SNCR-Fuel Additive Based Hybrid Technology for Low NO_x Pulverised Coal Combustion

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Objectives

- Briefly discuss NO_x technologies
- Discuss the applicability of Fe-based additives
- Present the findings of an investigation into the combination of selective non-catalytic reduction (SNCR) and Fe-based additives

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The NO_x Problem

- Air quality has become an international health issue
- Nitrogen oxides largely to blame
- Released during combustion-related power generation
- Prominently from coal
- But coal is in decline…
- Or is it?

Johnston, I. (2017) Donald Trump suppressed report into coal mining's risk to public health, accuses world-leading Nature scientific journal. *The Independent. Available at: https://www.independent.co.uk/news/world/americas/us-politics/donald-trump-coal-mining-report-suppress-public-health-nature-journal-science-fossil-fuels-cimate-a7921821.html*

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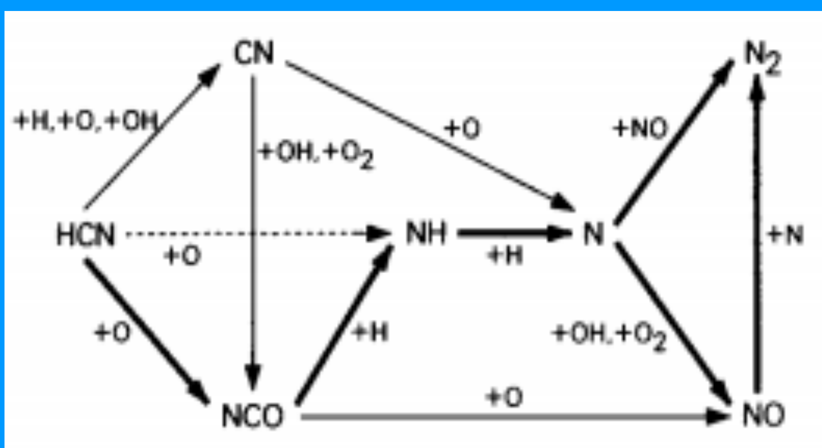
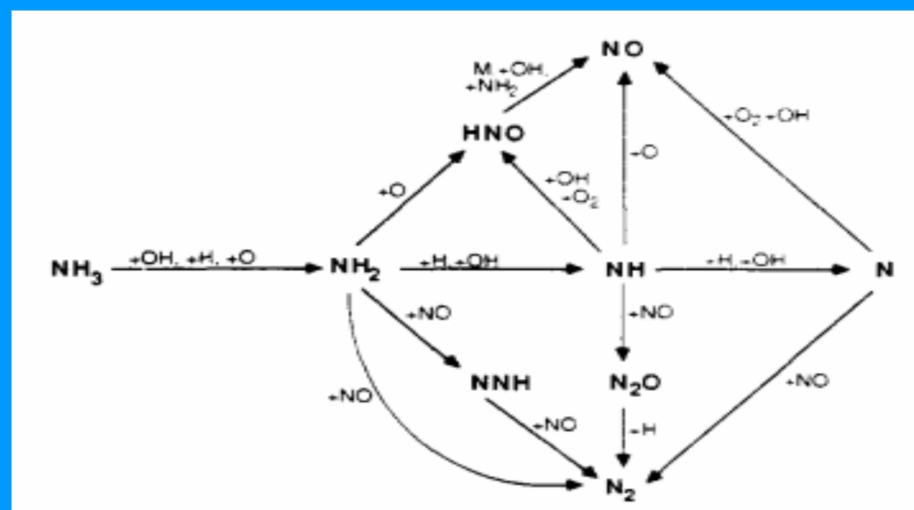
NO_x Formation

- Thermal NO_x
- Prompt NO_x
- Fuel NO_x → Volatile and char oxidation





Miller, J.A., Branch, M.C., McLean, W.J., Chandler, D.W., Smooke, M.D., Kee, R.J. (1985) The conversion of HCN to NO and N2 in H2-O2-HCN-Ar flames at low pressure. *Symposium (International) on Combustion*, 20(1), 673-684.

Miller, J.A. and Bowman, C.T. (1989) Mechanism and modeling of nitrogen chemistry in combustion. *Progress in Energy and Combustion Science*, 15(4), 287-338.

