Doosan Babcock Energy

Doosan Babcock Oxyfuel R & D Activities

The Coal Research Forum

20th Annual Meeting And Meetings Of The Combustion And Advanced Power Generation Divisions

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Department: Research and Development

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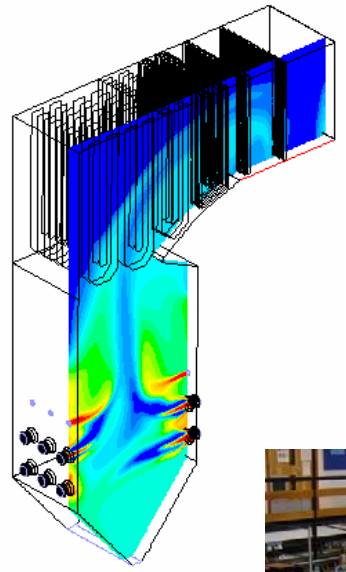
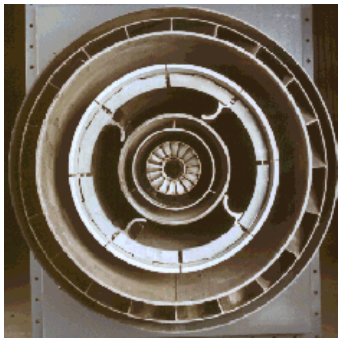
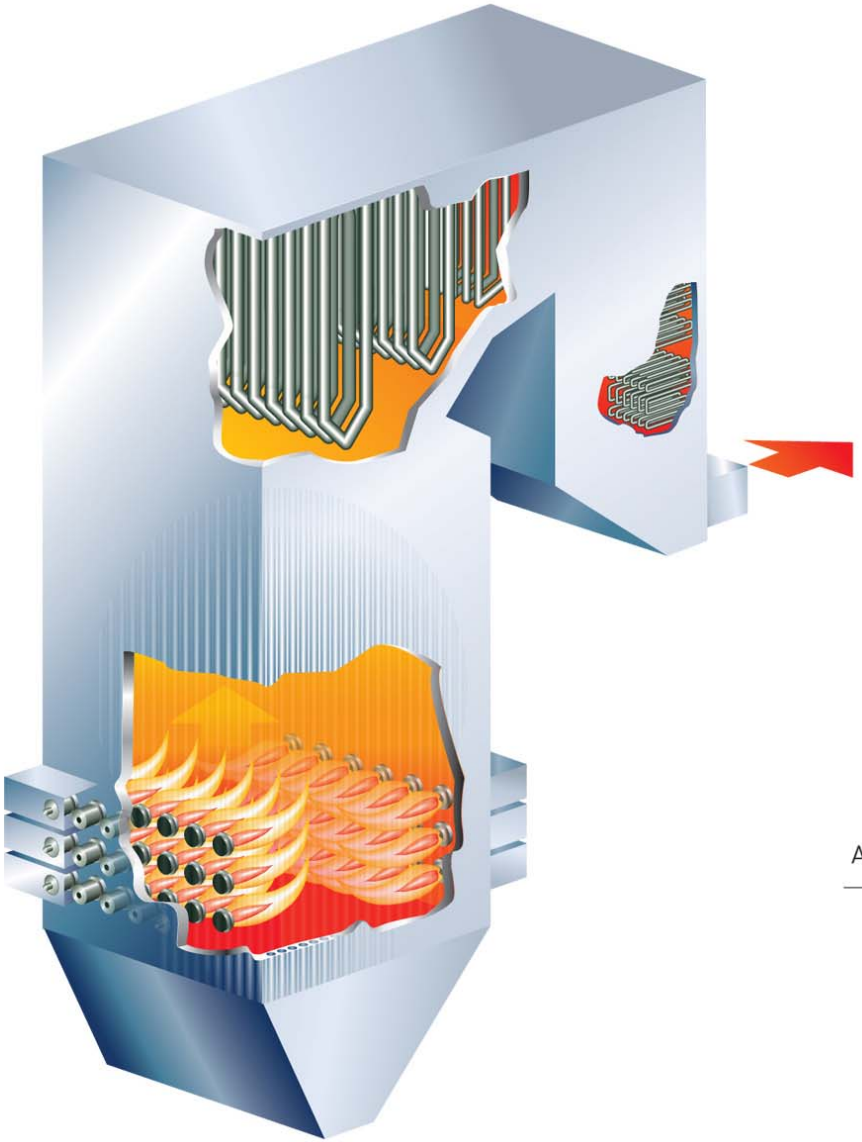
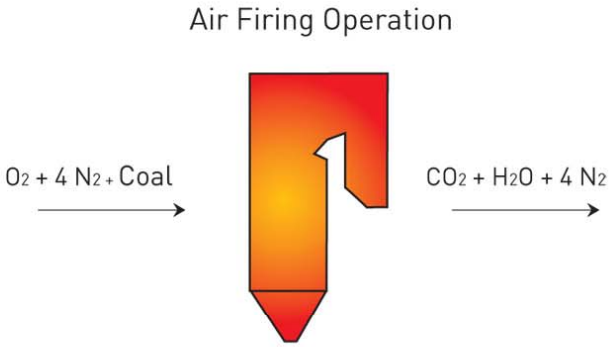
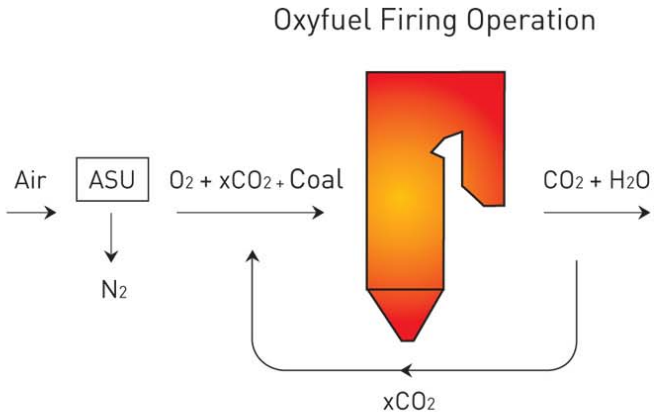




Oxyfuel Technology







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Studies On Oxyfuel Technology

International Energy Agency (IEA)

- Oxy-Combustion Processes for CO_2 Capture from Power Plant
  - Study led by Doosan Babcock to confirm feasibility and projected costs for CO_2 capture using oxy-combustion technology
  - A new build 500 MW_e advanced supercritical PF power generation plant firing bituminous coal
  - Paper presented at GHGT-7, Vancouver, September 2004
  - IEA GHG Report No. 2005/09

European Commission

- Enhanced Capture of CO_2 (ENCAP)
  - Development of oxyfuel and pre-combustion CO_2 capture options
  - 600 MW_e advanced supercritical boiler firing a South African world-traded coal
  - Doosan Babcock lead on detailed PFD and boiler design for oxyfuel
  - Lab- and pilot-scale testing was also undertaken by other project partners
  - Paper presented at GHGT-8, Trondheim, June 2006

Studies On Oxyfuel Technology

Department for Business, Enterprise & Regulatory Reform (BERR)

- Project 366 : Future CO_2 Capture Technology Options for the Canadian Market
  - Technical options and economics of oxyfuel and amine scrubbing technology
  - New-build 500MW_e advanced supercritical power plant or as a retrofit to an existing unit.
  - Lignite, sub-bituminous, and bituminous coals
  - BERR Report number COAL R309, BERR/Pub URN 07/1251

- Project 407 : Coal Fired Advanced Supercritical Boiler/Turbine with CO_2 Capture
  - Techno-economic evaluation of an advanced supercritical boiler/turbine retrofit; air firing ,oxyfuel firing, and amine scrubbing options for CO_2 capture
  - Results were compared against the pre-retrofit sub-critical boiler (500 MW_e)
  - Paper presented at GHGT-8, Trondheim, June 2006

