Chemical–Looping Combustion- A New CO_2 Management Technology

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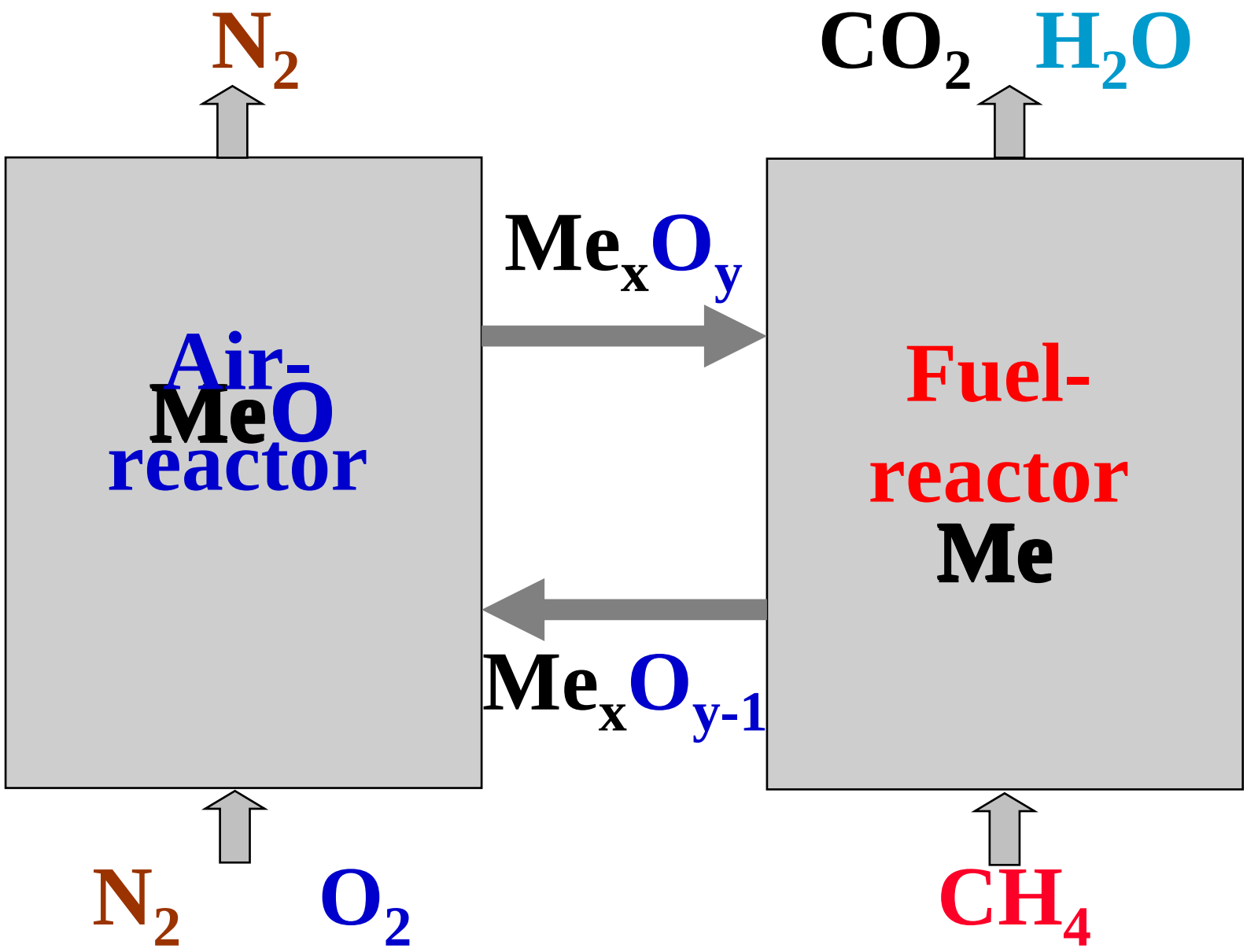
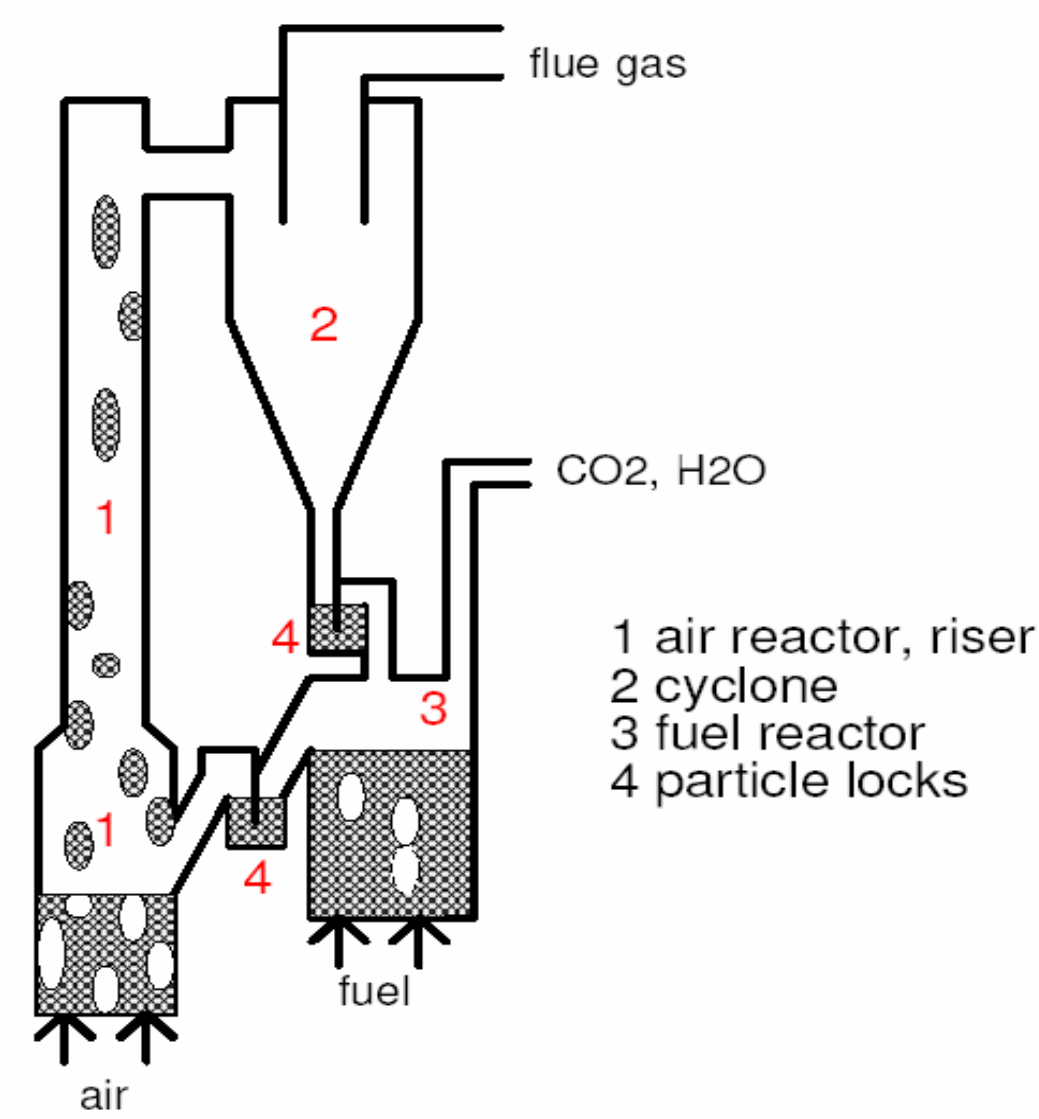
Chemical-looping combustion (CLC)