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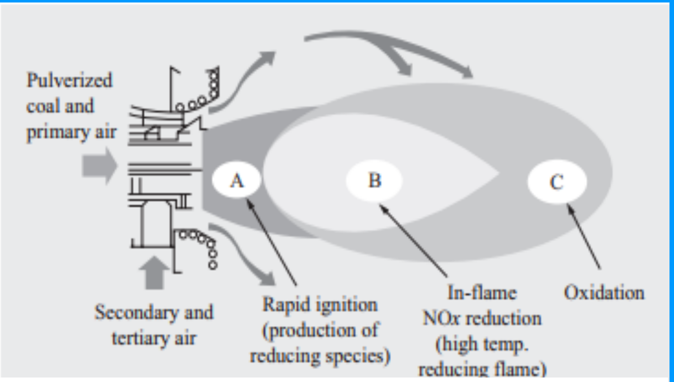
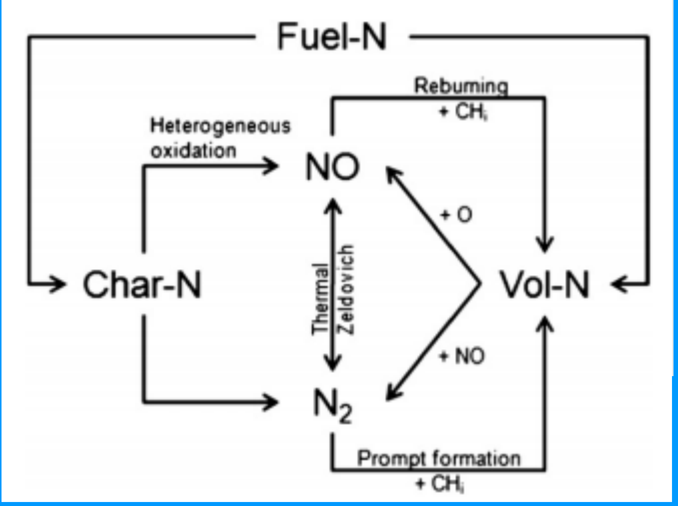
1° NO_x Abatement Options

Ochi, K., Kiyama, K., Yoshizako, H., Okazaki, H., Taniguchi, M. (2009) Latest low-NOx combustion technology for pulverised-coal-fired boilers. *Hitachi Review*, 58(5), 187-193.

- Low NO_x Burners (LNBs)
- Over-fire air (Air Staging)
- Reburning
- Flue gas recirculation (FGR)





Toftegaard, M.B., Brix, J., Jensen, P.A., Glarborg, P., Jensen, A.D. (2010) Oxy-fuel combustion of solid fuels. *Progress in Energy and Combustion Science*, 36(5), 581-625.

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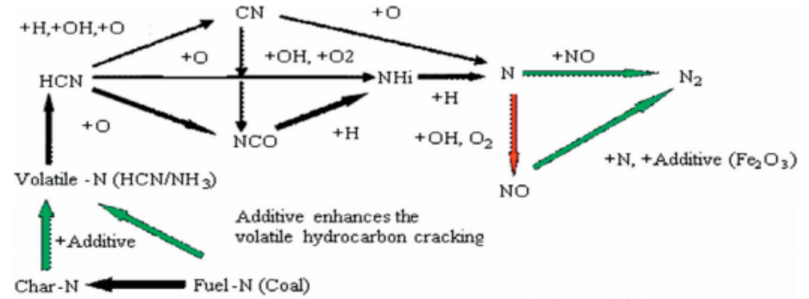
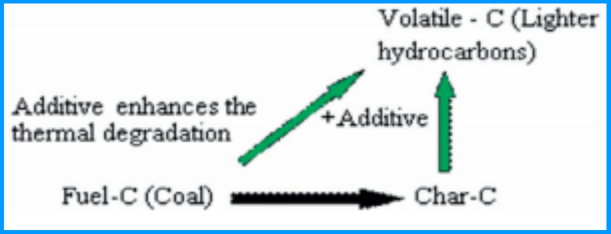
2° NO_x Abatement: SNCR and SCR

- Selective Non-Catalytic Reduction (SNCR) → low cost + moderate NO reduction + moderate risk of ammonia slip
- Temperature range: 875-1175 C
- Selective Catalytic Reduction (SCR) → high cost + high NO reduction + low risk of ammonia slip + subject to fouling
- Temperature range: 150-600 C
- Various catalysts have different properties
- Iron oxide investigated as a fouling-free catalyst

Fe-based Additives

- Iron reacts with NO and CO in the flame in a redox reaction
- Fe-based additive found to increase coal pyrolysis → increasing combustion efficiency + flame temperature
- Influences char/volatile spit → favours volatile split





Daood, S.S., Ord, G., Wilkinson, T., Nimmo, W. (2014) Fuel additive technology – NOx reduction, combustion efficiency and fly ash improvement for coal fired power stations. *Fuel*, 134, 293-306.