Test Rig Work On Oxyfuel Technology (NRTF)

European Commission

- JOULE Programme : first to test oxyfuel in Europe (At Doosan Babcock and IFRF)
  - Project started in 1992
- Modified an existing 160kWt combustion test facility
- Fired two bituminous coals under oxyfiring conditions
- Tested the impact of oxyfuel firing on NO_X, SO_2, burnout, in-furnace deposition, and convective pass fouling.
- A full report was prepared for the European Commission
  - "Pulverised Coal Combustion System for CO_2 Capture"
- Work included in an IEA review
  - Santos and Haines, Inaugural Workshop, IEAGHG International Oxy-fuel Combustion Network, 2005

Test Rig Work On Oxyfuel Technology (NRTF)

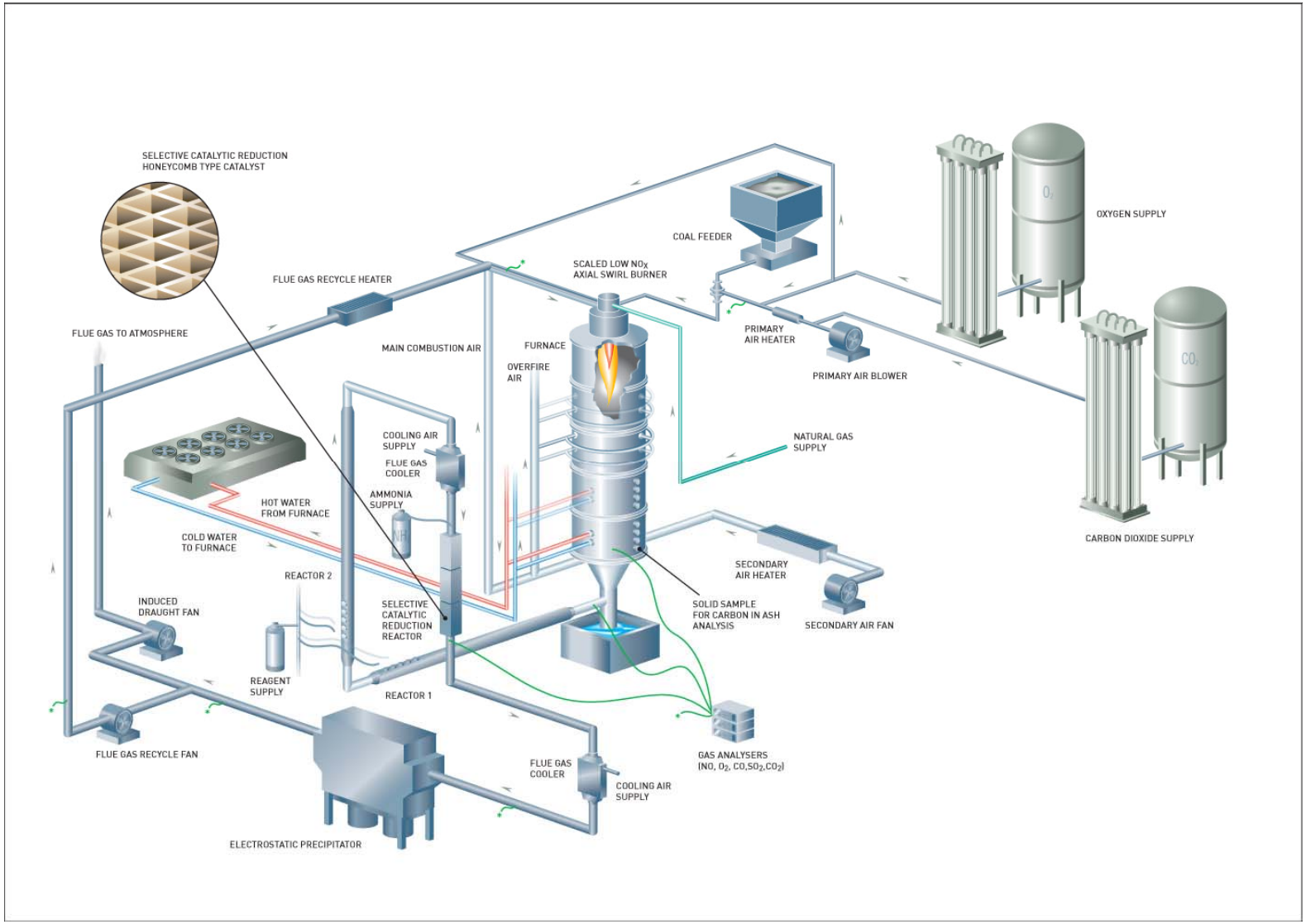
Department for Business, Enterprise & Regulatory Reform (BERR)

- OxyCoal-UK phase 1
  - Upgraded the present 160 kWt NRTF
  - Completed a total of 18 test days in discrete periods
  - Used a Colombian word traded coal commonly fired by UK power plants
  - Flue gas cleaning evaluated by other project partners

Technology Strategy Board (TSB)

- Impact of high concentrations of SO_2 and SO_3 in carbon capture applications and mitigation
  - Understand how SO_2 and SO_3 interacts with corrosion and mercury under oxyfiring conditions
  - Start in 2009 : an on-going project

Test Rig Work On Oxyfuel Technology (NRTF)



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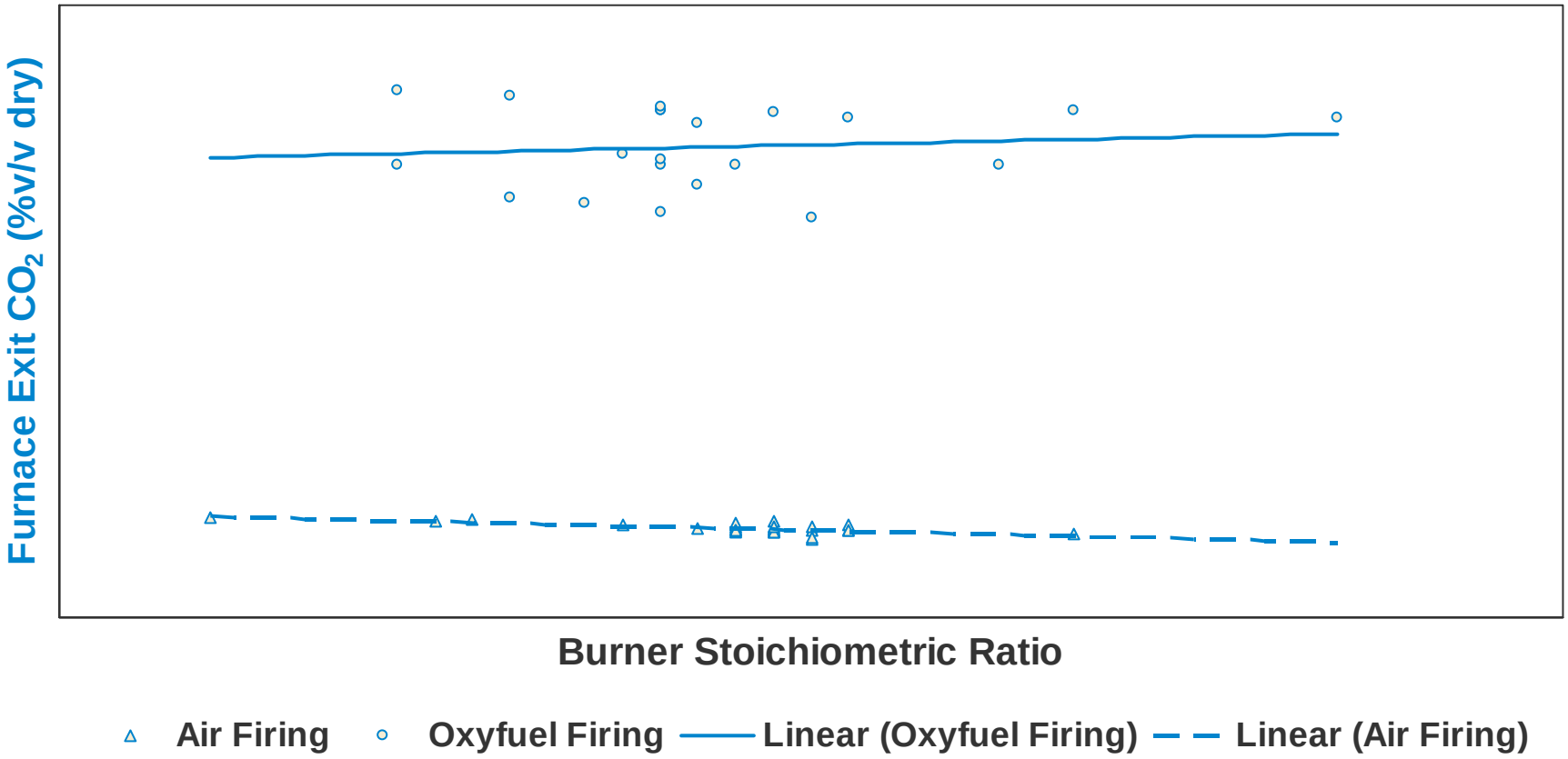
Test Rig Work On Oxyfuel Technology (NRTF)

