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The impact of multifunctional additives on NO_X emissions and bed agglomeration in fluidized bed combustion of biomass

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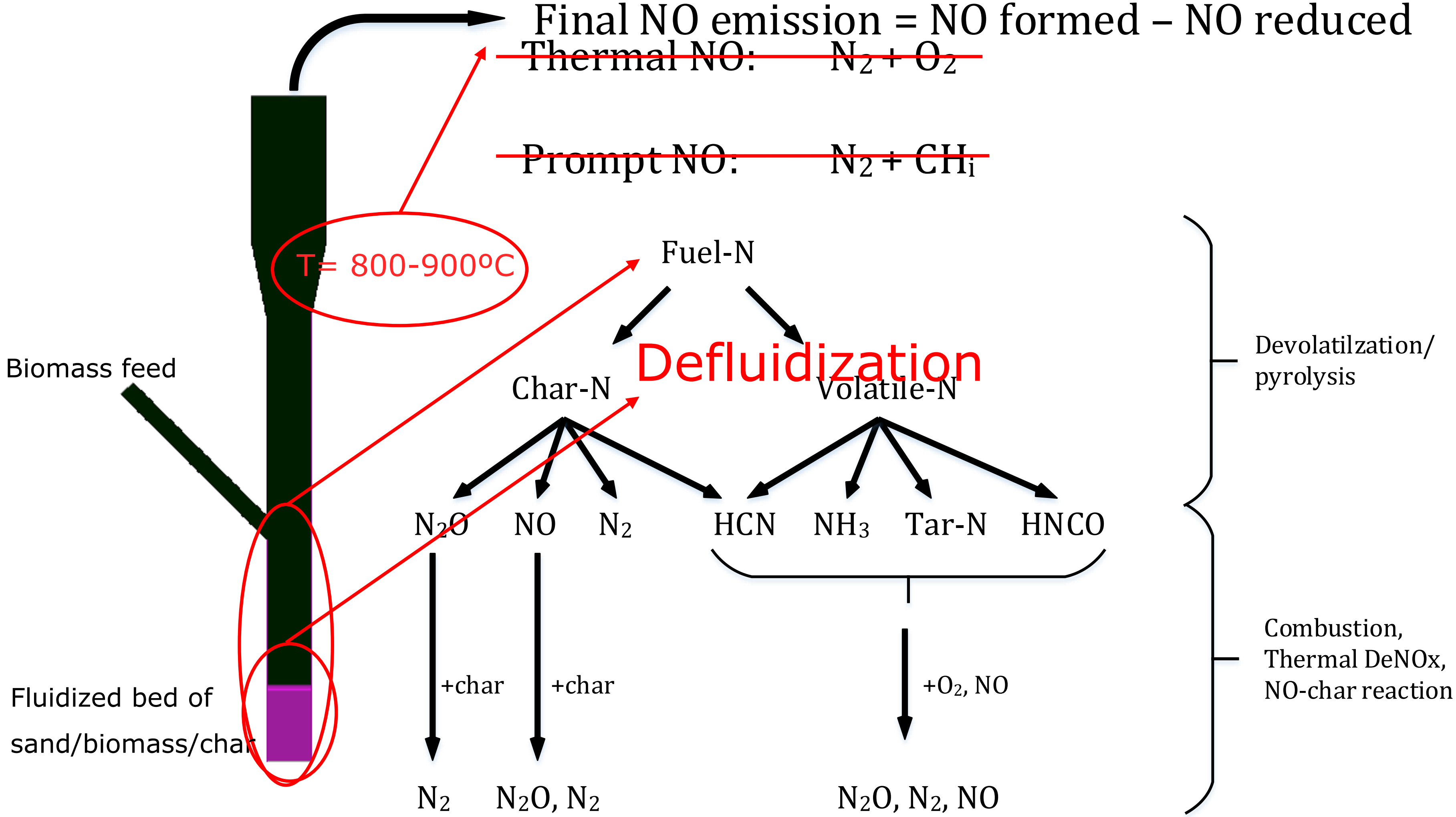
Brief background