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So, can using this additive affect SNCR utilization?

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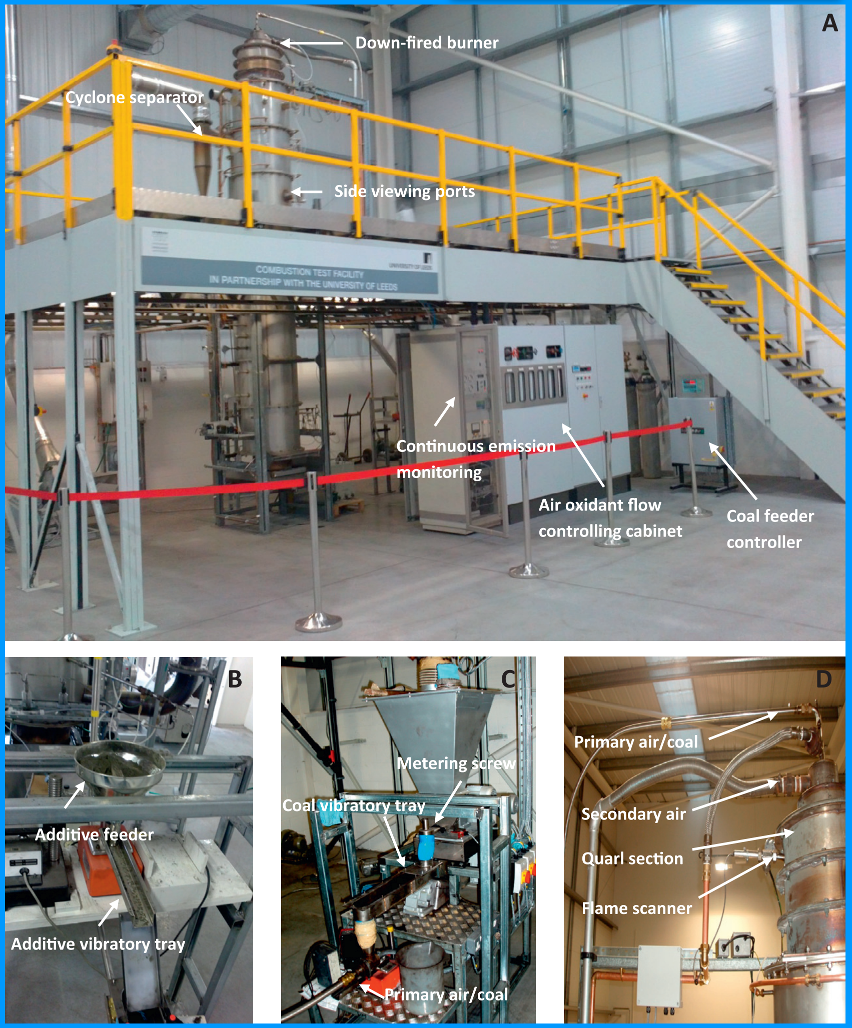
Experimental Setup

- 100 kWth combustion test facility
- Fe-based additive delivered to primary air with coal
- Ammonia, entrained in N_2, injected into section optimised for high NO_x reduction and a low ammonia slip (T=1050 C)
- NO, O_2, CO and CO_2 analysed at flue gas



