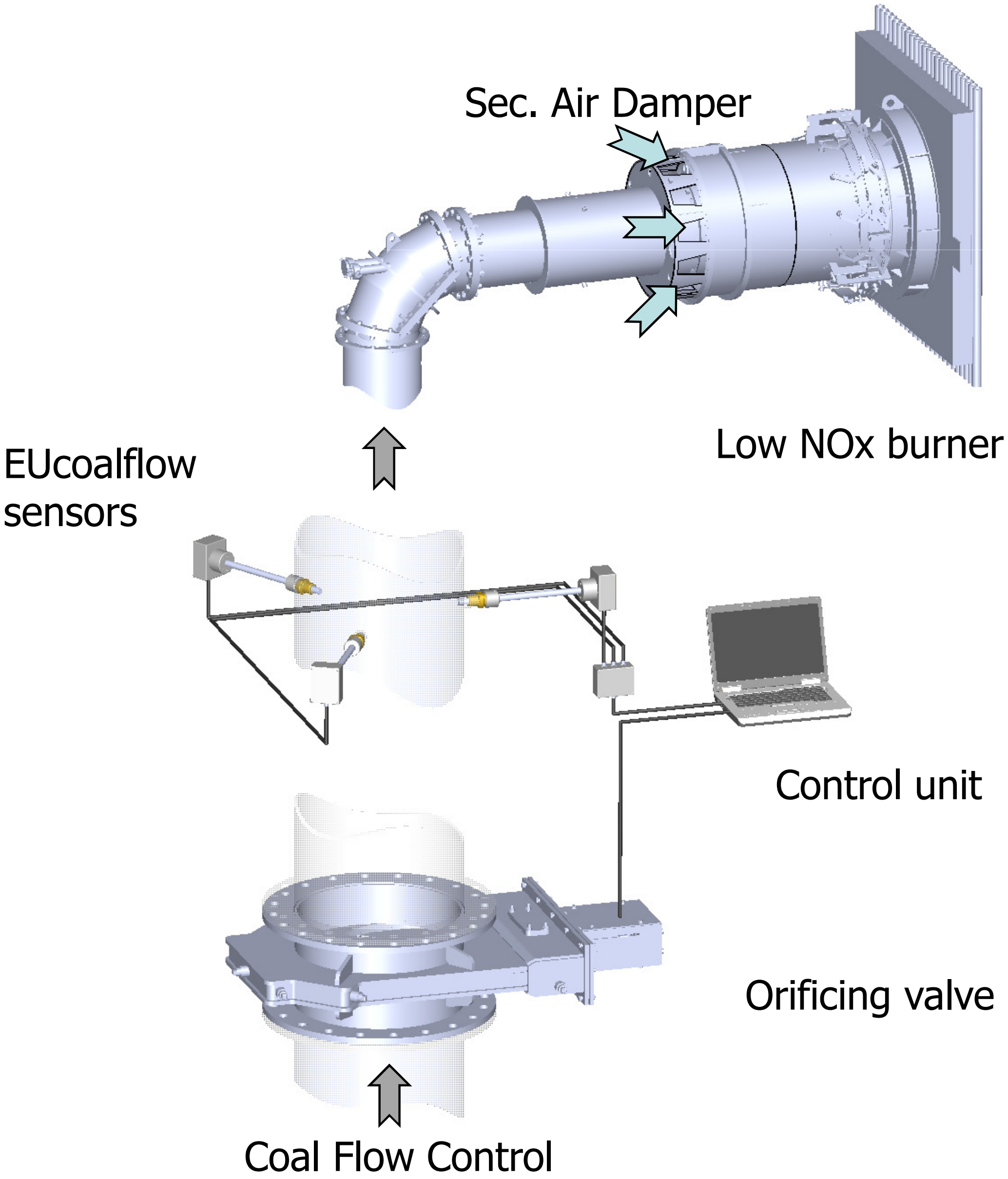


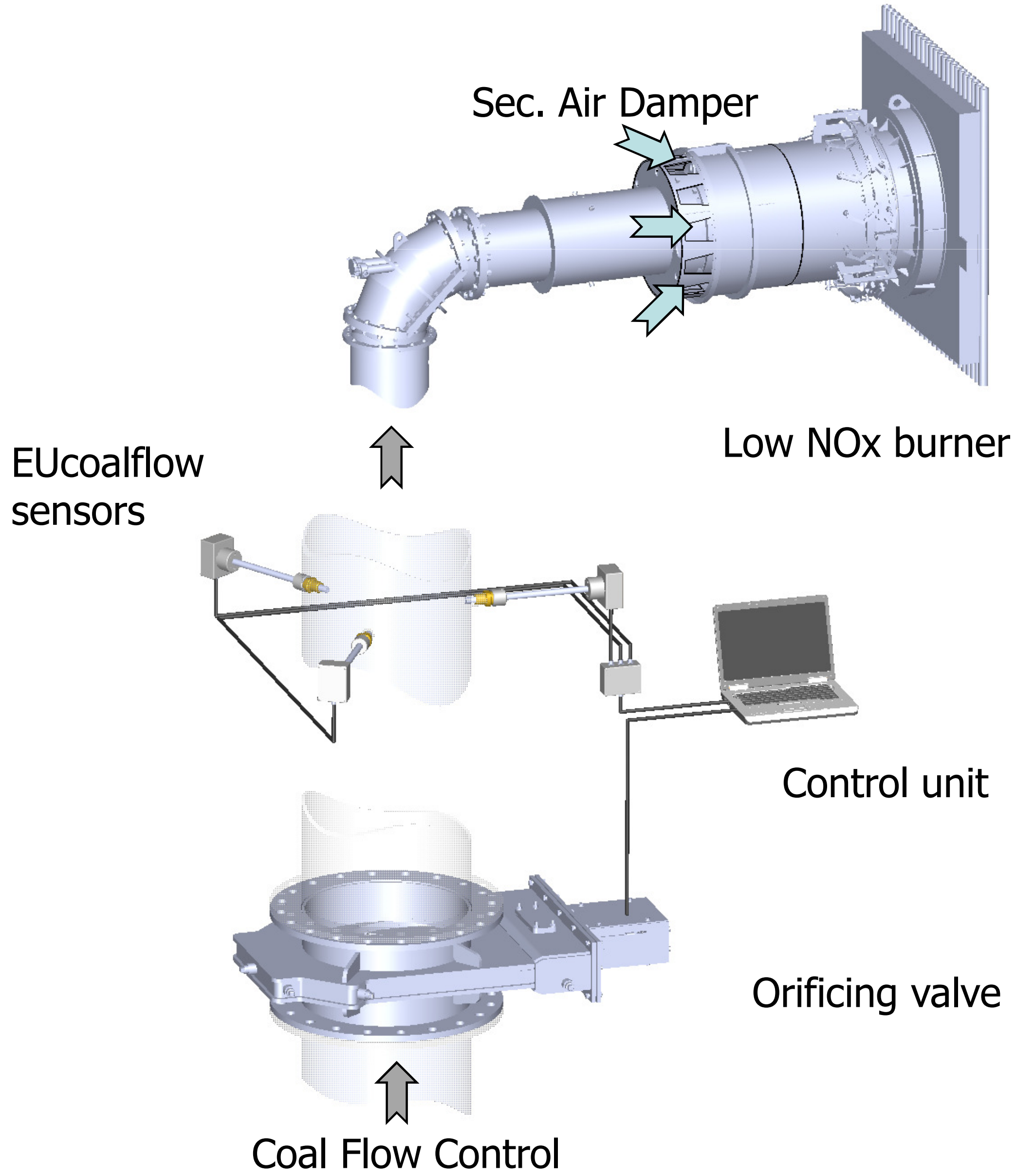
Monitoring – Controlling - Optimizing

The Basic Idea

Measure
If you can't measure,
you can't control.

Control
If you can't control,
you can't optimize.

Optimize
If you don't optimize,
you waste money.