Fuel NO: Fuel-N + O_2

Final NO emission = NO formed – NO reduced



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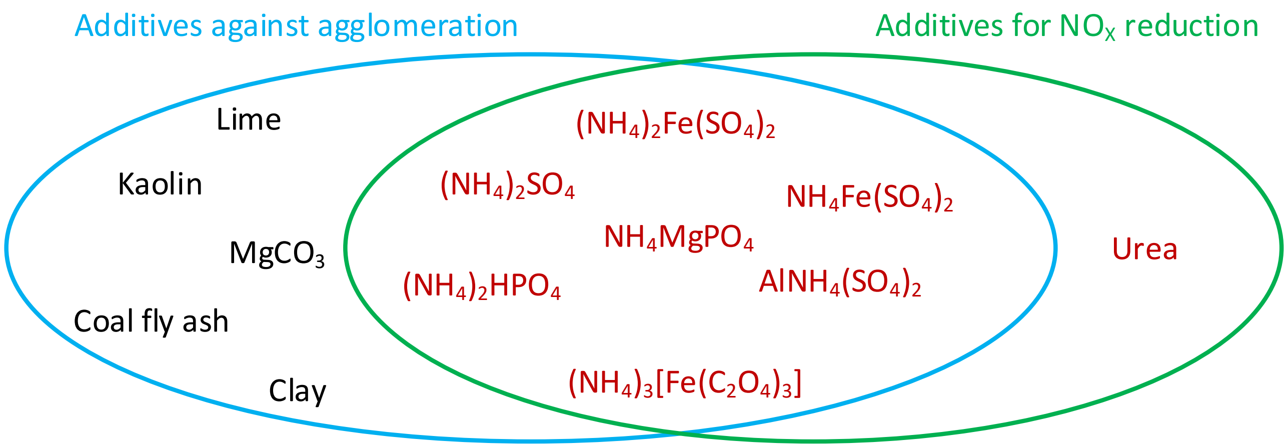
Objectives

- Investigate the impact of multifunctional additives on NO_X emission and bed agglomeration



Experiments including probe + FTIR

- Influence of
  - Additives NH_4MgPO_4 and $NH_4Al(SO_4)_2$
  - Fuel type: Straw and sunflower husk
  - Air staging: $\lambda_{primary\ gas}/\lambda = 1$ and 0.5
  - Additive particle size: $(NH_4)_2SO_4$: <45 and <106 μm

Materials

- Straw dry, pre-mixed with additives
- NH_3/fuel-N = 1.5
- Additives without NH_4 functionality: 4.7 g/100g straw

	Unit	Wheat straw
Moisture	% (wb)	12.5
Volatile matter	wt% (db)	76.5
Ash		4.6
N		**0.69**
C		48.7
H		5.8
O		40.2
Cl		0.18
S		0.08
Al	mg/kg (db)	230
Ca		3600
Fe		180
K		**8000**
Mg		630
Na		280
P		750
Si		11000
Ti		17