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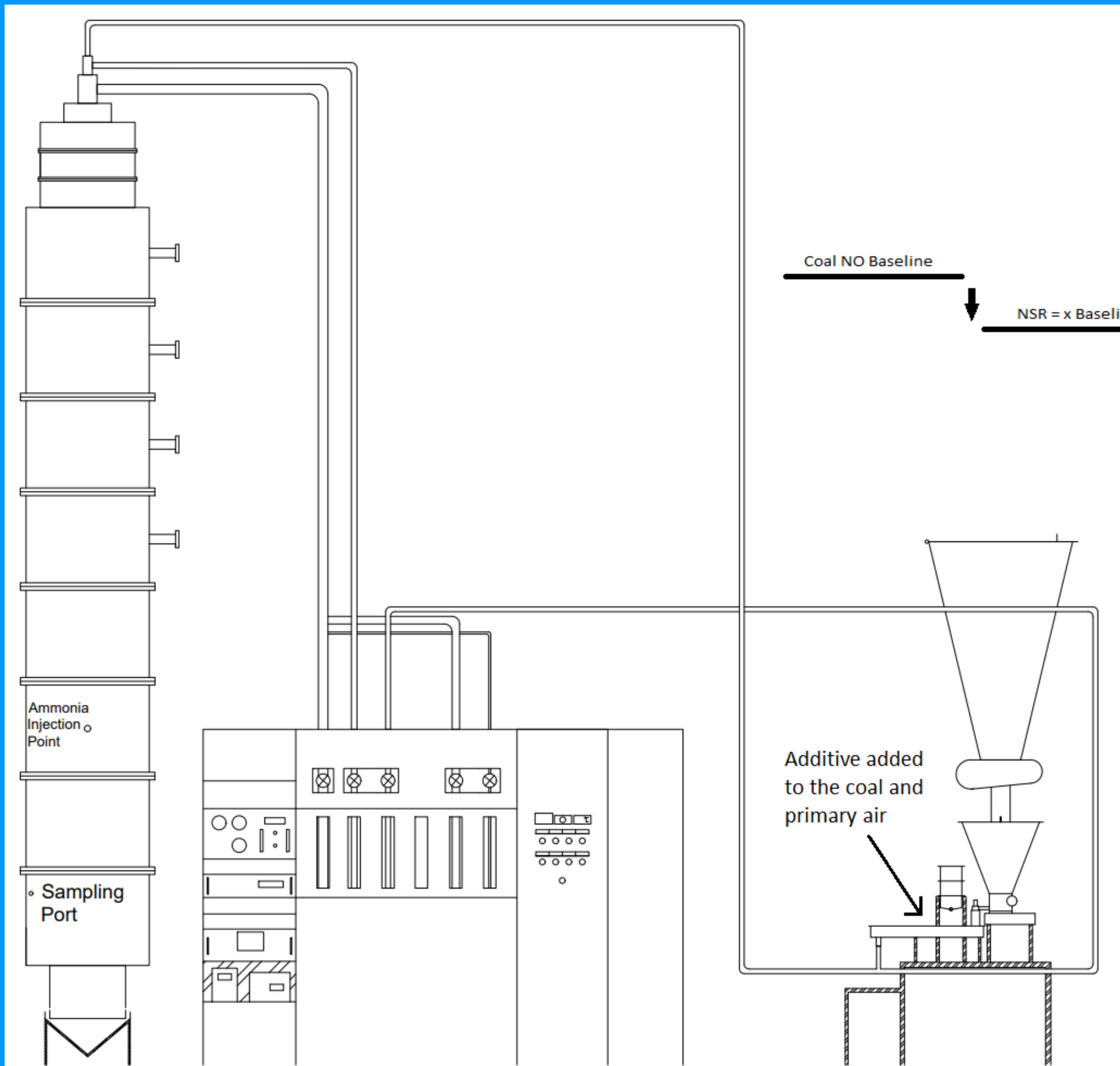
Test Procedure - Conditions



