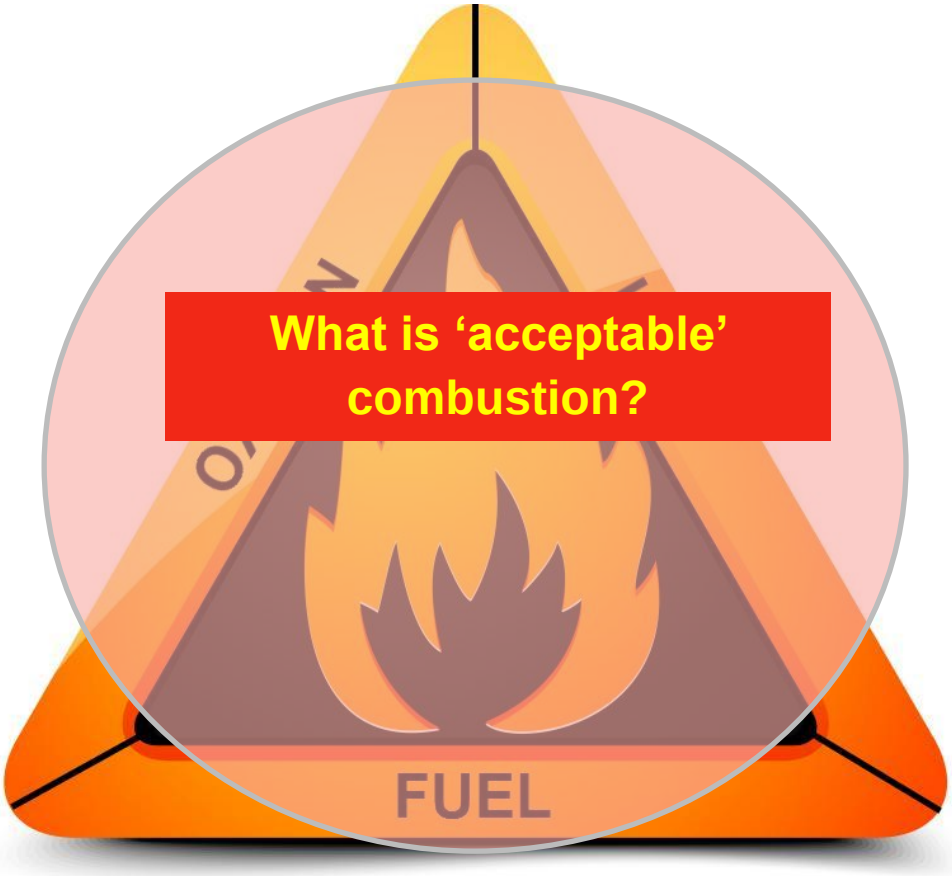
Combustion issues in low-carbon fossil power plants for the 21st Century

Robin Irons
E.ON Technologies Group, Technical Head, Zero Emission Power Plant

Combustion issues in low-carbon fossil power plants for the 21st Century

Combustion issues in low-carbon fossil power plants for the 21st Century



Combustion issues in low-carbon fossil power plants for the 21st Century

Combustion

Fuel

Comburent

Heat

Acceptability

Emissions

Materials

Flexibility

The Fuel Diet

UK Coal Market 2012

Coal Source	Mte	Domestic total
UK Deep*	6.2	
UK Surface	10.2	**16.8**
UK Other	0.4	
		Import Total
Russia	18.3	
Colombia	11.9	
USA	10.5	
Australia	2.3	**44.8**
EU (includes trans-shipment)	0.7	
RSA	0.6	
Canada	0.1	
Other	0.4	

* NB: data includes Daw Mill – Closed after fire in early 2013

Source UK Coal website

UK Coal Market 2012

Coal Source	Mte	Domestic total
UK Deep*	6.2	
UK Surface	10.2	**16.8**
UK Other	0.4	
		Import Total
Russia	18.2	
Colombia	11.9	
USA	10.5	
Australia	2.3	**44.8**
EU (includes trans-shipment)	0.7	
RSA	0.6	
Canada	0.1	
Other	0.4	

The UK Coal basket is as broad as ever and fuel of choice varies rapidly with regulation, politics and economics

* NB: data includes Daw Mill – Closed after fire in early 2013

Source UK Coal website

For Today’s power mix see

‘GridCarbon’ App

24 Feb data

13300MW	Coal
7300MW	Nuclear
5500MW	Wind
3400MW	Gas
2000MW	French Interconector
1000MW	Dutch Intrconector
1000MW	Hydro
560MW	Other