- Fuel is oxidized using metal oxide as an oxygen carrier, which transfers oxygen from combustion air to the fuel

- Fuel and air are not in direct contact ➔ pure stream of CO_2 is obtained without need of extra energy or any new separation equipment


N_2
CO_2 H_2O
Me_xO_y
Air-
MeO
reactor
Fuel-
reactor
Me
Me_xO_{y-1}
N_2 O_2
CH_4


flue gas
2
CO2, H2O
1
4
3
1 air reactor, riser
2 cyclone
3 fuel reactor
4 particle locks
1
4
fuel
air

Properties of oxygen carriers

- Able to convert fuel to CO_2 and H_2O (ideal 100%)
- High reactivity with fuel and air
- Low attrition rate and tendency against agglomeration
- Cheap and environmentally friendly

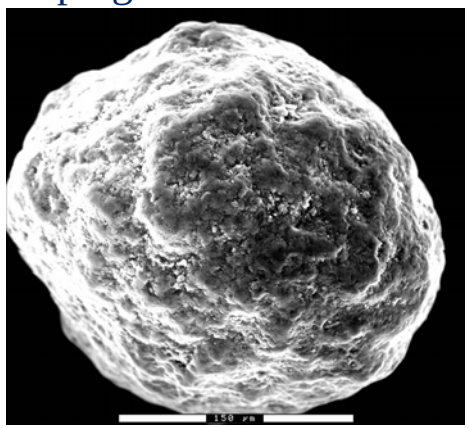
CLC status 2002

- It was a paper concept
- Never been tested
- Only a limited number of particles were tested for limited number of cycles