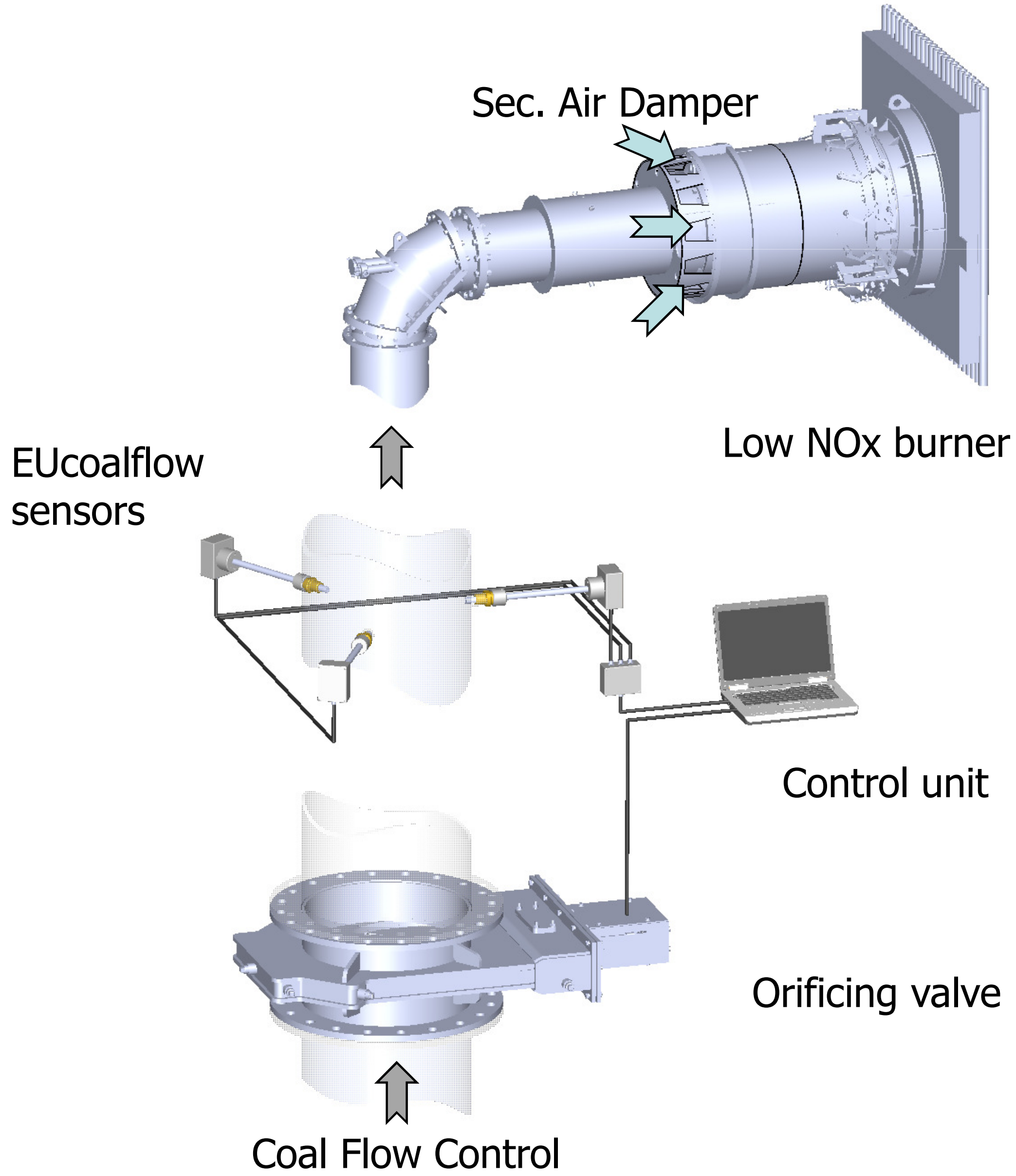
System structure

EUcoalflow Sensor
- Coal mass flow
- 2 – 3 Sensors per pipe

Orificing valve
- Basic adjustment
- Pipe-to-pipe balancing
- Manual or motor driven

SA-Damper Control
- Automatic adjustment of SA
- AFR at prescribed level

Optimisation (EUcontrol)
- Optimal air/coal distribution and biasing



EUcoalflow – Closed-loop Control

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Strategy

1. Measure the coal flow and PA flow in each pipe
2. Adjust coal flows to acceptable reference limits (manual or by motor)
3. Determine SA flow in each pipe from damper position and pressure differential (soft sensoring)
4. Adjust SA dampers to balance AFR ratio at each burner while maintaining overall SA intake