New Biomass plants – E.ON's Blackburn Meadows

- 30MWe
- CHP
- Waste Wood
- Fluid Bed Combustion
- NE of Sheffield

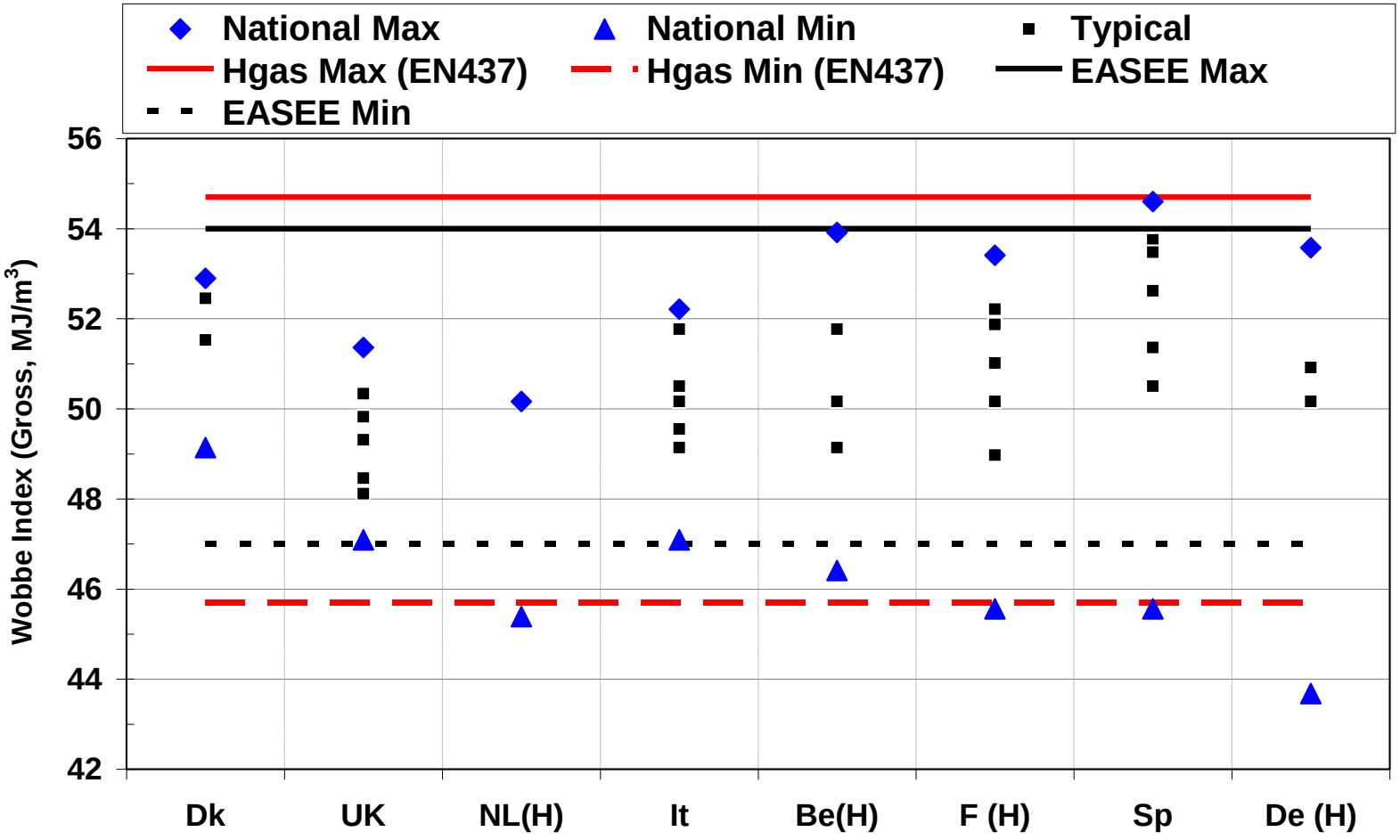
Biomass-Cofiring in Existing Plants

Variables Include
Base Fuel (coal) and variability
Biomass %
Biomass Type (and variability)
Economic incentives
Boiler Design
Emissions Regulations
Emission Control technologies

Source, Alstom Website

But natural gas is just natural gas, isn’t it…….?