OxyCoal-UK Phase 1: Project partners

- Lead Company
  - Doosan Babcock Energy
- Industrial Participants
  - Air Products
  - E.ON UK
  - RWE
  - bp
- University Participants
  - Imperial College London
  - The University of Nottingham
- Sponsors / Sponsor Participants
  - Scottish and Southern Energy
  - ScottishPower
  - EDF Energy
  - Drax Power Limited
  - DONG energy
  - Vattenfall
- Government Support
  - Technology Strategy Board – Driving Innovation
  - EPSRC Engineering and Physical Sciences Research Council

Test Rig Work On Oxyfuel Technology (NRTF)

Oxyfuel combustion generates a CO_2 rich flue gas typically 80%v/v dry.



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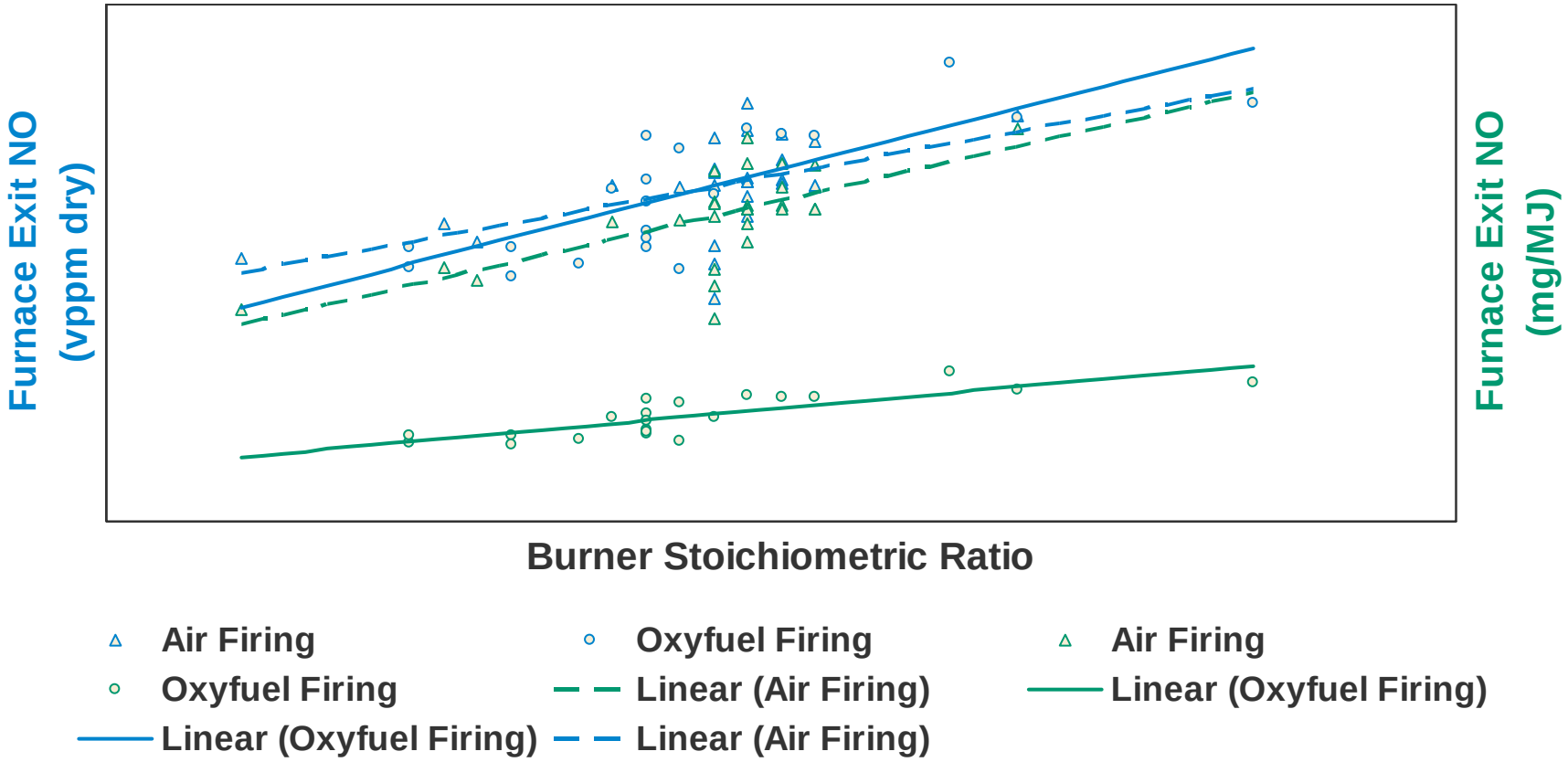
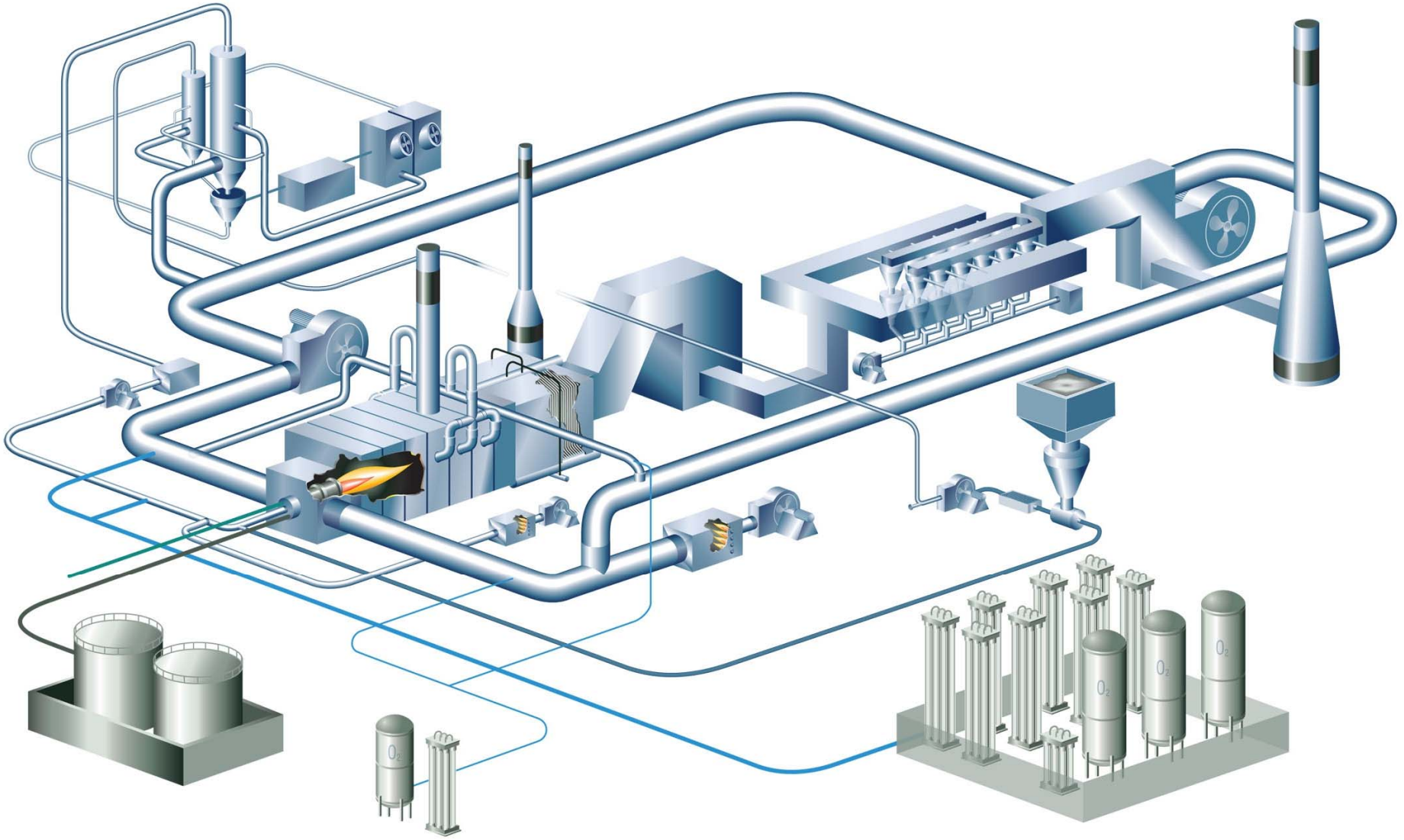
Test Rig Work On Oxyfuel Technology (NRTF)