5. Use excess O2 as control variable to fine-tune SA-damper position (adaptive, corrective loop)
6. Optimize (emissions, heat rate, LoI, slagging, ...)

EUcoalflow Sensor

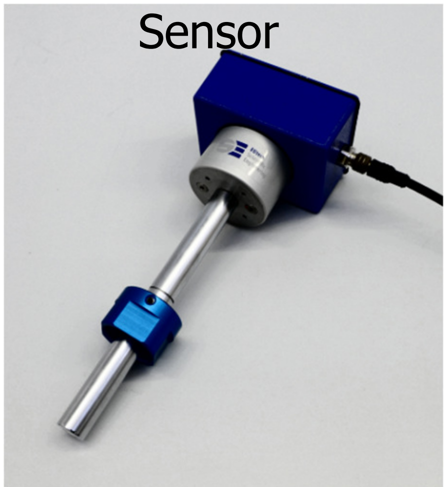
Specifications

Sensor type	Microwave
Measuring range	0 - 400 mm
Operating temp.	< 200 °C
Flow density	< 1000 g/m³
Sensor diameter	20 mm
Power supply	110/240 V AC
Sensor set-up	2 or 3 per pipe

System set-up

Control unit

- Online determination of
  - Coal mass flow
  - Gas velocity & volume flow
- Pipe to pipe distribution
- Statistic functions



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EUcoalflow Sensor

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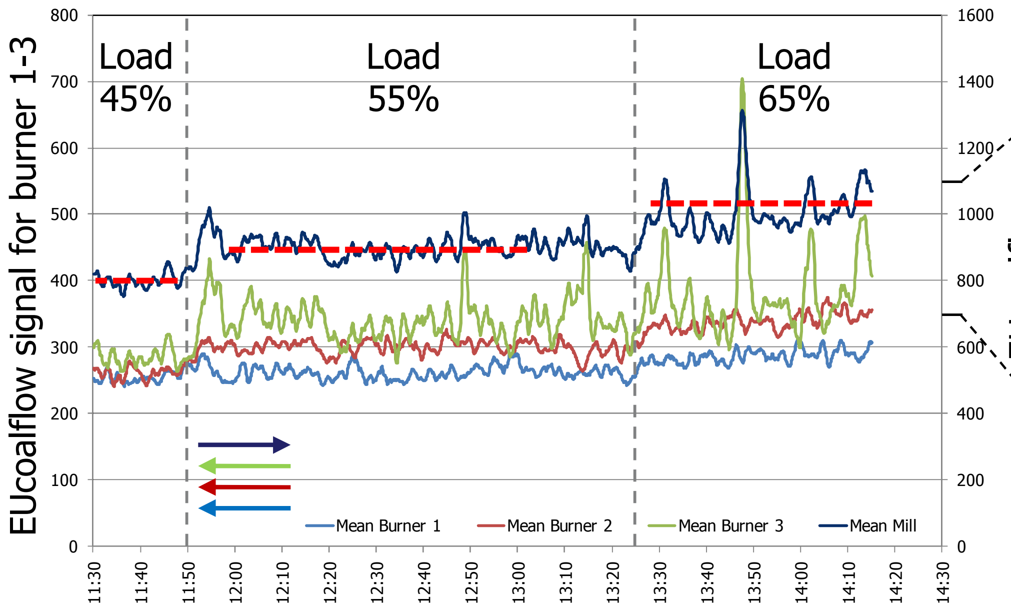
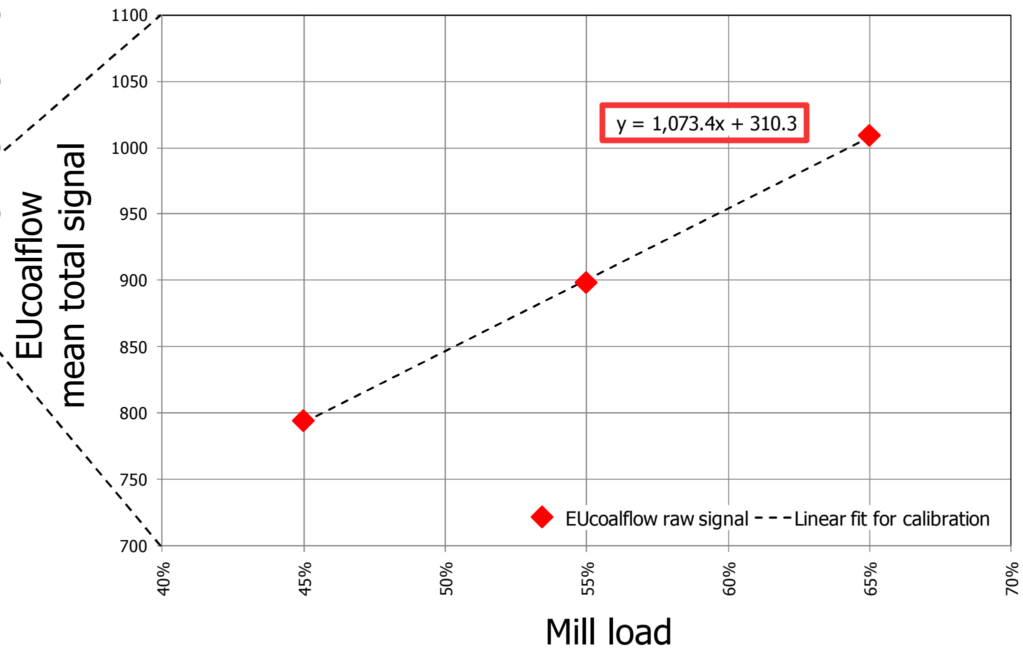
Application – lignite fired plant