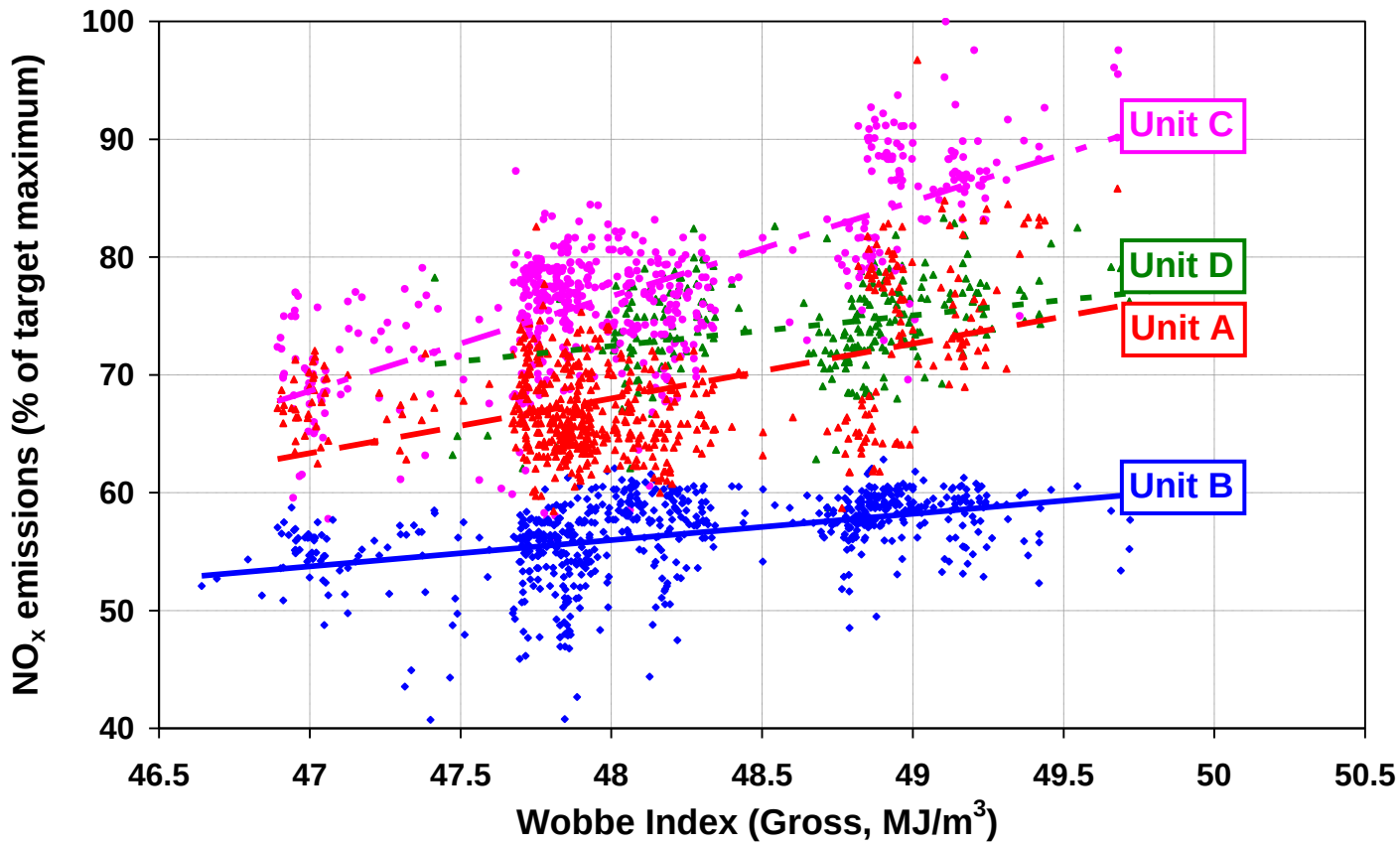
EASEE-Gas Gas Quality Specifications



Wobbe Index = GCV/(Specific gravity)$^{0.5}$

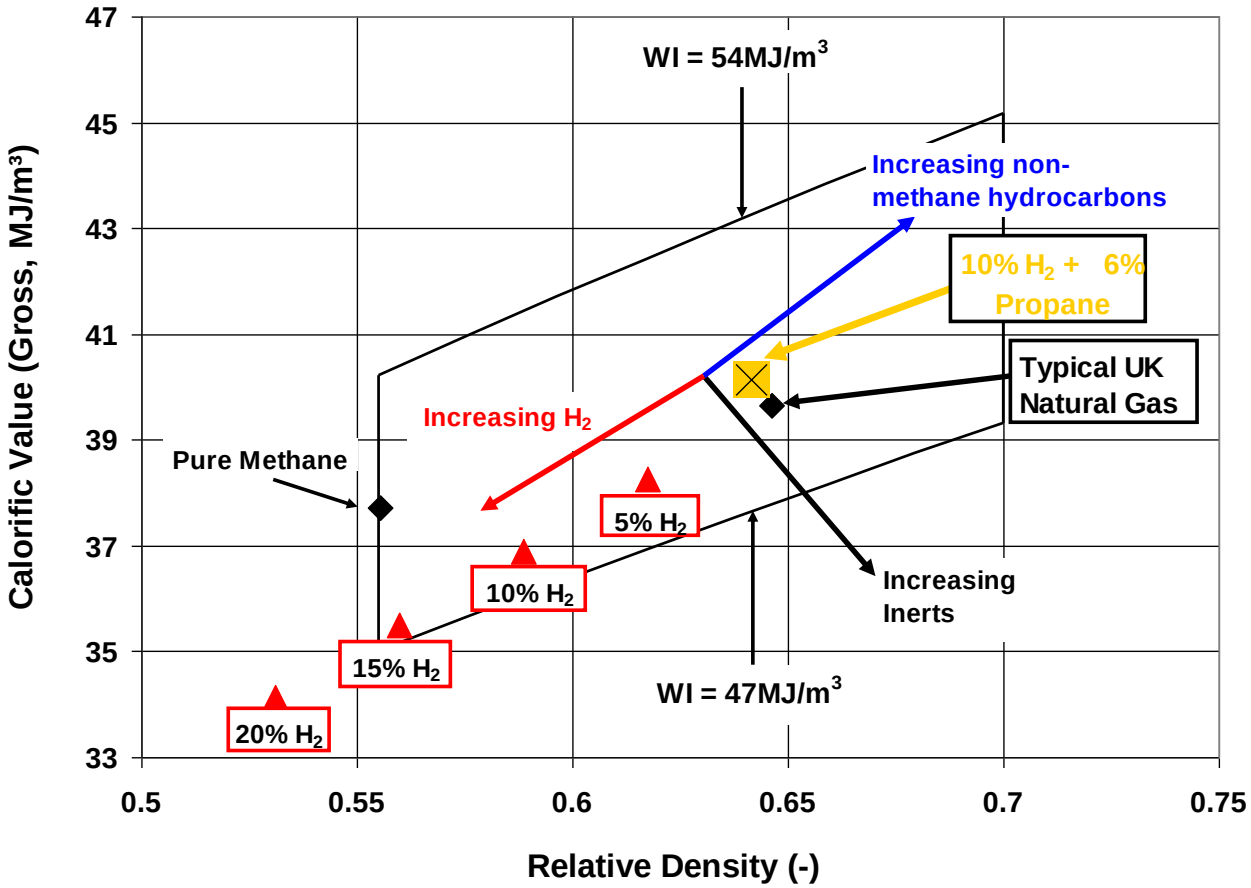
Impact on NO_x Emissions

- Site with 4 GTs of same design
- Increasing trend in NOx emissions with fuel Wobbe Index
- Impact of fuel quality on NO_X emissions varies between the 4 units



Potential for Hydrogen

- Significant amounts of hydrogen can be accommodated within the EASEE-Gas envelope
- This could cause significant issues for gas turbines



Black line represents EASEE-Gas quality specification

Flashback and Burner Damage

- Flashback and burner damage as seen at an E.ON GT site has been linked to high levels of higher hydrocarbons (C2+)
- No longer a major issue for E.ON as flashback prone burners have been replaced by flashback resistant design
- There is still potential for flashback on some burners with fuel quality changes, e.g. increasing C2+.

New Areas for Power Plant

Is CCS Relevant to Combustion Issues?