Oxyfuel combustion reduces NO emissions by approximately 50% on a heat input basis (mg/MJ).



Test Rig Work On Oxyfuel Technology (MBTF)



Test Rig Work On Oxyfuel Technology (MBTF)

OxyCoal-UK Phase 2: Project partners

- Lead Company

  Doosan Babcock Energy

- University Participants

  Imperial College London

  The University of Nottingham

- Prime Sponsor

  Scottish and Southern Energy

- Sponsors

  Air Products, E.ON UK, ScottishPower, EDF Energy, Drax Power Limited, DONG energy, Vattenfall, UK Coal

- Government Support

  Department of Energy & Climate Change

Test Rig Work On Oxyfuel Technology (MBTF)

Oxygen Storage Area

Oxygen Control Skid

Test Rig Work On Oxyfuel Technology (MBTF)

FGR duct from grit arrestor

Spray cooling system

Test Rig Work On Oxyfuel Technology (MBTF)

PFGR fan

SFGR fan

Test Rig Work On Oxyfuel Technology (MBTF)

Plan for OxyCoal™ testing on the MBTF

- Cold commissioning of the new systems
  - Primary flue gas recycle line
  - Secondary flue gas recycle line
  - Transport flue gas recycle line
  - Spray cooling system

- Isothermal testing of the new 40 MW_t OxyCoal™ burner

- Hot commissioning of the MBTF
  - Air firing with oil
  - Air firing with coal

- 40 MW_t OxyCoal™ testing on the MBTF
  - flue gas recycle rates
  - flue gas recycle oxygen enrichment
  - thermal load

Modelling Work On Oxyfuel Technology

European Commission

- Mathematical Modelling for Oxyfuel Combustion (OxyMod)
  - Development of modelling tools for oxyfuel combustion (CFD and engineering models)
  - Lab- and pilot-scale testing also being undertaken by other project partners

Technology Strategy Board (TSB)

- Optimisation of Oxyfuel PF Power Plant for Transient Behaviour
  - Develop a dynamical model of ultra-supercritical power station with applied oxyfuel combustion

Department for Business, Enterprise & Regulatory Reform (BERR)

- OxyCoal-UK phase 1
  - MBTF OxyCoal™ CFD modelling
  - Utility plant OxyCoal™ CFD modelling
- OxyCoal-UK phase 2
  - MBTF OxyCoal™ CFD modelling

Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

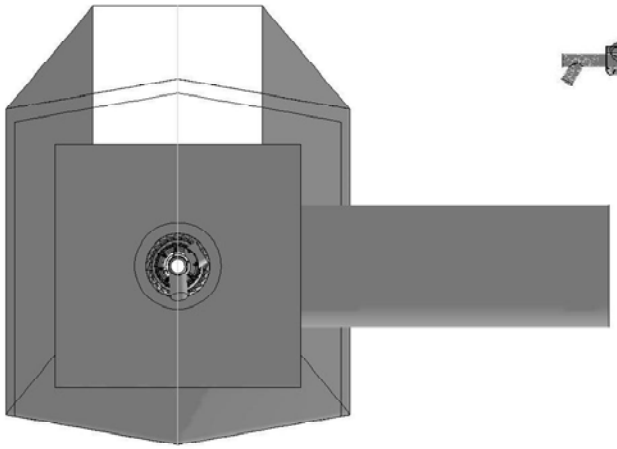
- CFD input : Drop tube furnace (University of Nottingham) and PC Coal Lab
- UK bituminous coal, high firing pattern
- Air Firing
  - Low NO_x burners
  - Two stage with Boosted Overfire Air
  - Known boiler performance
- Oxyfuel Firing
  - OxyCoal™ burners
  - Single stage operation
  - Maintain PFGR O_2 and volumetric flow
  - Stoichiometry 1.17
  - Flue gas weight significantly reduced
- Uniform coal and air distribution,
- Utility plant case : idle burner in-leakage only

Component (% vol)	Air	Primary FGR	Secondary FGR
O_2	21.0	18.48	47.23
CO_2	-	75.97	40.96
H_2O	-	2.73	9.62
N_2 (plus inerts)	79.0	2.81	2.19