Sensor accuracy

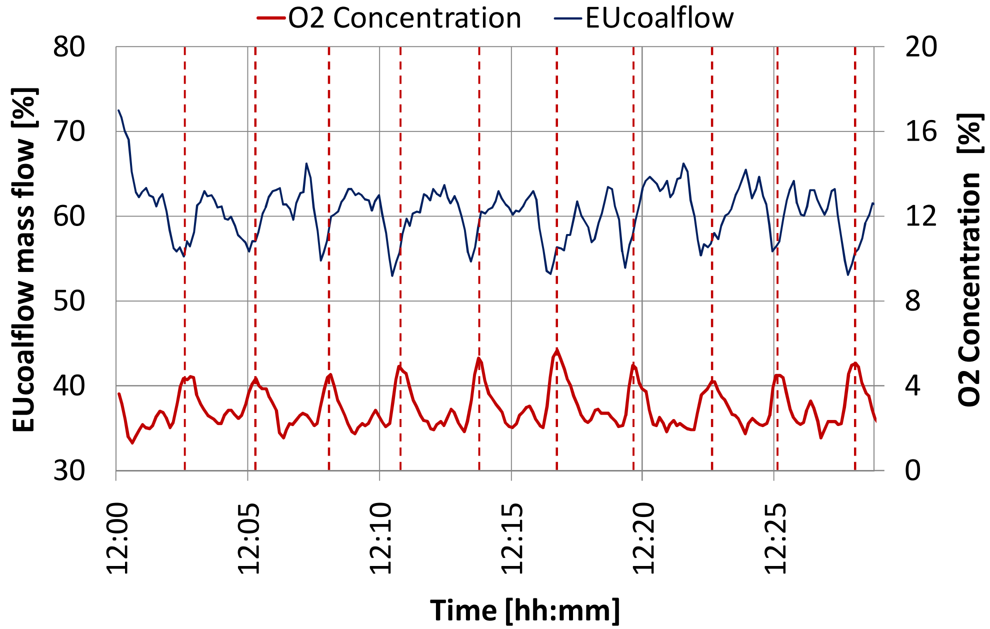


Conclusion

- Tests with three mill settings
  - Precise, stable and reproducible signal
  - Direct monitoring of load changes in each burner pipe
  - Very good correlation between EUcoalflow mass flow signal and mill load
- Linear fit can be used for absolute signal calibration

EUcoalflow Sensor

Application – dense phase



Signal analysis

- High fluctuation in the mass flow signal causes
- fluctuating excess oxygen (DCS signal)
- at constant load set point

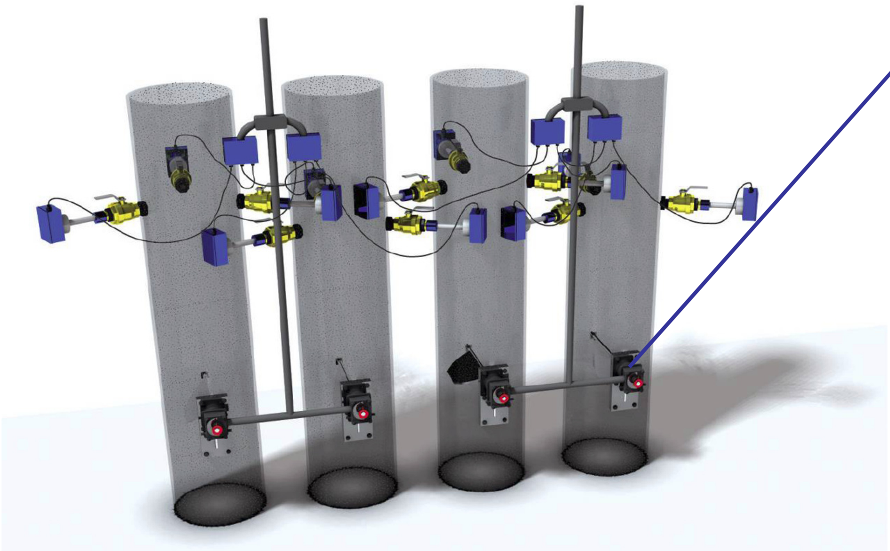
Conclusion

- High correlation of excess oxygen signal with coal mass flow
- Direct visualisation of feeding and milling malfunctions
- Control of secondary air flow