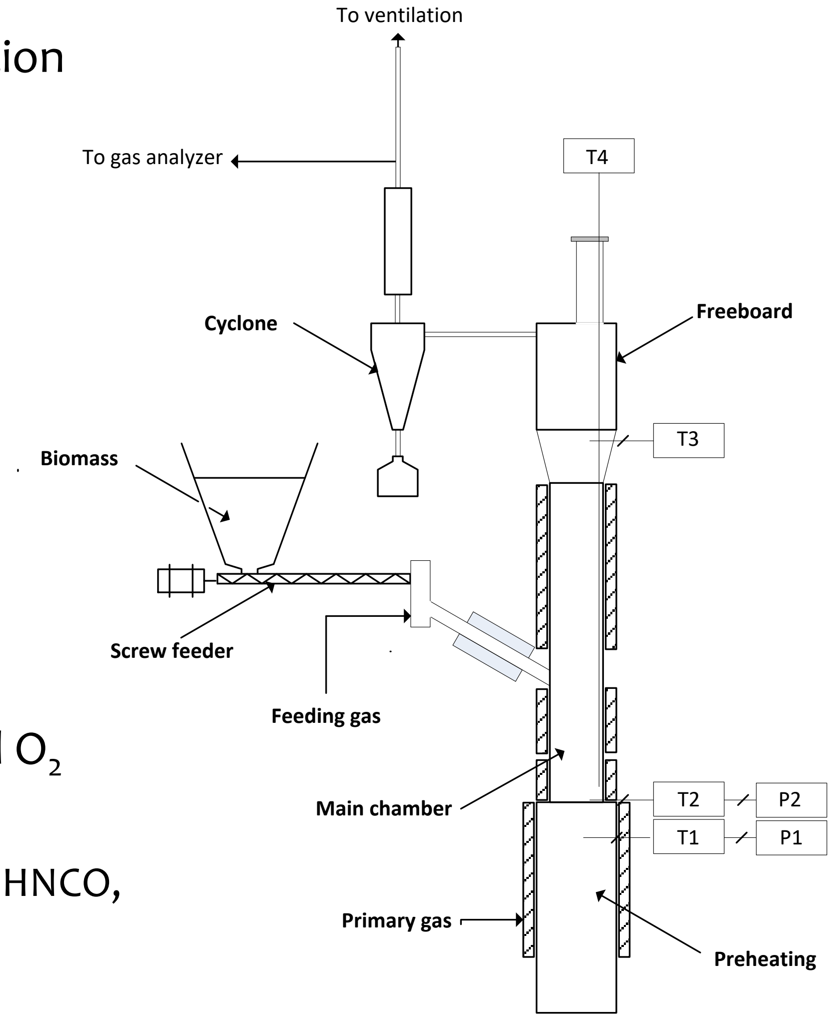
Experimental setup

- Bubbling fluidized bed reactor for combustion

Standard conditions

Parameter	Value
Bed temperature	850°C
u_g/u_{mf}	4
Primary gas flow	11.5 NL/min air
Feeding gas flow	15.5 NL/min N2
Silica sand bed	500 g, 10 cm static bed height, D_{50} 273 µm (Geldart B)
Excess air ratio	1.4
Fuel particle size	0.6 – 4 mm
Additive size	<106 µm

- Ex-situ gas measurement: NO, CO, CO_2, and O_2
- Water cooled sampling probe + FTIR:
  - In situ measurements of: CO, NO, NO_2, NH_3, HNCO, N_2O etc.