Oxyfuel Combustion

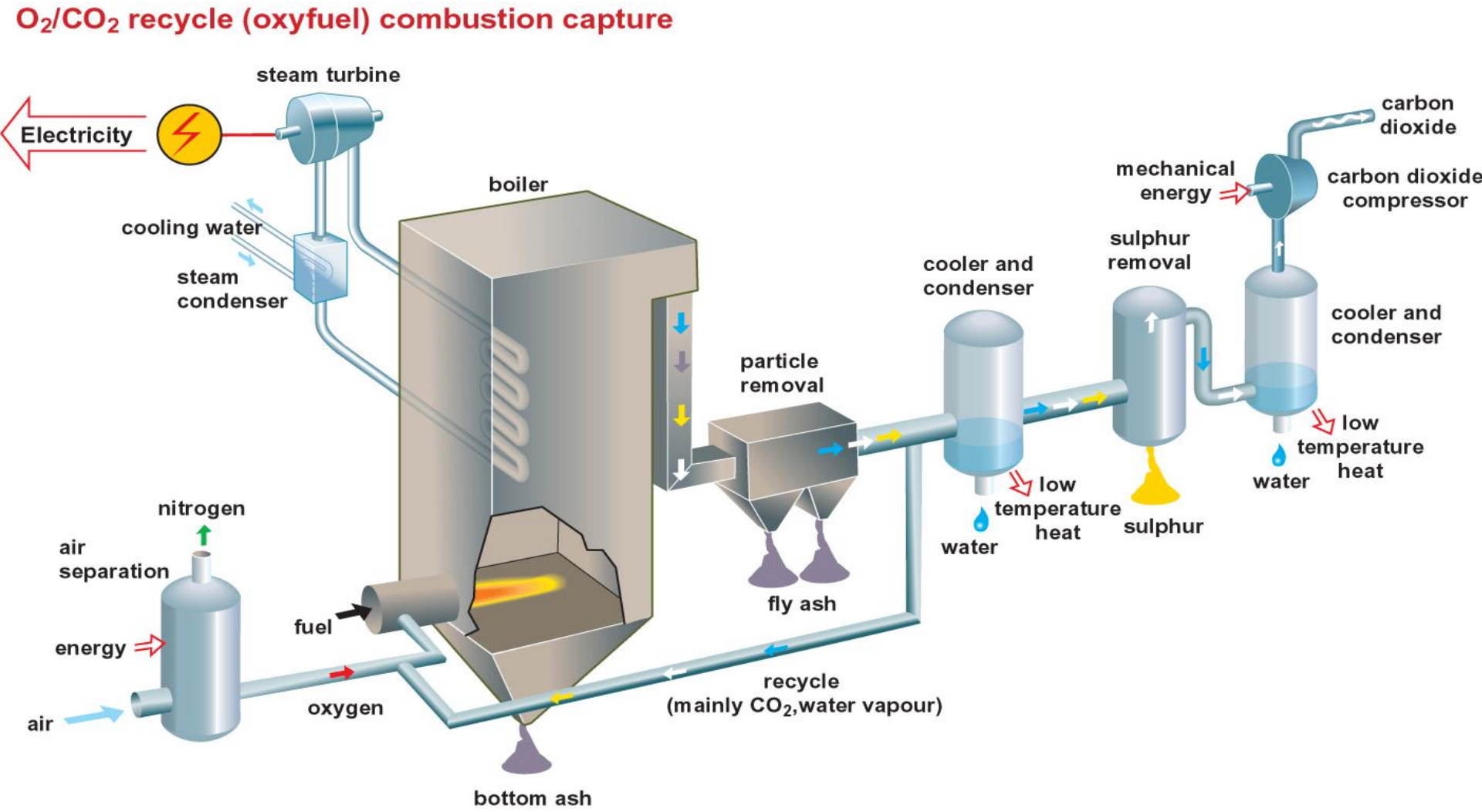


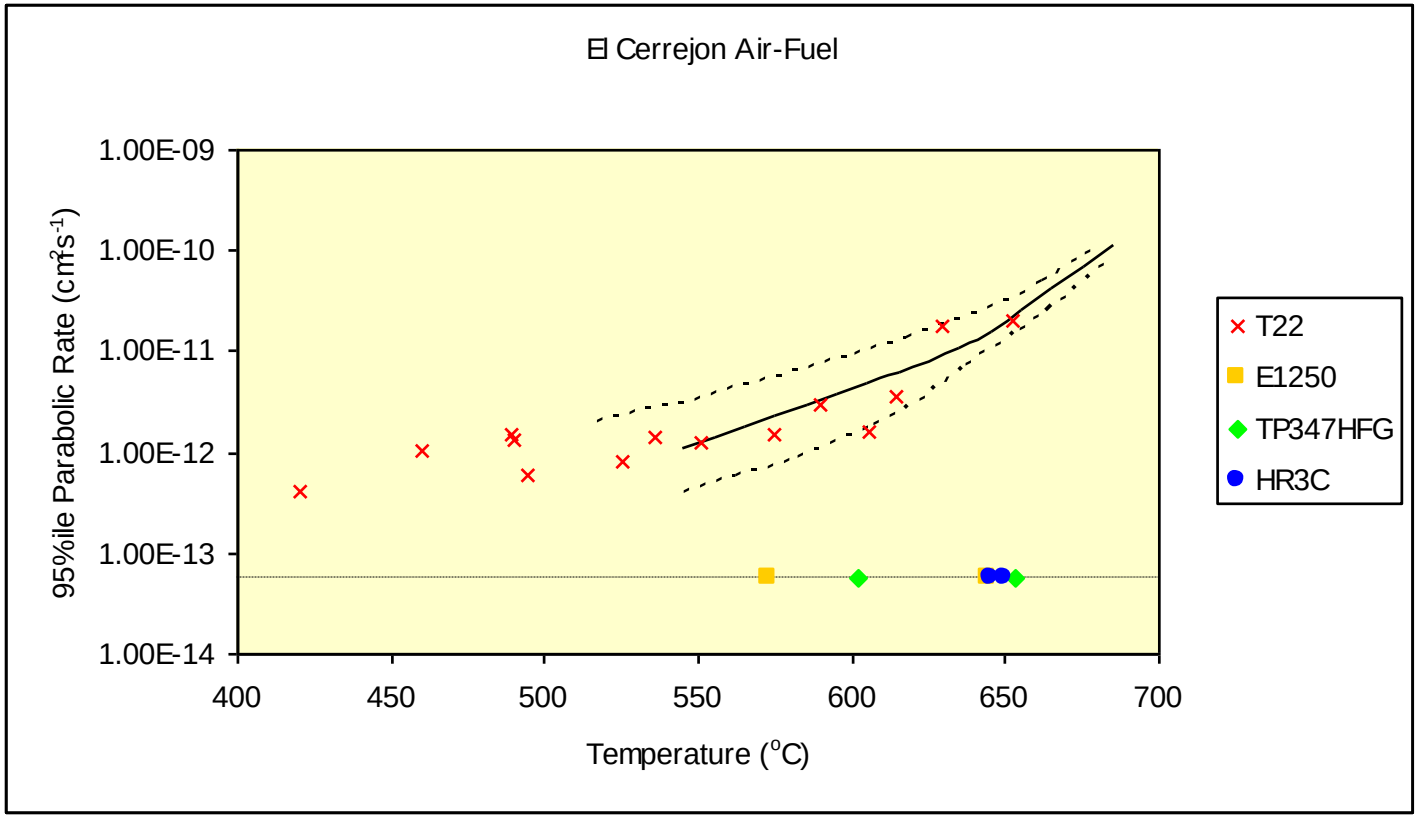
Figure courtesy Vattenfall

Corrosion in Oxyfuel

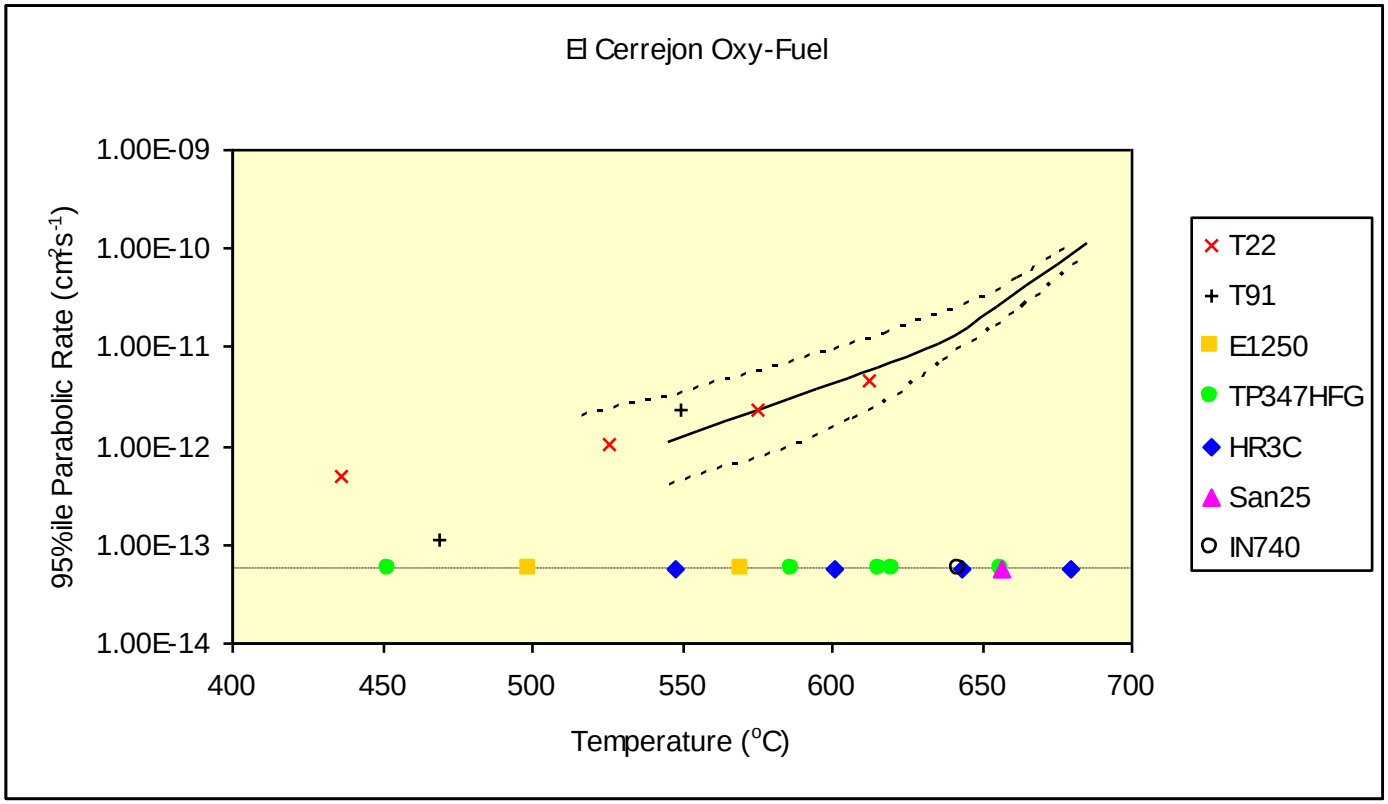
			El Cerrejon	Thoresby
Moisture	%wt AR		5.8	4.8
Ash	%wt AR		8.6	11.8
Volatile	%wt AR		34.8	32.3
	%wt DAF		40.7	38.7
Fuel ratio	(Fixed C:VM)		1.46	1.58
Net CV	kJ/kg AR		27,122	27,393
S	%wt AR		0.58	1.61
	%wt DAF		0.68	1.93
Cl	%wt AR		0.02	0.45
	%wt DAF		0.02	0.54
N	%wt AR		1.42	1.55
	%wt DAF		1.66	1.86