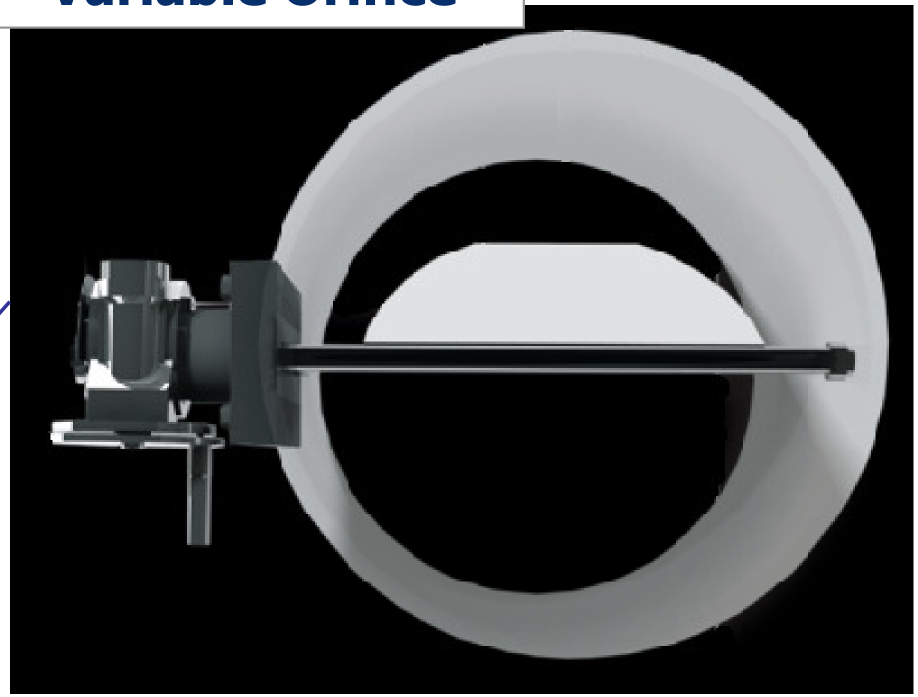
EUcoalflow – Actuators

Required Features

- Easily adjustable (no “freeze up”)
- Linear valve characteristics
- Abrasion resistant (flow & material)
- Easy installation
- Manual or motored versions



Variable Orifice



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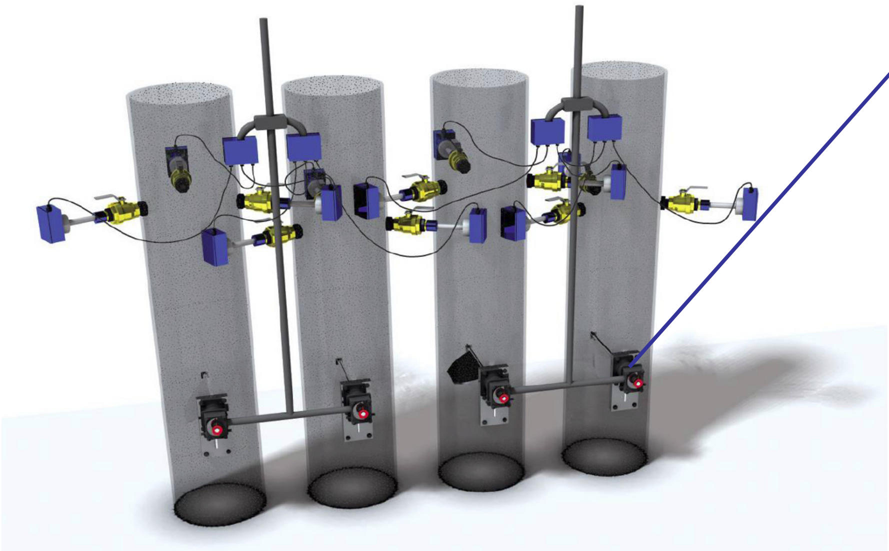

Variable Orifice

EUcoalflow – Actuators

Material and Design

- Innovative adjustable orifice valve technology (V-valves) with chromium-carbide coating (patent pending)
- The below shown valve was installed in May of 2007 and pulled out for inspection in March of 2009. The chromium-carbide coating shows no signs of wear.