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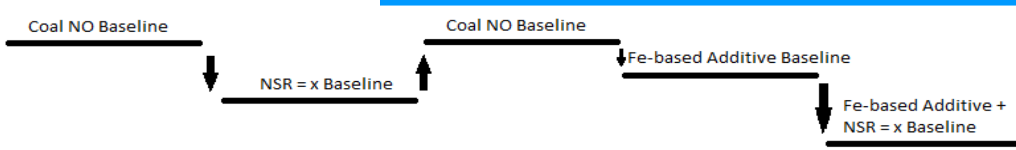
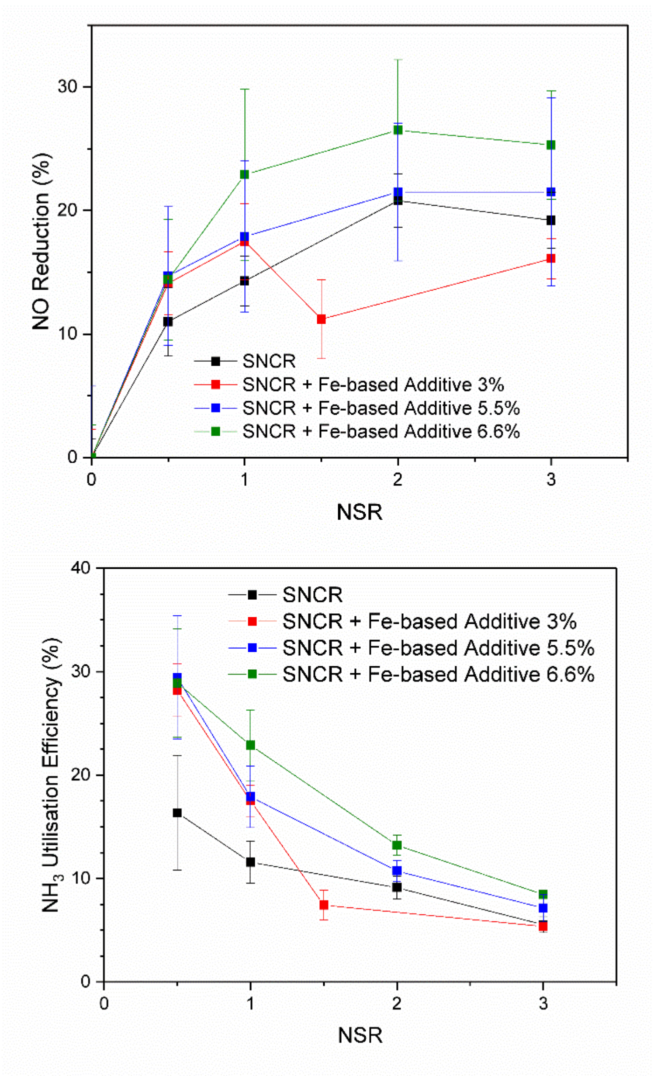


- Coal baseline
- SNCR
- Fe Baseline
- Fe + SNCR

SNCR Effectiveness

- NO reduction due to SNCR increased by up to ~10%
- The amount of ammonia involved in reducing NO increases by over 10% at low NSRs
- Greater amount of Fe-based additive leads to greater ammonia utilisation and hence NO reduction



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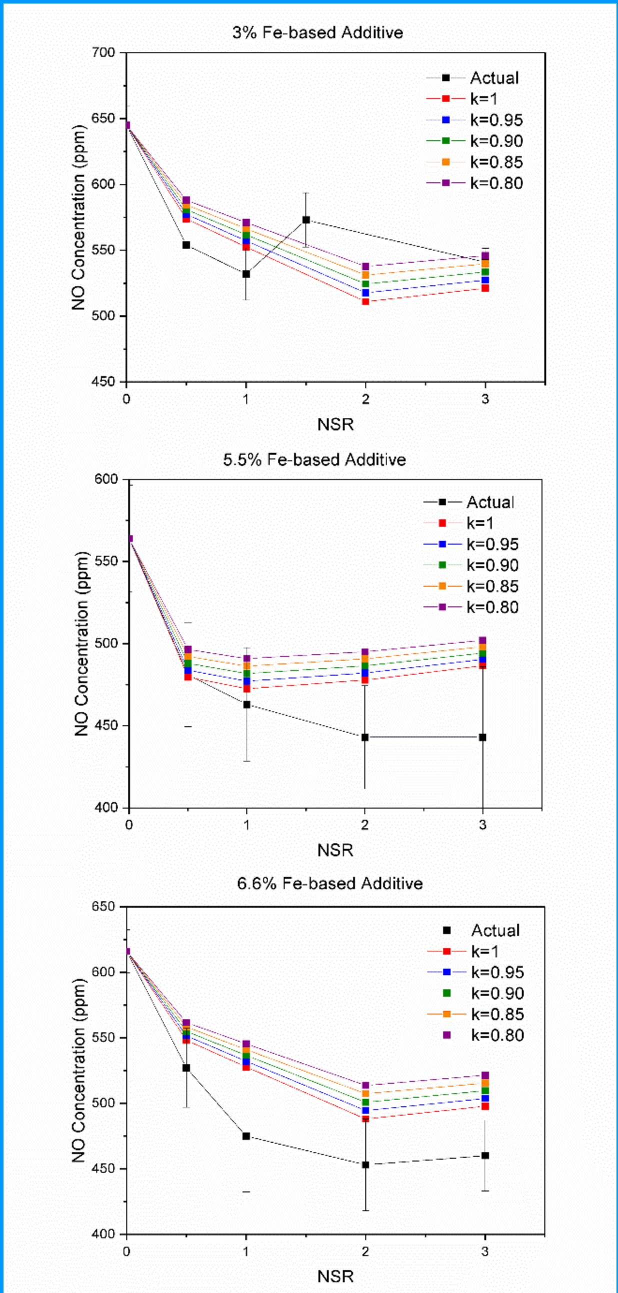
Actual Effect vs Predicted Effect