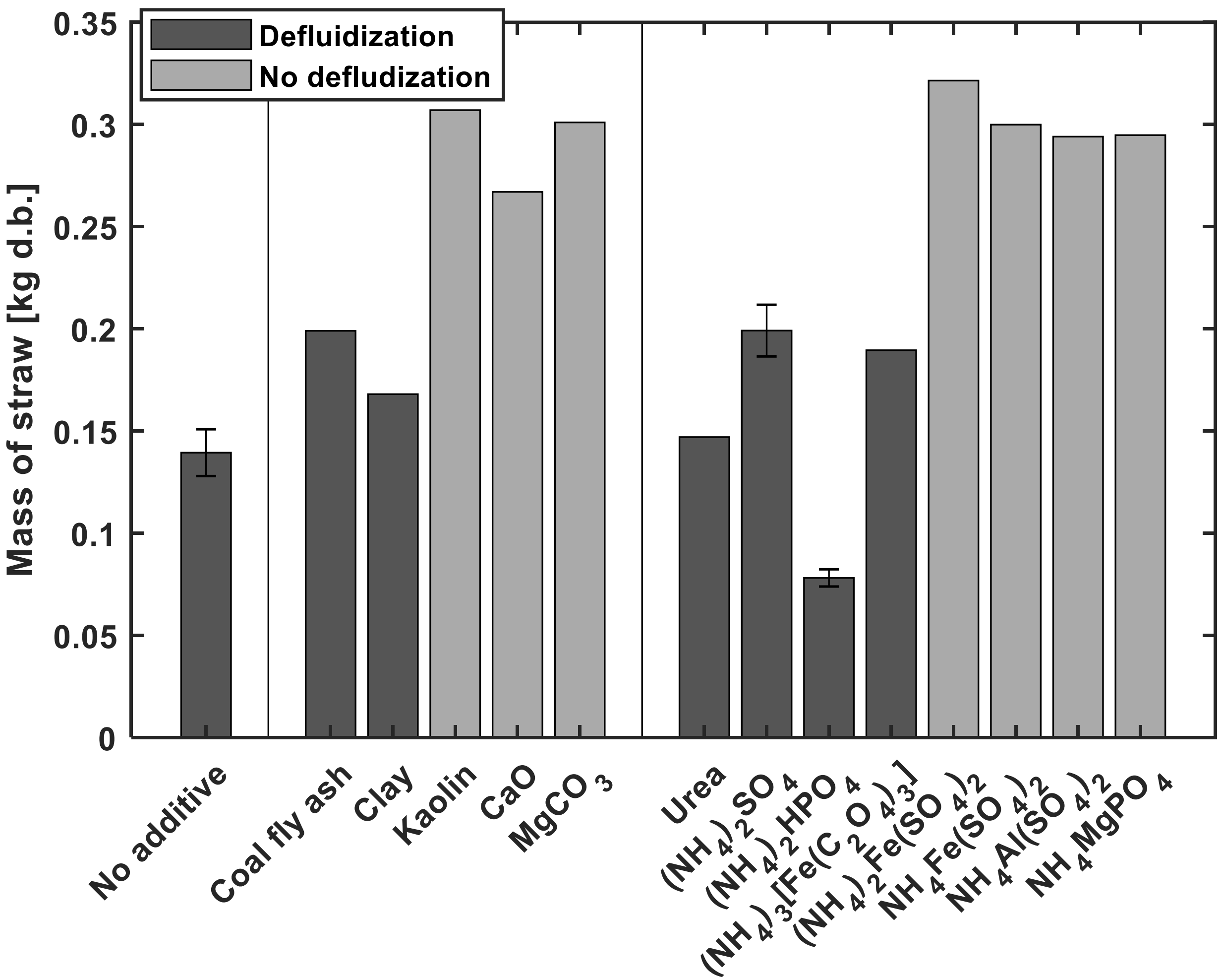
Example video – straw combustion

Initial

Defluidization

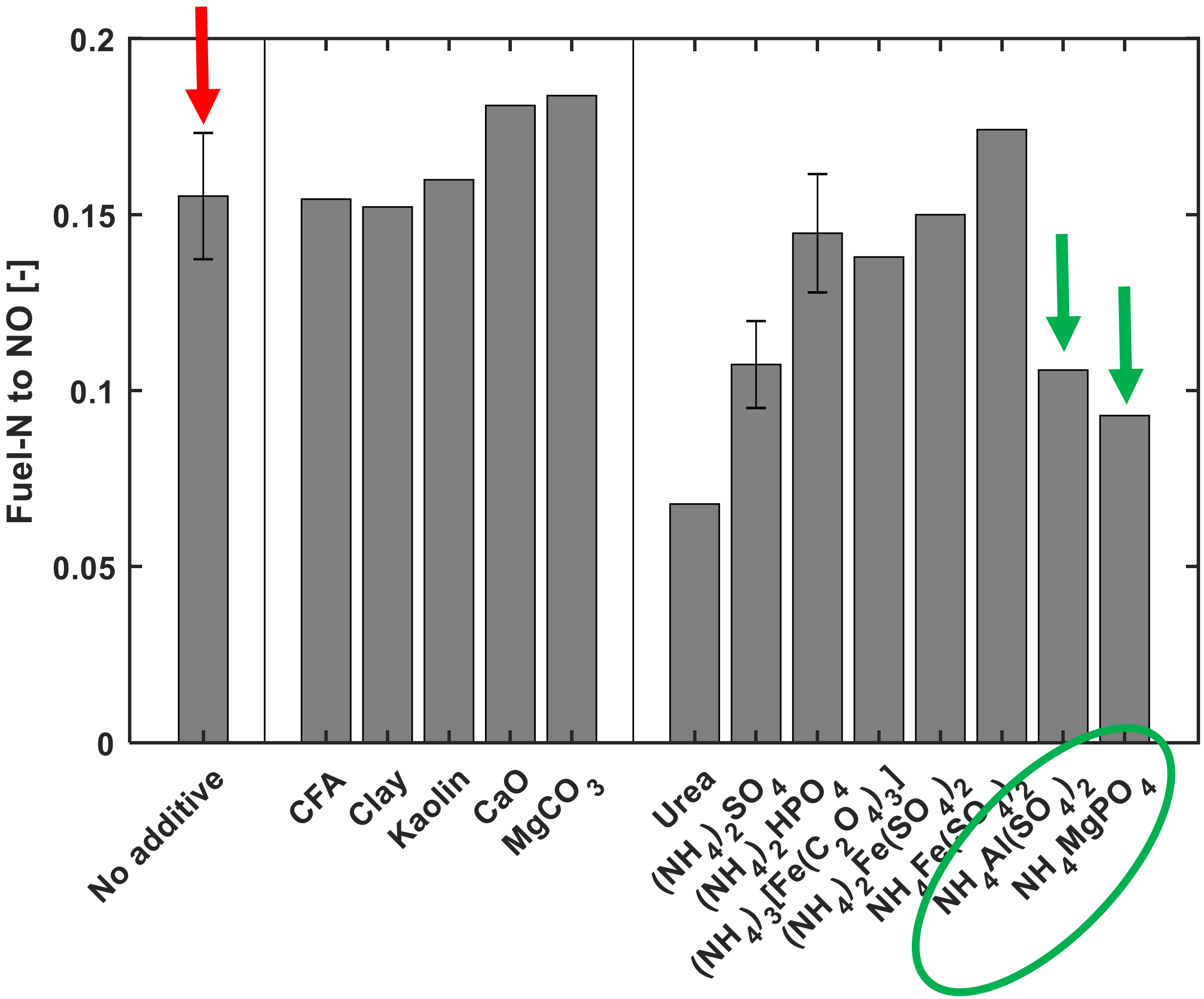
Steady state

Defluidization tendency – straw, unstaged



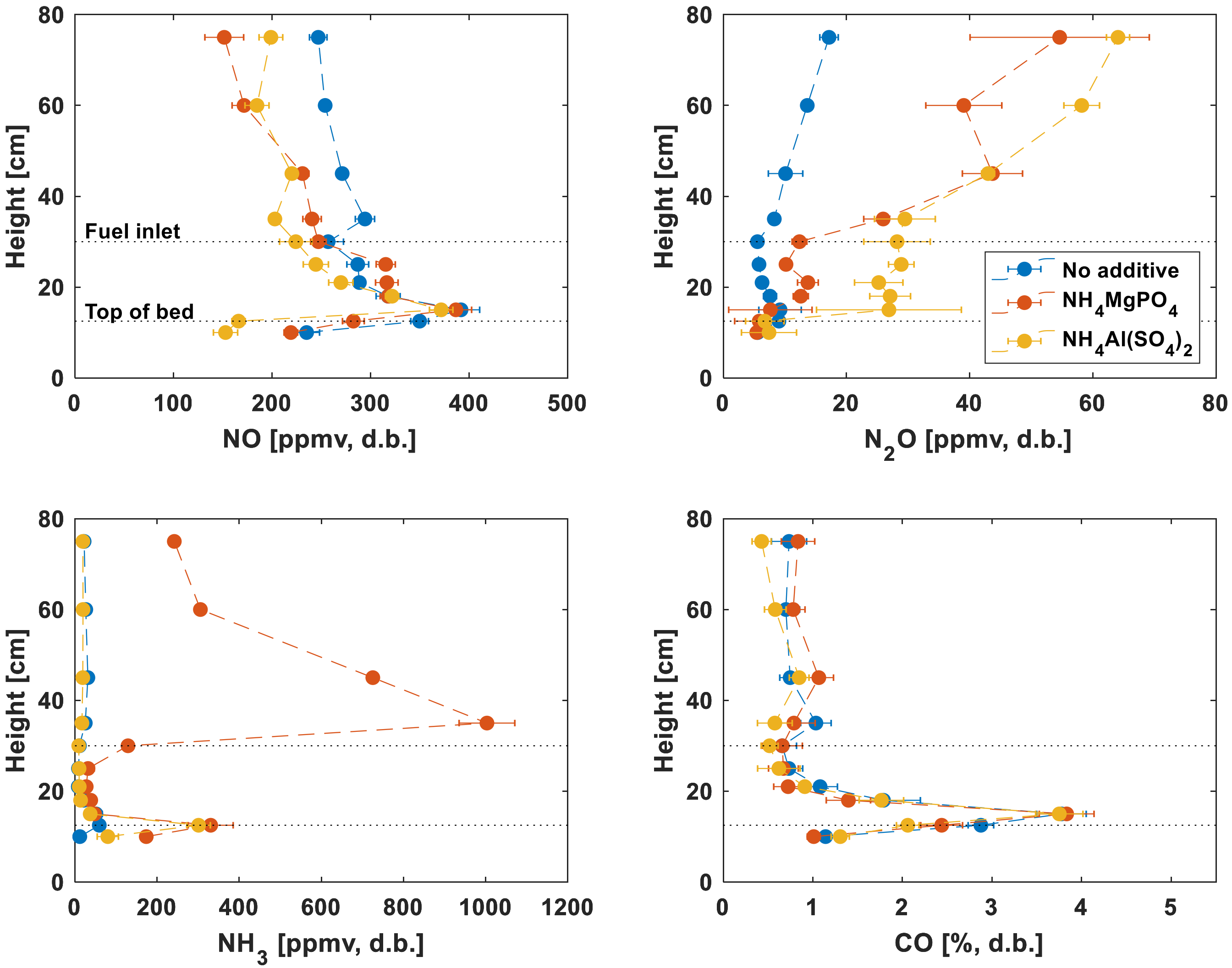
- NH_4 based additives that prevent defluidization
  - $(NH_4)_2Fe(SO_4)_2$
  - $NH_4Fe(SO_4)_2$
  - $NH_4Al(SO_4)_2$
  - $(NH_4)_2MgPO_4$
- Metal additives that prevent defluidization
  - Kaolin
  - CaO
  - MgCO3

Fuel-N to NO – straw, unstaged



- NH_4 salt necessary to reduce conversion of fuel-N to NO
- Additives that reduce fuel-N to NO conversion and prevent defluidization
  - $NH_4Al(SO_4)_2$
  - NH_4MgPO_4

Concentration profiles



- NO and CO peaks and declines in the freeboard
  - Reduction primarily by CH_i and CO
- Inhomogeneous distribution in bed
  - Turnover of fuel
- NH_3 release from additives → Thermal $DeNO_X$
  - Above fuel feeding
  - Top of bed
- Explanations for increase in N_2O
  - NH_i + NO/NO_2
  - Other gaseous compounds (HCN not measured)

Conclusions

- NH_4 salts can influence **both agglomeration tendency and NO_X chemistry** when dry mixed with fuel during continuous fluid bed combustion

- NH_4MgPO_4 and $NH_4Al(SO_4)_2$ **prevented defluidization** and **reduced the conversion of fuel-N to NO** during **straw combustion**

- NH_4MgPO_4 and $NH_4Al(SO_4)_2$ released NH_3 above the fuel inlet and/or the fuel bed, thereby reducing NO by **thermal $DeNO_X$**

Questions and suggestions are most welcome