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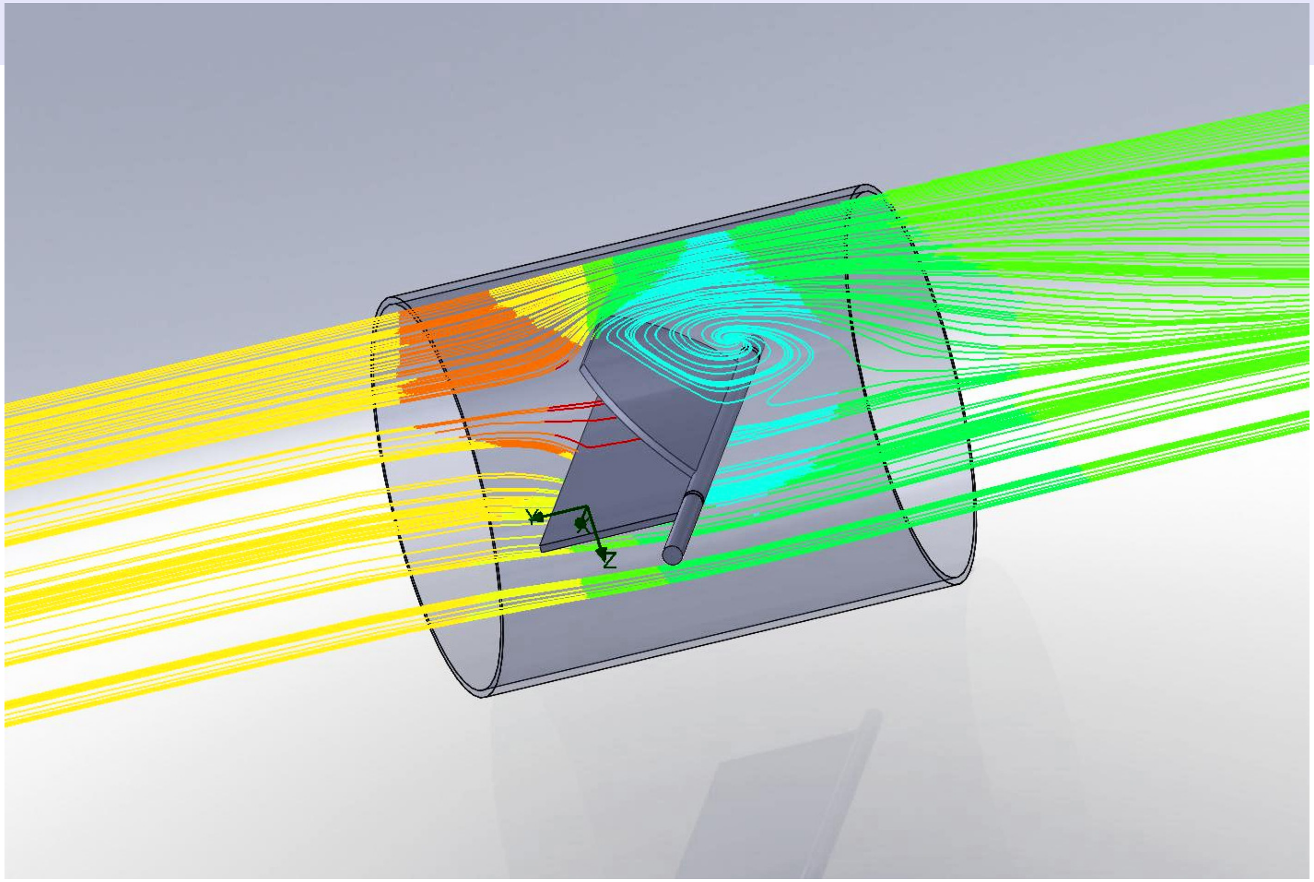
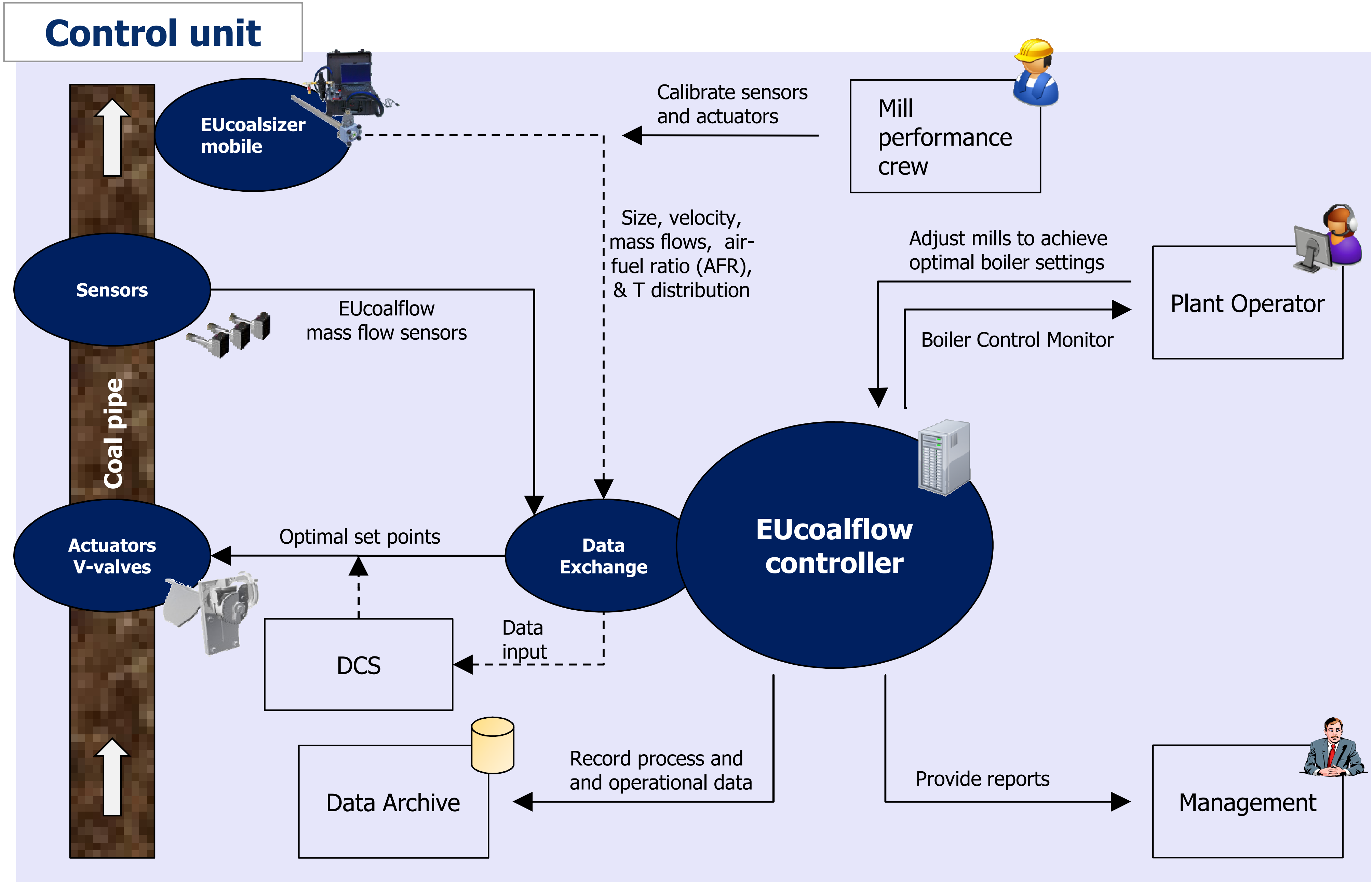
EUcoalflow – Actuators