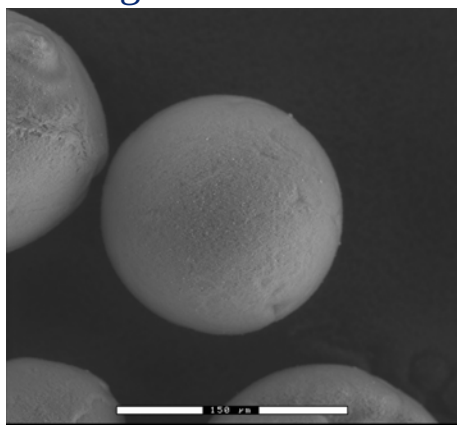
Oxygen carriers particles

- Active metal oxides: NiO, CuO, Fe_2O_3, Mn_3O_4
- Support materials: Al_2O_3, SiO_2, TiO_2, ZrO_2 and $MgAl_2O_4$

Impregnated



Freezegranulated



- > 300 particles have been tested
- MeO/inert ratio, production method, sintering temperature

Pros and cons for the active oxides

	Fe	Mn	Cu	Ni
Reactivity	--	-	+	++
Cost	++	+	-	--
Health				-
Thermodynamics				-[1]
Reaction with CH_4			+[2]	
Melting point			-[3]	

[1]maximum conversion 99-99.5%
[2]exothermic reaction in fuel reactor
[3]melting point Cu: 1085 °C

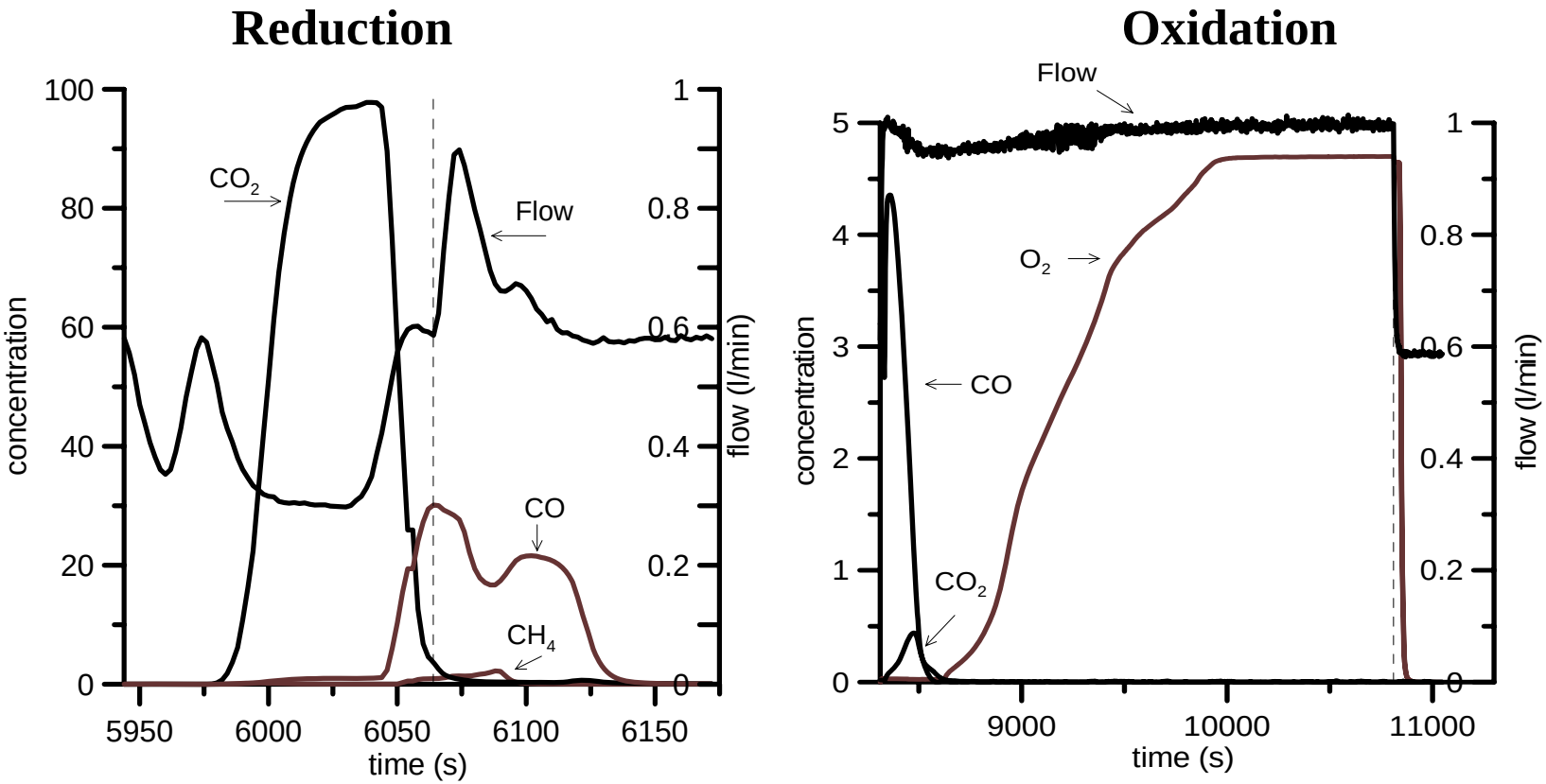
Investigations in batch laboratory reactors