- SNCR efficiency should reduce with decreasing initial NO concentration
- A coefficient 'k' is used to represent this drop in efficiency
- E.g. k=0.8 → 80% of original SNCR efficiency and k=1 → no drop in efficiency
- When the Fe-based additive is used, there is a lower initial NO concentration
- So NO concentration in the flue gas should be within range of k values
- Instead, SNCR efficiency has increased



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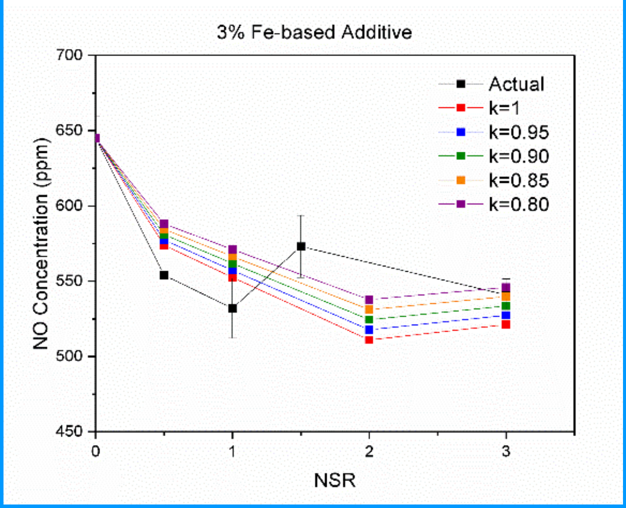
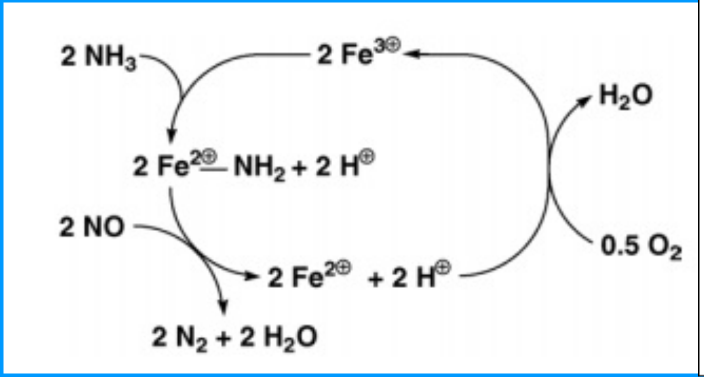
Possible Mechanism for Ammonia-Fe Interaction

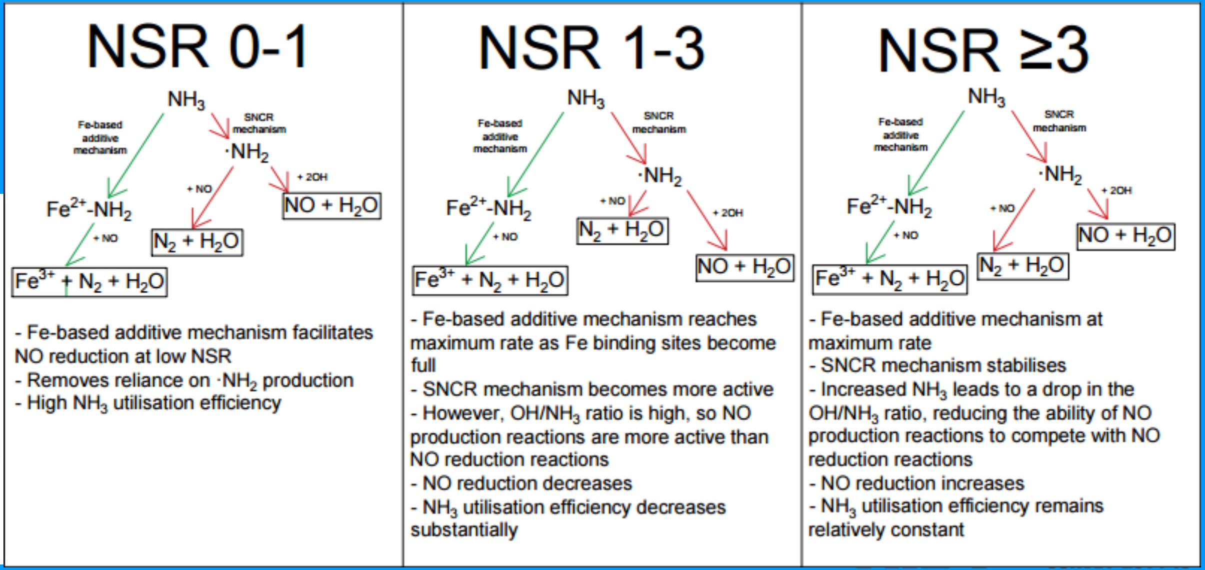
- Iron oxide has been previously tested as a catalyst for SCR
- Fe^{3+} ion acts as a binding site for ammonia
- Facilitating NO reduction by removing reliance on radicals to initiate the SNCR reaction mechanism