AR = As Received - DAF dry, ash-free

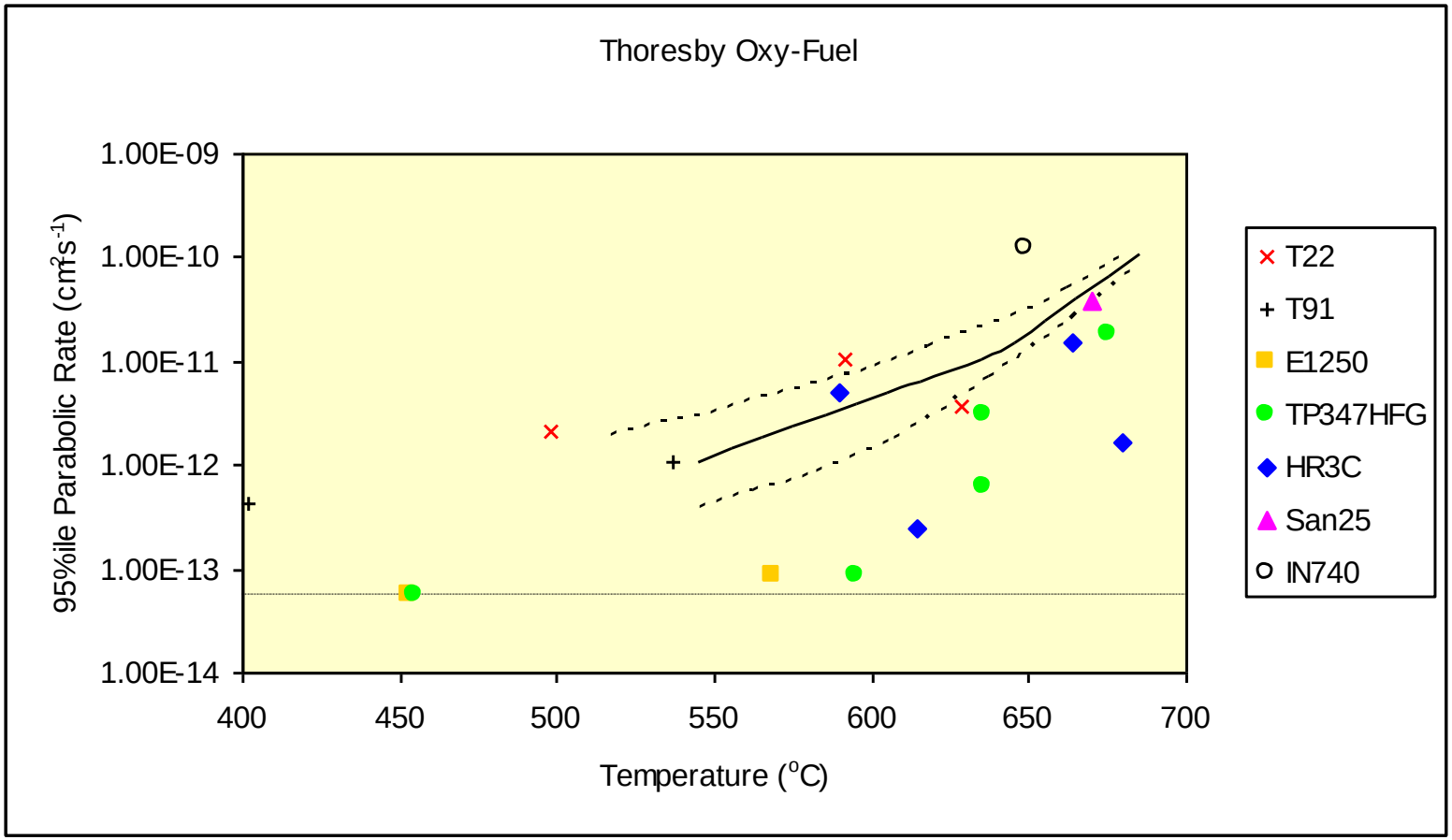
CORROSION - AIR



CORROSION - Low-S/Low-Cl



CORROSION - High-S/High-Cl

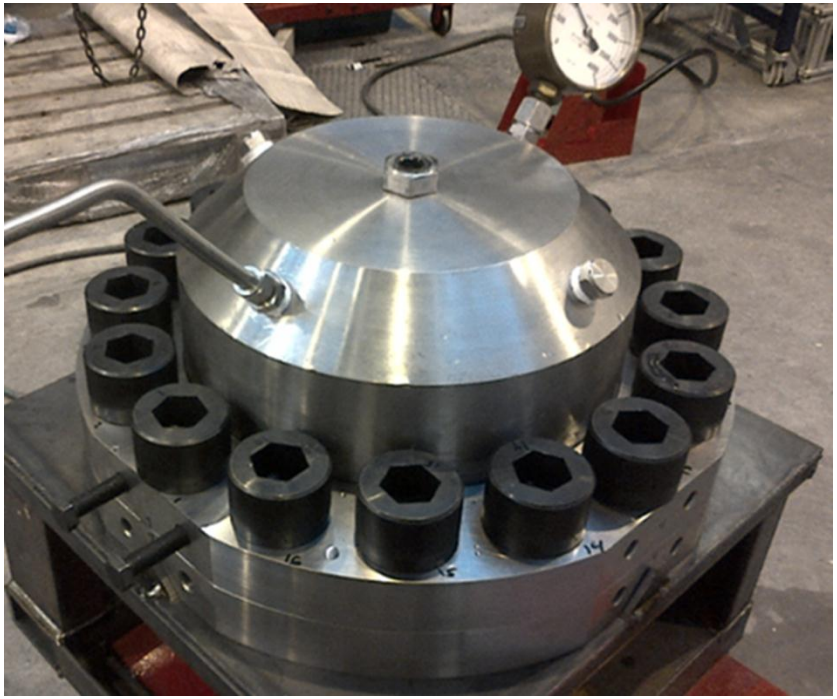


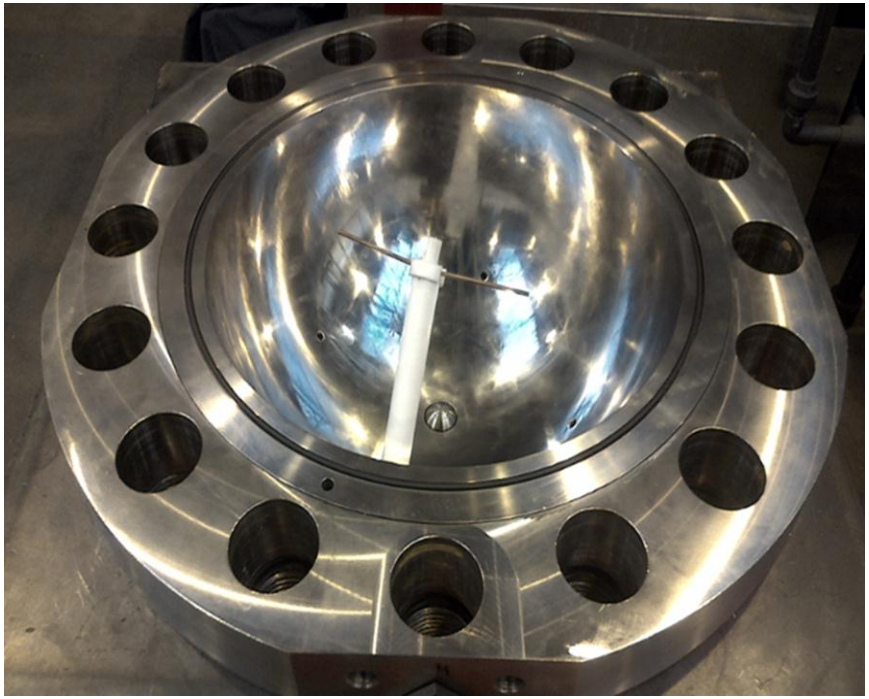
OxyCAP UK R-20 ignition chamber

THE UNIVERSITY of EDINBURGH

Task: ST1-A (P.F. experiments in oxy-combustion)

Goals: a) Determine safe levels of O_2 in O_2/CO_2 in primary recycle (PR).