Flow Characteristics

- Innovative adjustable orifice valve technology (V-valves) with chromium-carbide coating (patent pending)
- The below figure shows a CFD calculation of the particle flow through the valve. Determination of pressure drop and valve characteristics.



EUcoalflow – Closed-loop Control



Project Timeline

Steps to success

- Feasibility
  - Site familiarisation and review of existing plant equipment
  - Test with EUcoalflow mobile
  - Identify additional equipment requirements
  - Review of available data and data quality
  - System identification using available data
  - Parametric testing using Design of Experiments
- Control
  - Prediction models for control/optimisation
  - Process/plant model for model-in-the loop testing (hardware-in-the loop)
  - Smart sensoring
- Implementation
  - Operate in advisory mode
  - Extend to closed loop

Typical project time is 2 – 3 months

Implementation, Installation and Commissioning

Steps 1 – Advisory Mode

- The ECF coal flow sensors are installed and connected to the ECF control module
- Variable orificing valves are installed (static coal flow adjustment)
- A "soft sensor" module for the determination of SA flow is installed on the ECF It calculates optimal SA flows according to the measured coal mass flow in the pipe and translates these into damper settings
- The SA damper set points are manually adjusted by the operator via DCS interface at reasonable intervals (e.g. 15 min).

Steps 2 – Closed-loop Control

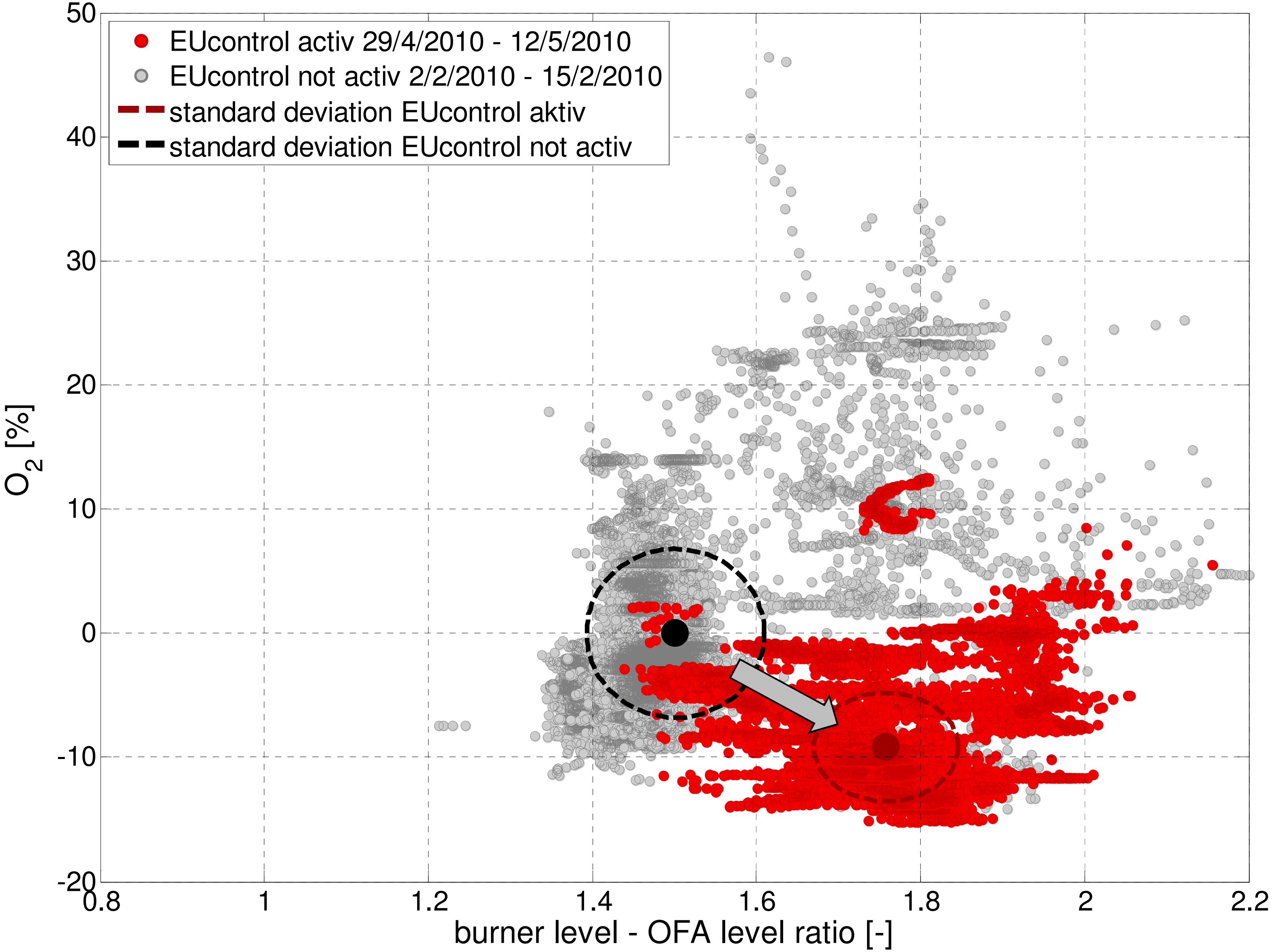
- Interface to plant DCS via OPC or generic interface protocol.
- Controller adjustment and test using model based design approach
- Commissioning of closed loop system