Daood, S.S., Yelland, T., Nimmo, W. (2017) Selective non-catalytic reduction – Fe-based additive hybrid technology. *Fuel*, 208, 353-362.

Apostolescu, N., Geiger, B., Hizbullah, K., Jan, M.T., Kureti, S., Reichert, D., et al. (2006) Selective catalytic reduction of nitrogen oxides by ammonia on iron oxide catalysts. *Applied Catalysis B: Environmental*, 62(1-2), 104-114.





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So, what does this mean for operators?

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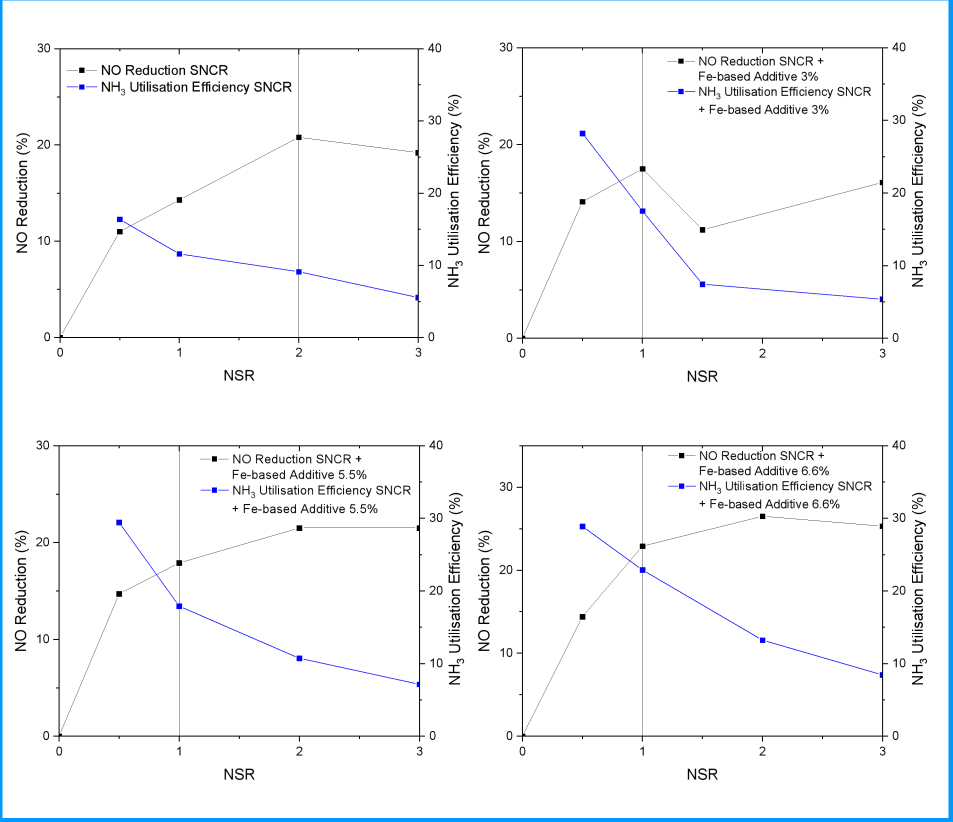
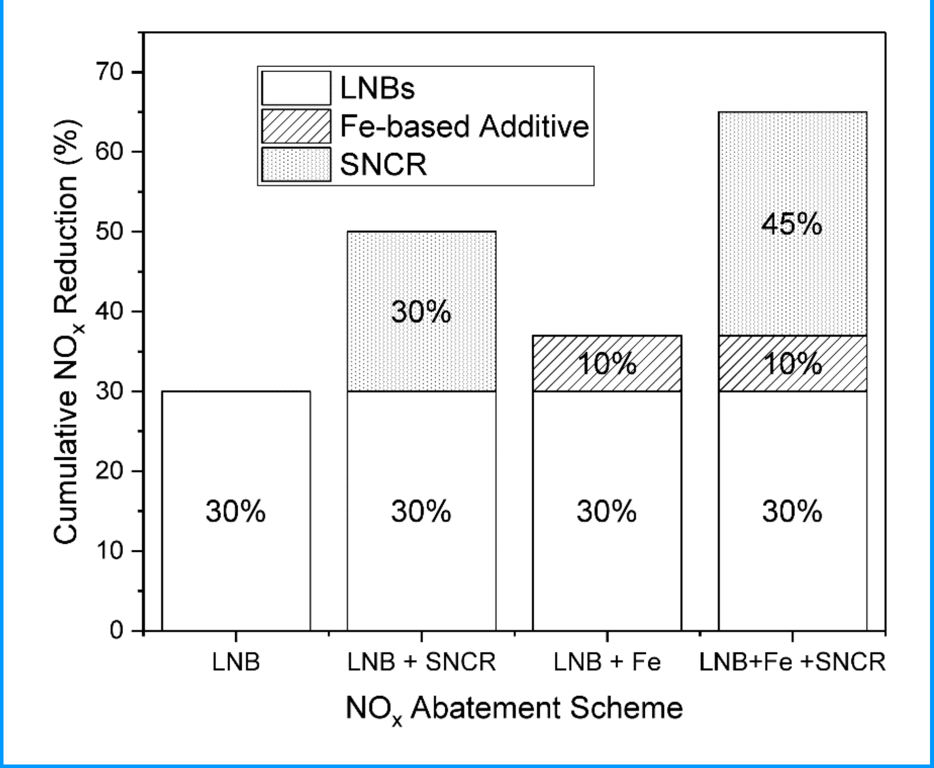
- One option: Reduce ammonia usage and maintain NO reduction
- Or: Maintain ammonia usage and greatly improve NO reduction