b) Mill safety.
c) Ignition/combustion fundamentals under oxy-fuel conditions.



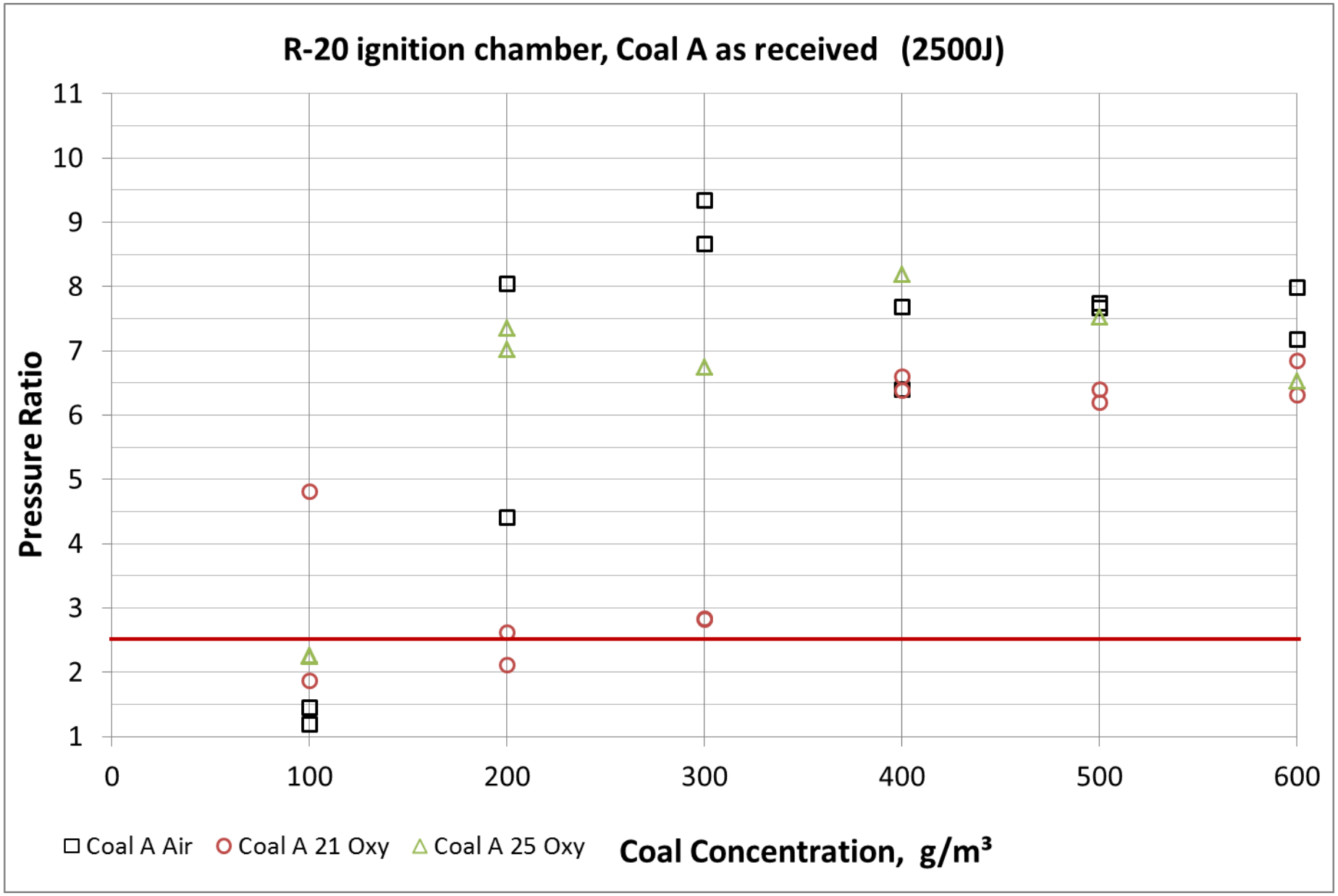


R-20 assembled (left) rated for 50 bar and R-20 bottom half with perforated nozzle (right)

Methodology: Dust ignition tests under oxy-fuel conditions in 20 L chamber.
Peak pressure and dP/dt measurement for positive ignition.