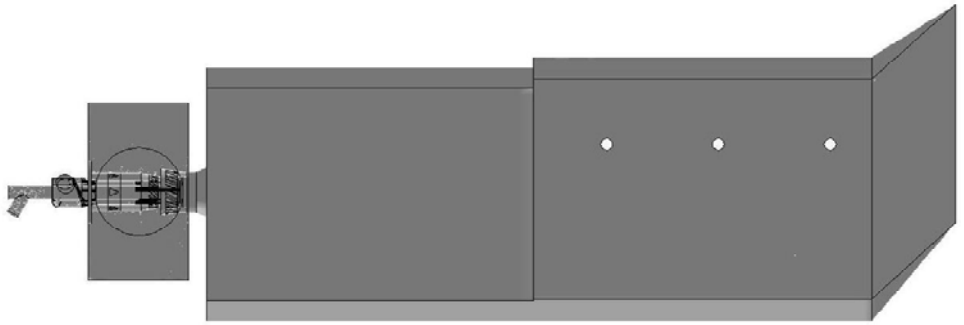
Gas Compositions

Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

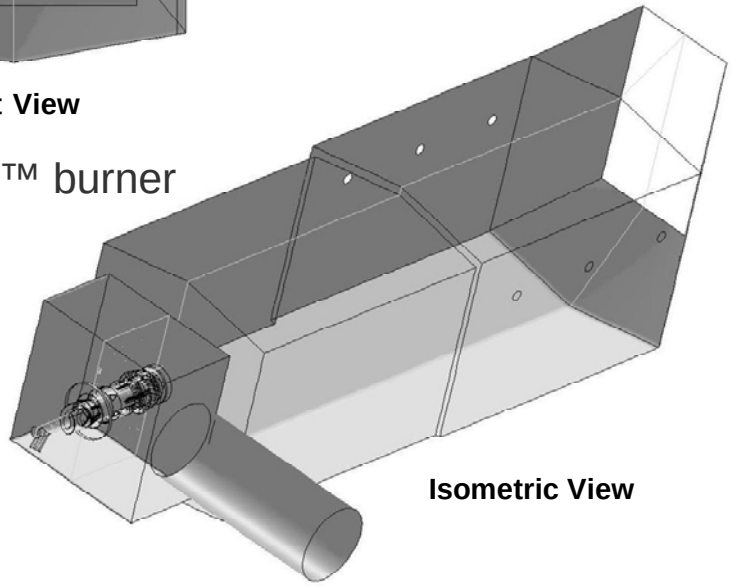
MBTF modelling



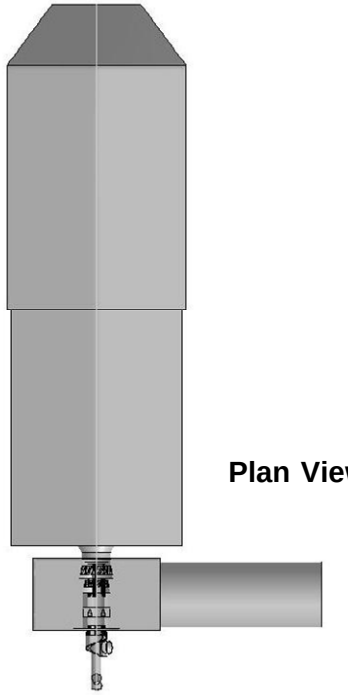
Front View



Elevation



Isometric View

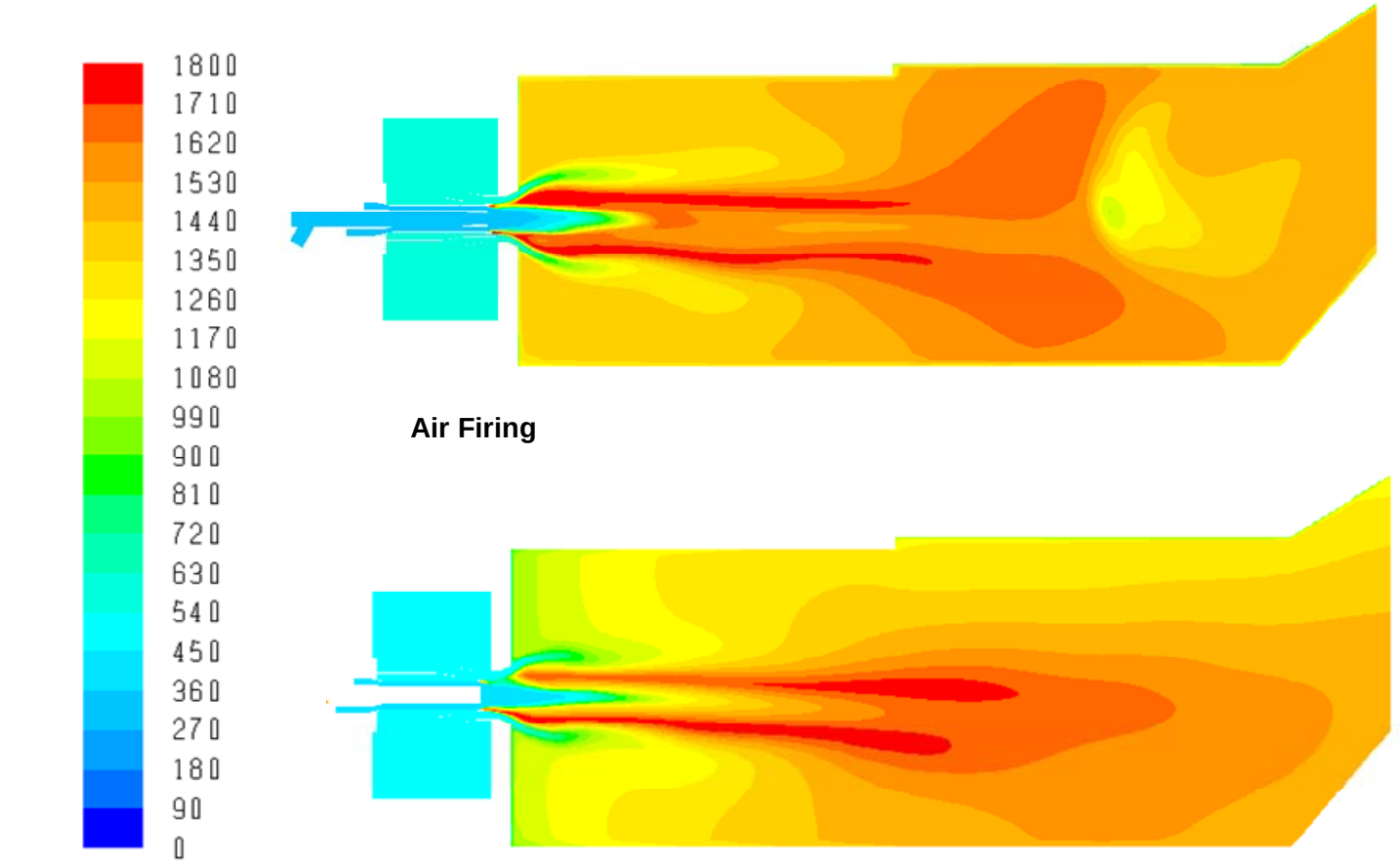


Plan View

- A single 40 MW_t OxyCoal™ burner
- Overfire Air system

Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

Oxycoal™ case has higher peak temperature but reduced FEGT



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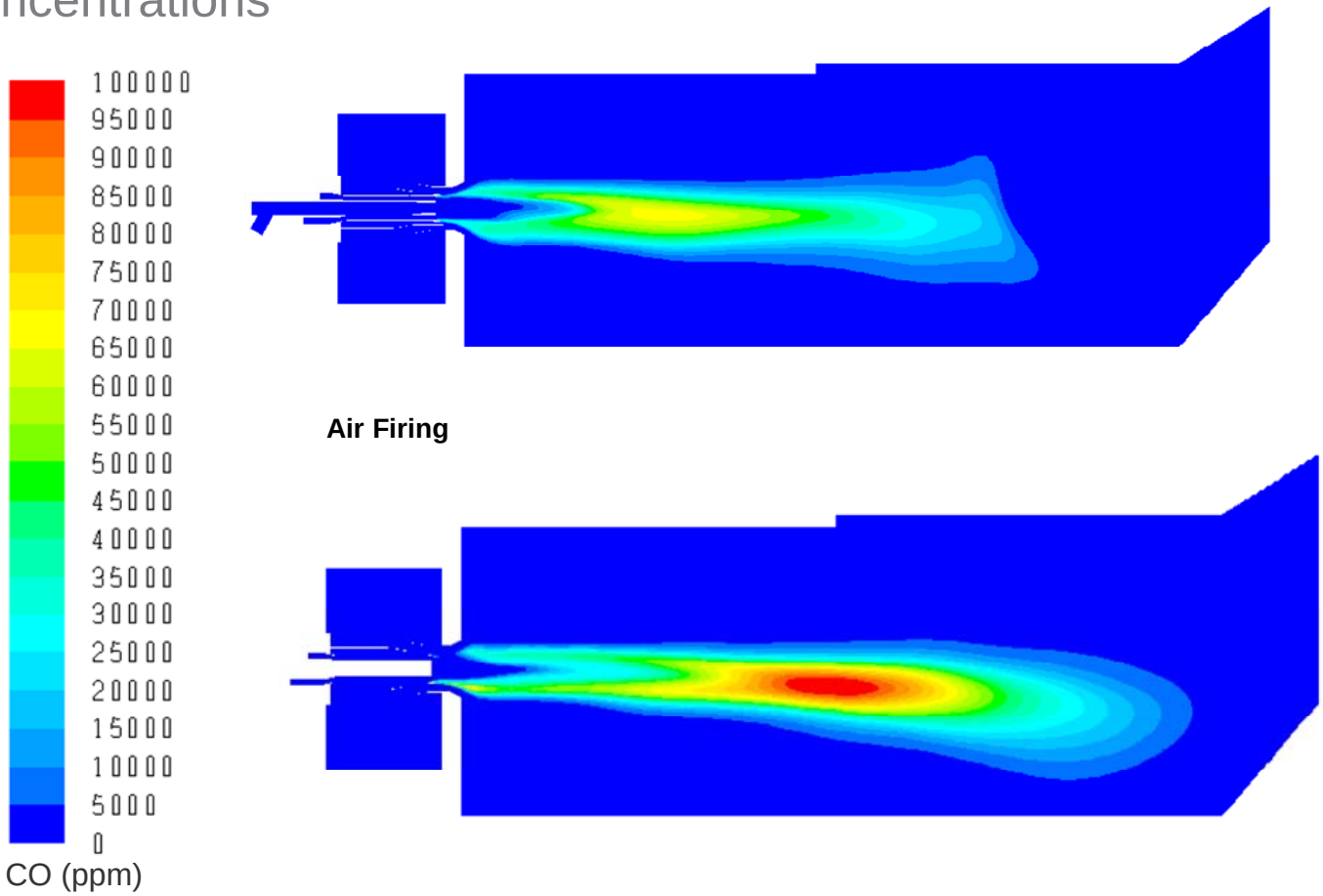
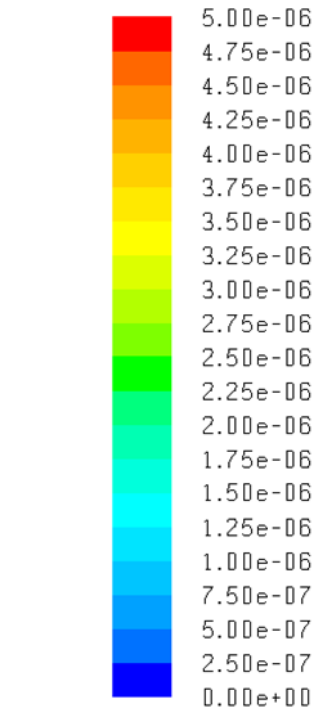
Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

OxyCoal™ case has higher local flame CO concentrations but lower furnace exit CO concentrations

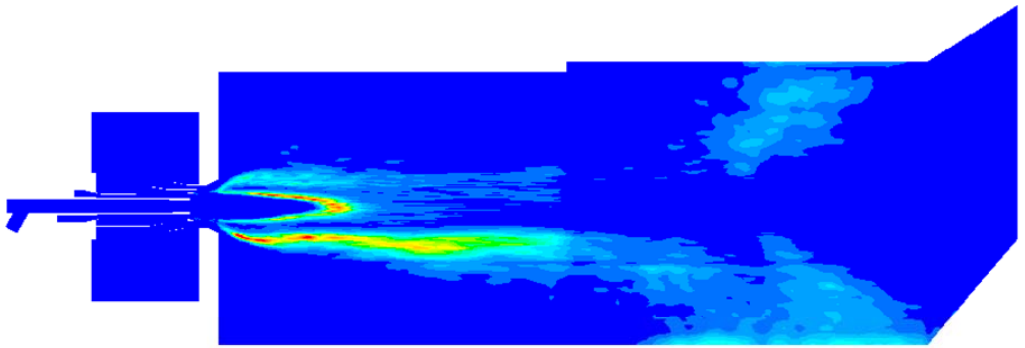


Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

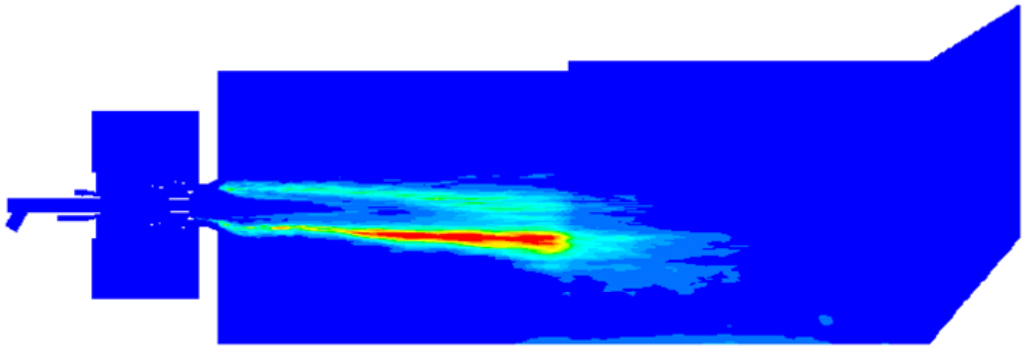
OxyCoal™ case has improved char burnout and a narrower flame



Char burnout (kg/s)



Air Firing



Oxyfuel Firing

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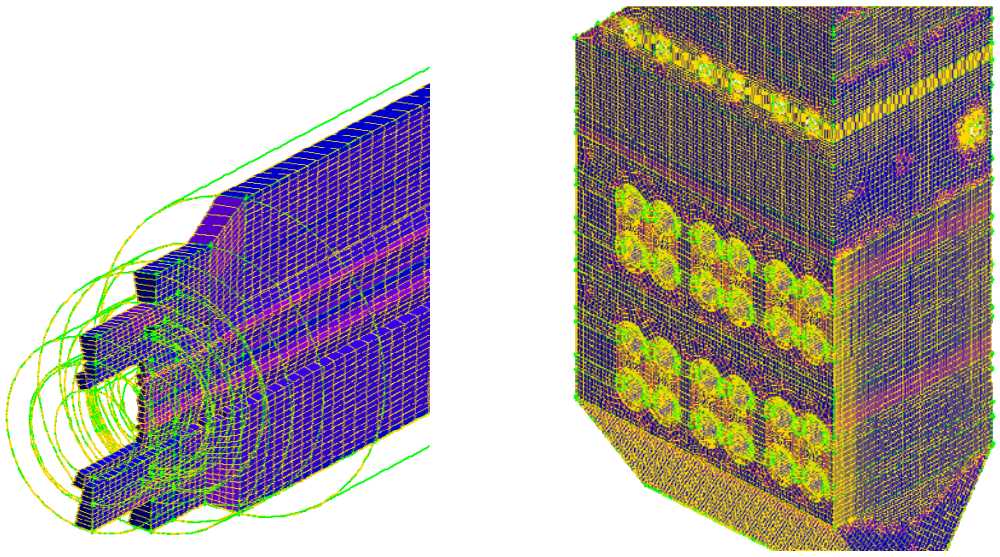
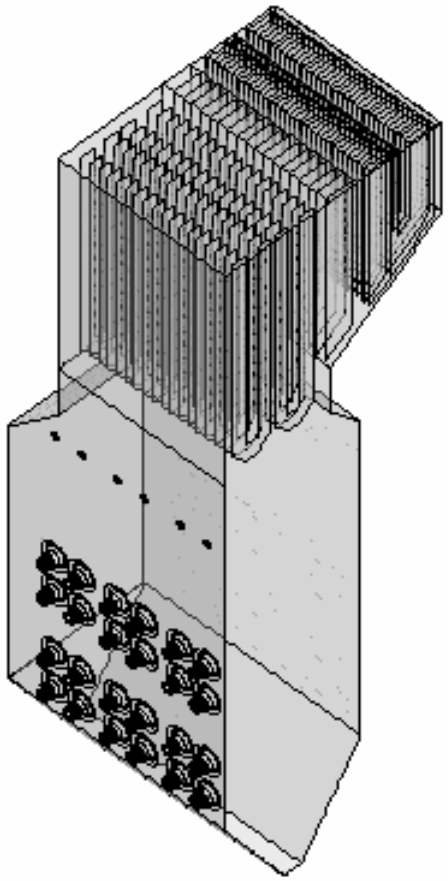
Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