Steps 3 – Online Optimization

- Use coal and air flow control for combustion optimization

Results – Reduced excess O2

Enhanced boiler operation - O_2 and air-fuel ratio



Results - AFR

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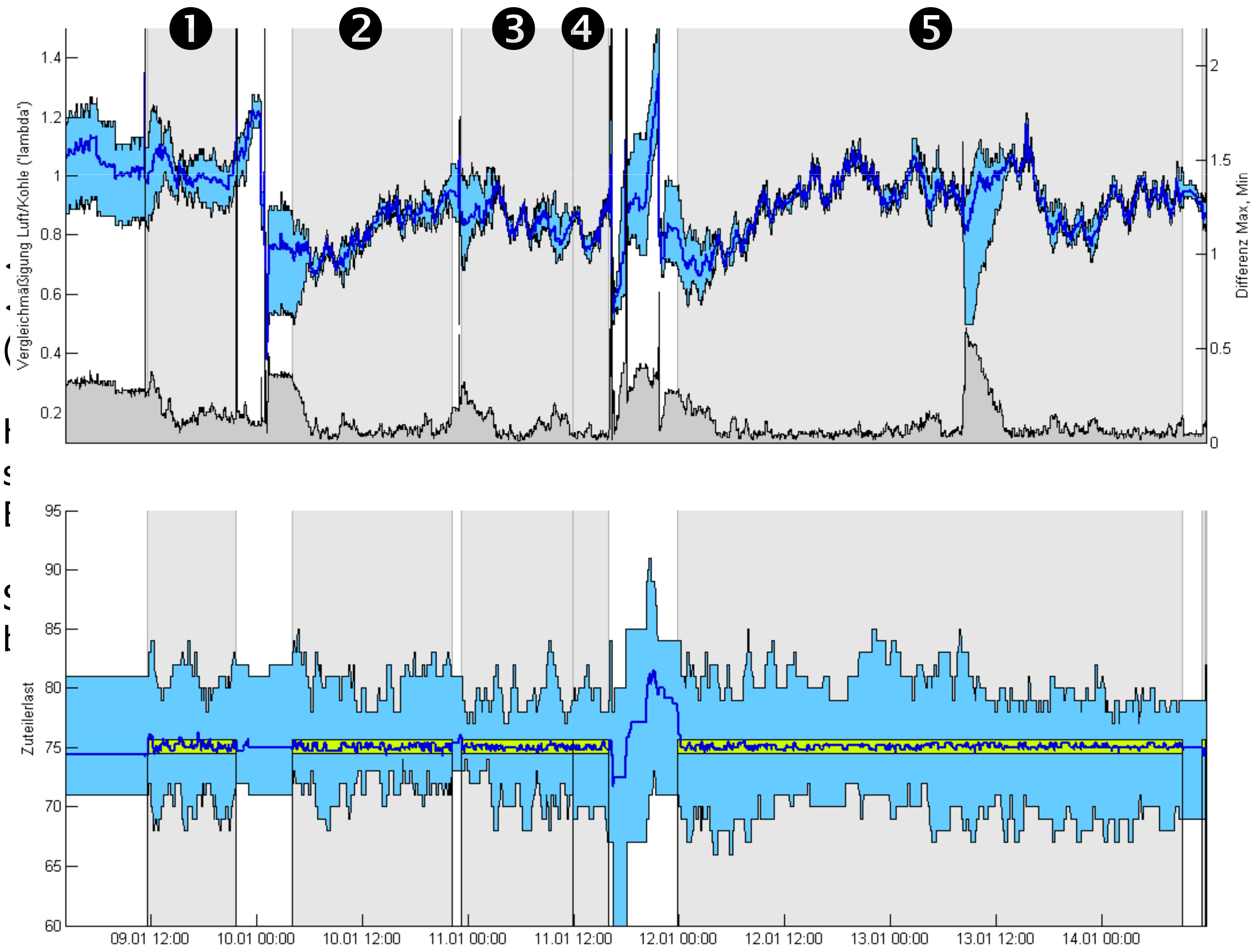
Process stabilization



Active optimizer
Limit values

Air/fuel ratio 'lambda´
- Range of all active mills
- Average

Diff. Max, Min

Hopper speed
- Range of all active mills
- Targeted area
- Average

Summary

Benefits

- Improved heat rate (1 to 3 %)
- Reduced LoI
- Reduced NOx and CO emissions (- 5 to - 15%)
- Avoid material stresses and abrasion in pipes
- Reduce slagging and fouling, limit soot blower operation
- Less material stress in furnace due to more even temperature distribution

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Thank you for your attention!

For more information you can find us at booth G100