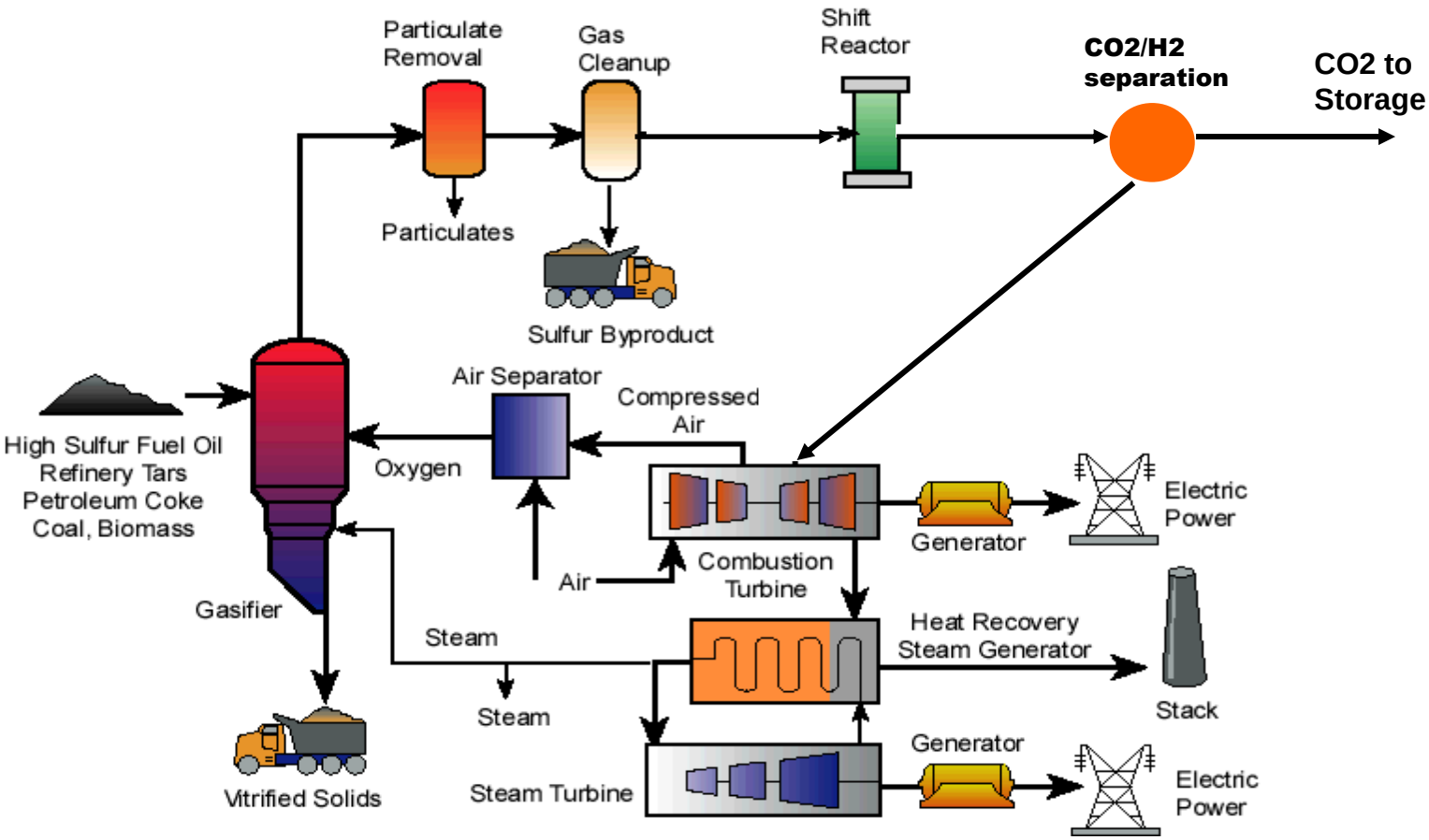
OxyCAP UK R-20 ignition chamber

THE UNIVERSITY of EDINBURGH



Example of Pressure ratio (P/R) values vs coal concentration. Positive ignition when P/R >2.5