Utility plant modelling

- 500 MW_e front wall fired furnace
- Forty-eight 37 MW_t burners
- Boosted Overfire Air system



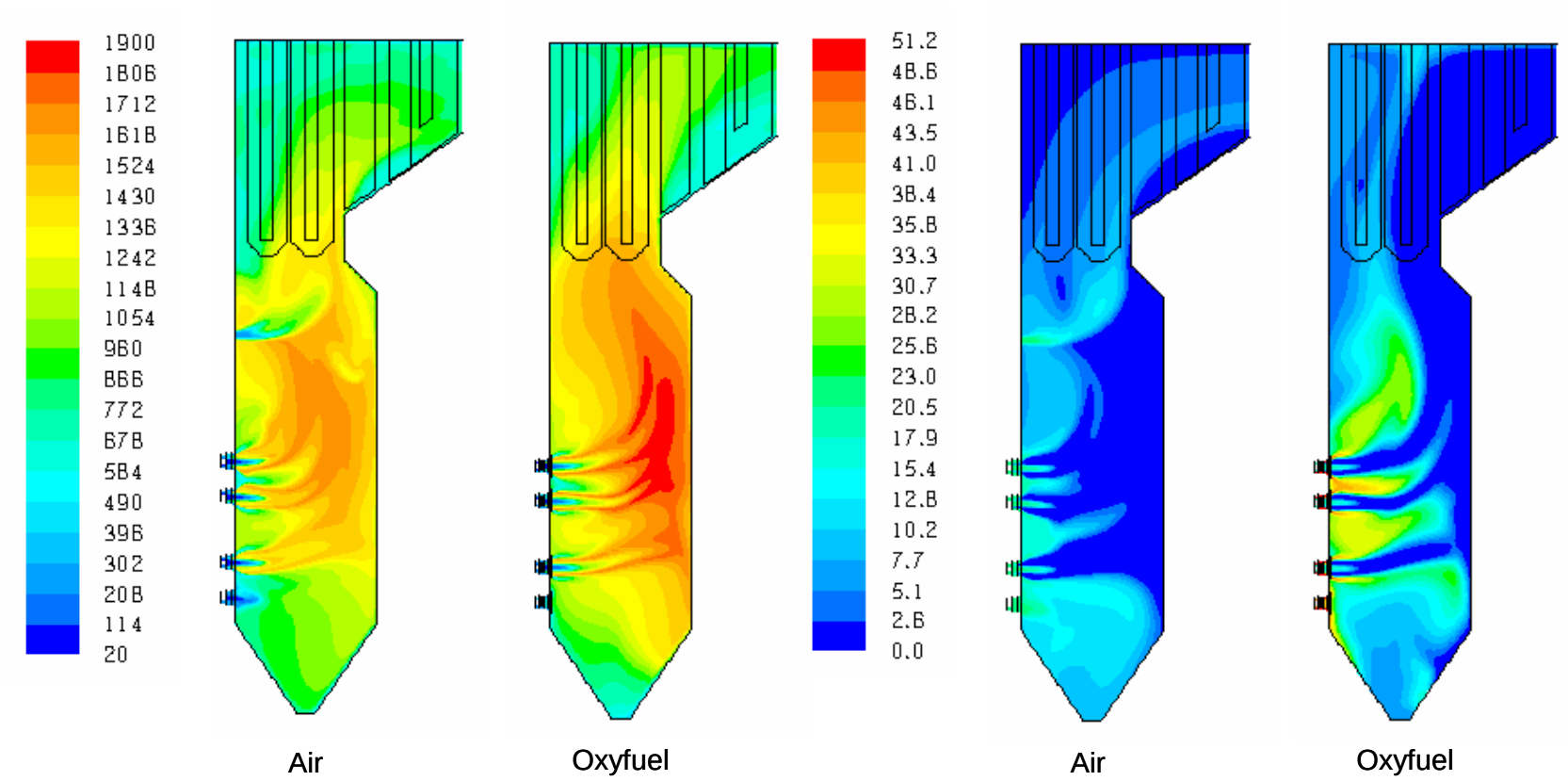
Burner and Furnace Mesh Detail



Furnace Grid Outline

Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

OxyCoal™ case has increased gas temperatures and an elongated flame shape



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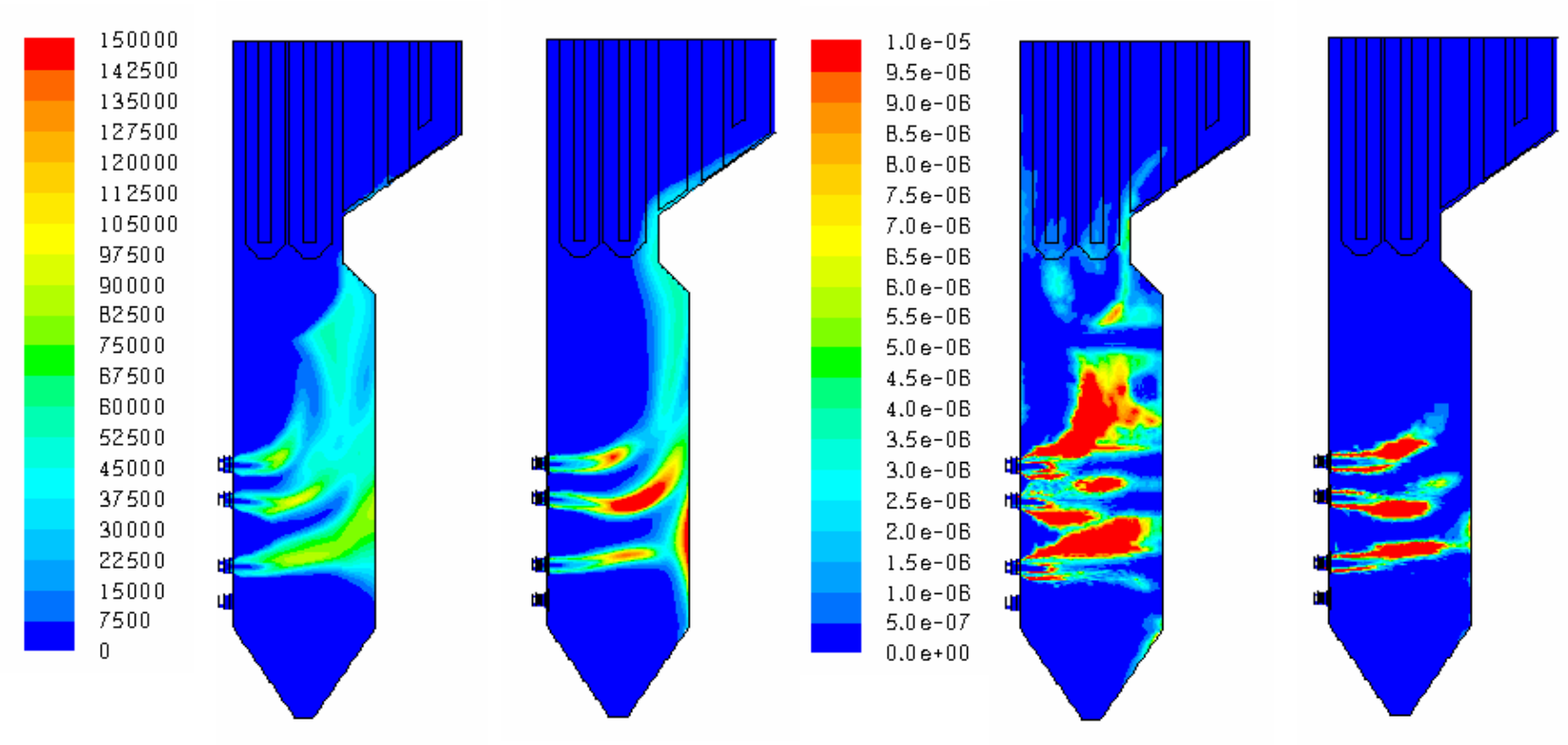
Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