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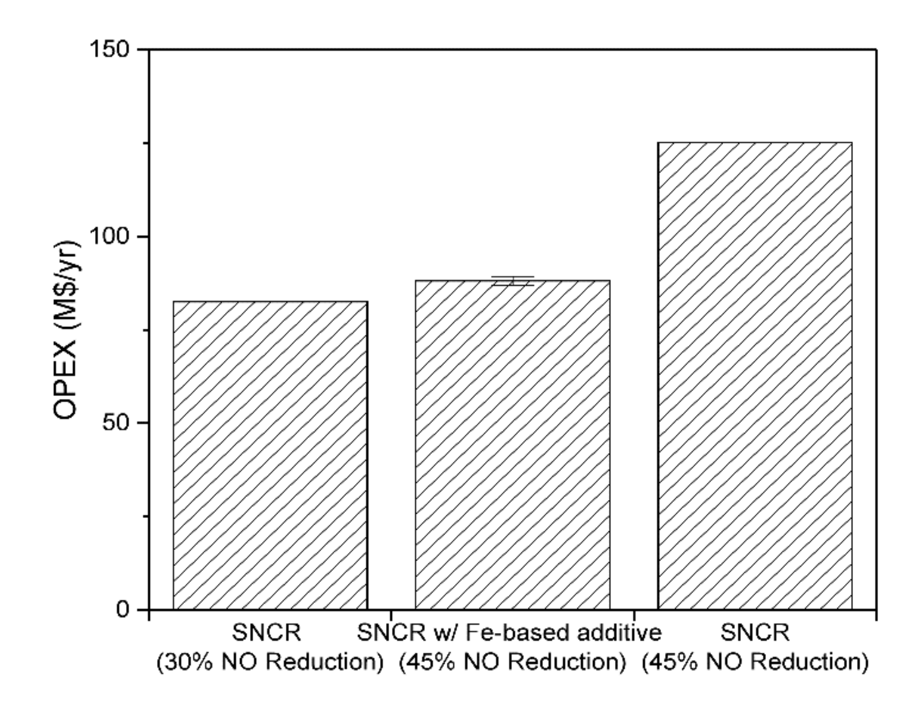
Economic Benefits

Using the Integrated Environmental Control Model (IECM) to calculate the effect on the OPEX of a 650 MW coal power plant when a SNCR's NOx reduction is increased from 30% to 45%:

- Use of the Fe-based additive is far more economically viable (assuming a cost of £45/ton) than increasing ammonia usage



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Thanks for listening!

Any Questions?