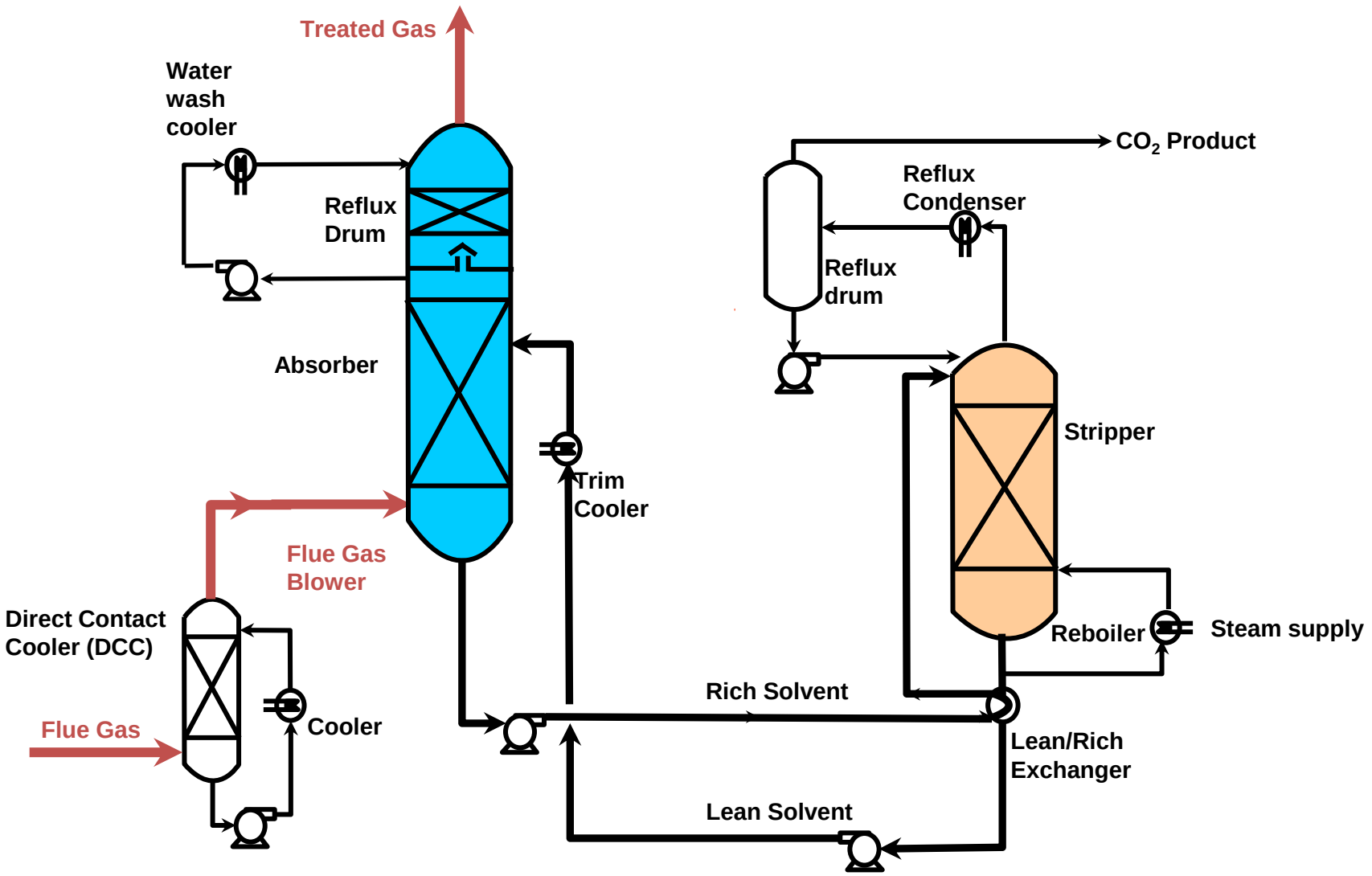
IGCC with CO_2 Capture



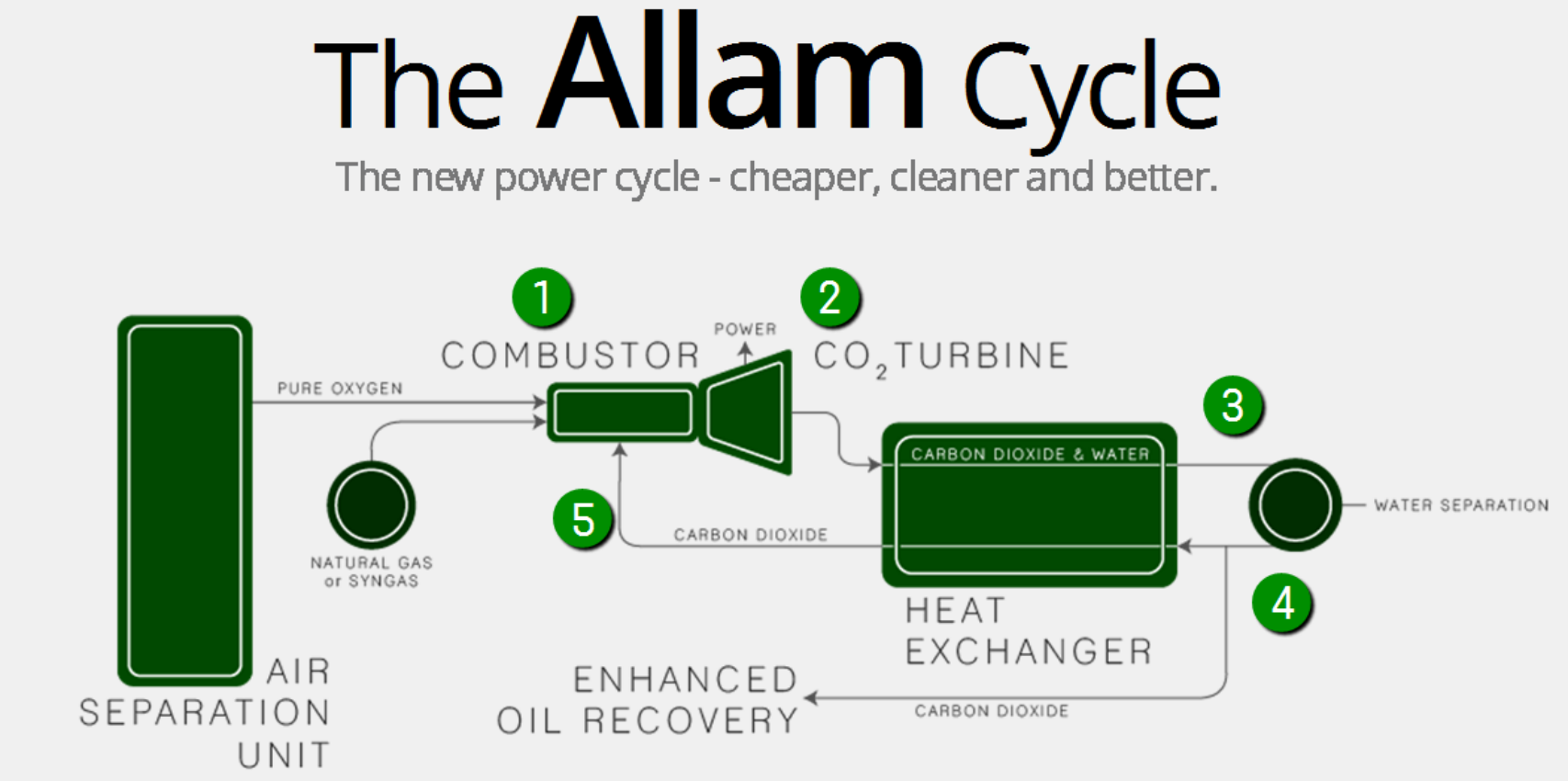
H2 Combustion - Standalone

- Not just an IGCC issue - Possible new energy vector
- Excess Renewable power used for hydrolysis
- Requires GTs or other devices to reconvert to H2
- H2 derived from water, not fossil fuel
- Various scales may be optimal – IC engines, fuel cells, gas turbines – dependent on market drivers

Amine Capture



Novel cycles – e.g. NetPower



Source Netpower website

Aspects of the Allam Cycle

Pure O2 – from ASU
Gas
Bulk flow CO2
High Pressure
High Temperature
High inerts (CO2) concentration
High Efficiency

Emissions – new substances and new regulations

Industrial Emissions Directive

New limits for ‘old’ pollutants

NOx, SOx, Dust (regulatory)

National Ceiling Directive

‘New’ Pollutants

Black Carbon,

PM2.5,

Hg

Reduction Driven by process requirements

NO_2, SO_2, $\mathbf{SO_3}$ (Post combustion carbon capture)

Flexibility

Lower load
Emissions maintained across a wider range of loads
Improved control for faster pickup
Interaction with materials

Conclusions

- The fundamentals of combustion haven’t changed
- The market-place continues to change requiring new innovations as

  - Fuel composition changes – sourcing/blending/regulation/innovation
  - Emissions constraints tighten
  - Operational requirements mean old plants must operate in different ways
  - New Cycles/configurations come to market.

- All offer new RD&D challenges in the field of combustion.