OxyCoal™ case has increased peak CO, increased exit CO but similar burnout



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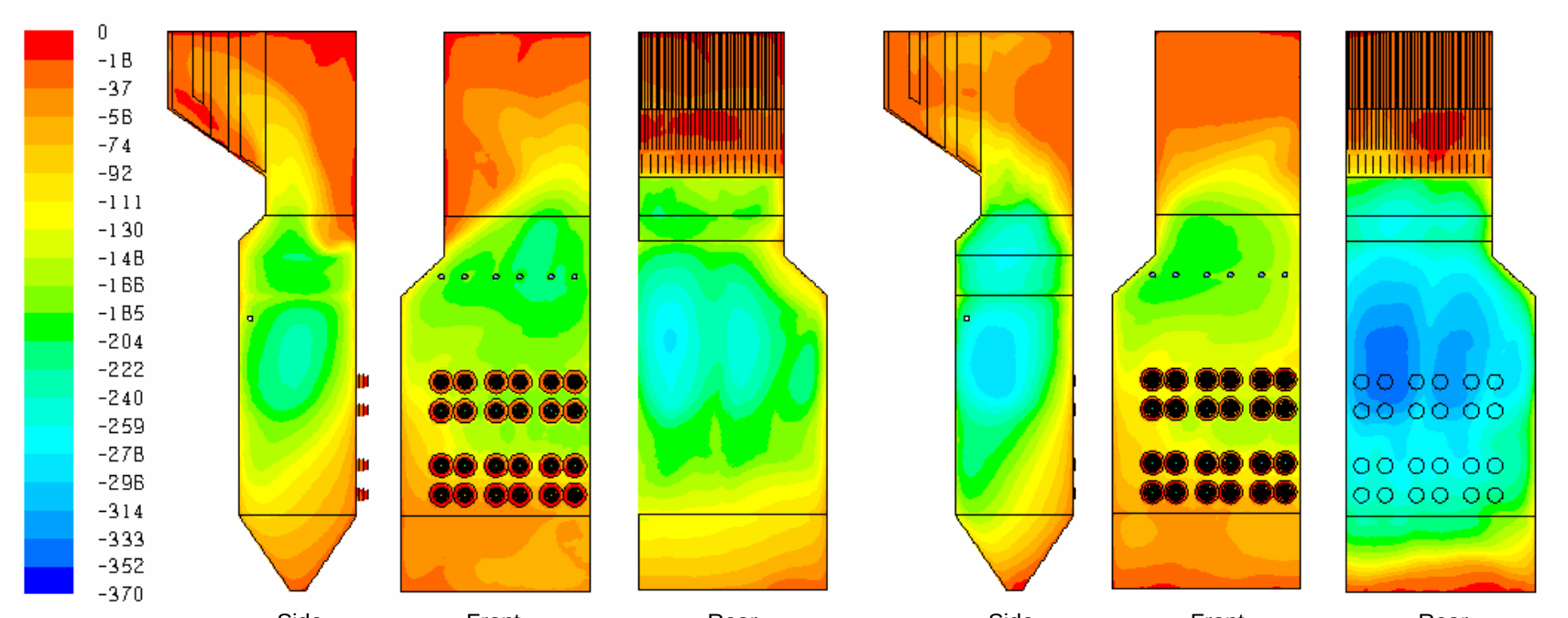
Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

OxyCoal™ case has earlier heat release and higher heat transferred to the furnace



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Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

Thermal Performance

Scenario	Air, Two Stage	OxyCoal ™ Single Stage
Arch Temperature (°C)	1418	1513
Furnace Exit Gas Temperature (°C)	1072	1061
Outlet Temperature (°C)	843	790
Total Heat In (MW)	1413.6	1411.5
Heat to Walls (MW)	440.2	544.0
Heat to Pri and Sec Platen SH (MW)	239.0	270.2
Heat to SH Inlet and Outlet (MW)	105.4	122.6
Heat to RH Outlet (MW)	74.2	61.2
Heat in Flue Gas (MW)	532.0	393.2
Unburned Loss (MW)	7.8	0.0
Imbalance (%)	-1.0	-1.4

- Compared to air firing, the OxyCoal™ case gives
  - Higher arch level temperature
  - Similar FEGT, reduced outlet temperatures
  - Increased heat absorption by furnace walls (+24% air case)
  - Increased absorption by platen superheater surfaces (+13% air case)
  - Reduced reheater pick-up
- Radiative heat transfer in oxyfuel case is increased through increased flame temperatures and gas emissivity

Modelling Work On Oxyfuel Technology (OxyCoal-UK Phase 1)

Emissions Performance

Plant	MBTF		Utility Plant	
Scenario	Air	OxyCoal™	Air	OxyCoal™
Oxygen (% v/v dry)	2.93	5.30	2.98	5.60
CO (ppm @ 6% O_2)	145	114	291	1001
CO (mg/MJ)	82	12	59	122
Unburned Loss (% GCV)	0.4	0.0	0.6	0.6
Carbon in Ash (%)	1.5	0.1	2.0	2.0
NO_x (ppm @ 6% O_2)	207	111	156	92
NO_x (mg/MJ)	94	14	40	10

- Different CO results
  - Lower CO emissions for MBTF OxyCoal™
  - Higher CO emissions for utility plant OxyCoal™
- Different CIA results
  - Lower CIA for MBTF OxyCoal™
  - Similar CIA for utility plant
- Reduced NO_x emission
  - Negligible thermal source
  - Fuel NO_x generation limited by flame structure
- Lower than expected baseline NO_x and high burnouts may also relate to assumption of ideal furnace operation
  - Fuel/air distribution
  - Air ingress

Concluding Remarks

Doosan Babcock are taking a proactive role in the development and implementation of oxyfuel combustion and carbon capture technologies.

- Started investigating oxyfuel technology since 1992
- Completed numerous studies, rig tests and CFD analysis on oxyfuel technology
- OxyCoal-UK Phase 1: Fundamentals and Underpinning Technologies
  - Theoretical modelling, laboratory and pilot-scale testing to address critical technology gaps
  - Operating experience of the oxyfuel combustion process has been extended
- OxyCoal-UK Phase 2: Demonstration of an Oxyfuel Combustion System
  - MBTF oxyfuel upgrade
  - 40 MW_t Oxycoal™ burner testing will be carried out in the near future
- Demonstration of our full-scale (40 MW_t) OxyCoal™ burner will form the foundation for an oxyfuel boiler reference design

Contact Details

Thank you for your attention.

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