- Fluidized bed reactor
- TGA (Thermogravimetric analyzer)

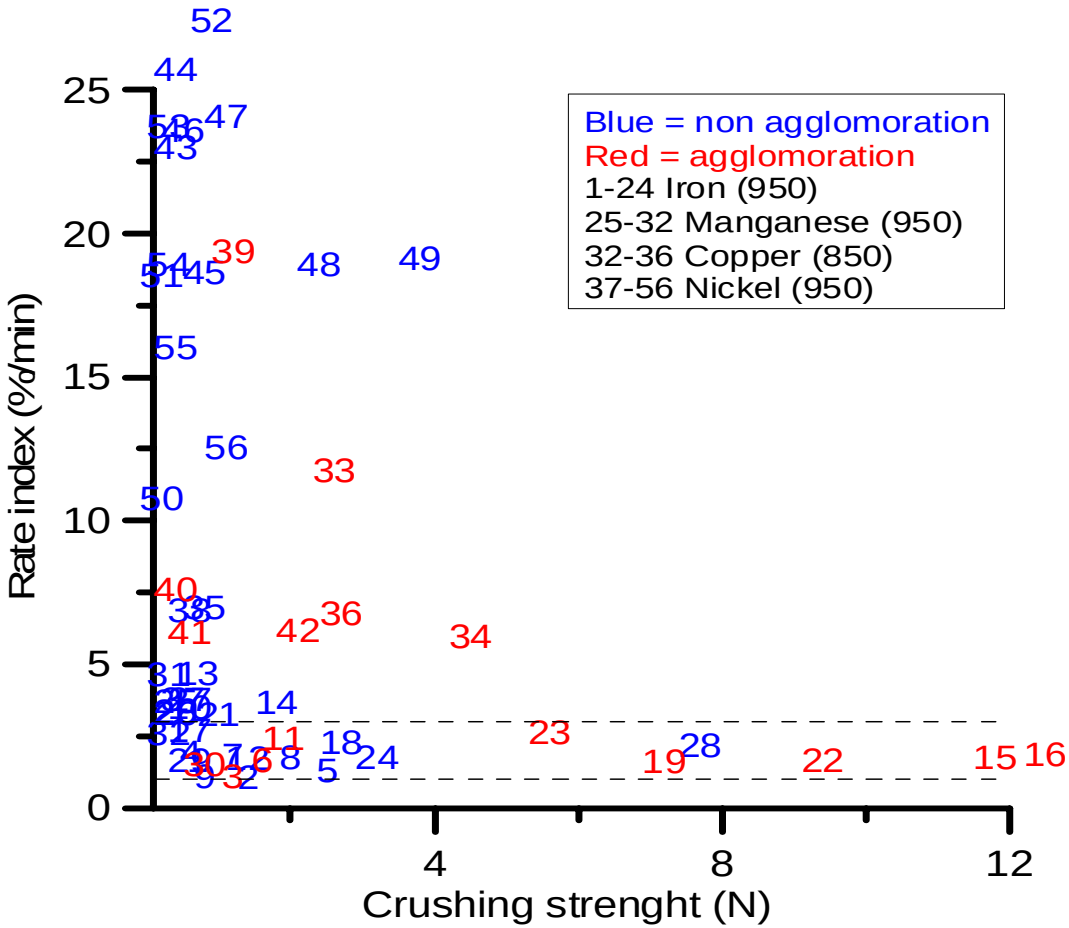
- Particles are exposed alternatingly to fuel and air in laboratory batch reactors

- Fuel: CH_4 and syngas (CO/H_2)
- Temp: 650-950 °C

Outlet gas concentration profile from fluidized bed reactor using $NiO/NiAl_2O_4$ at 950°C

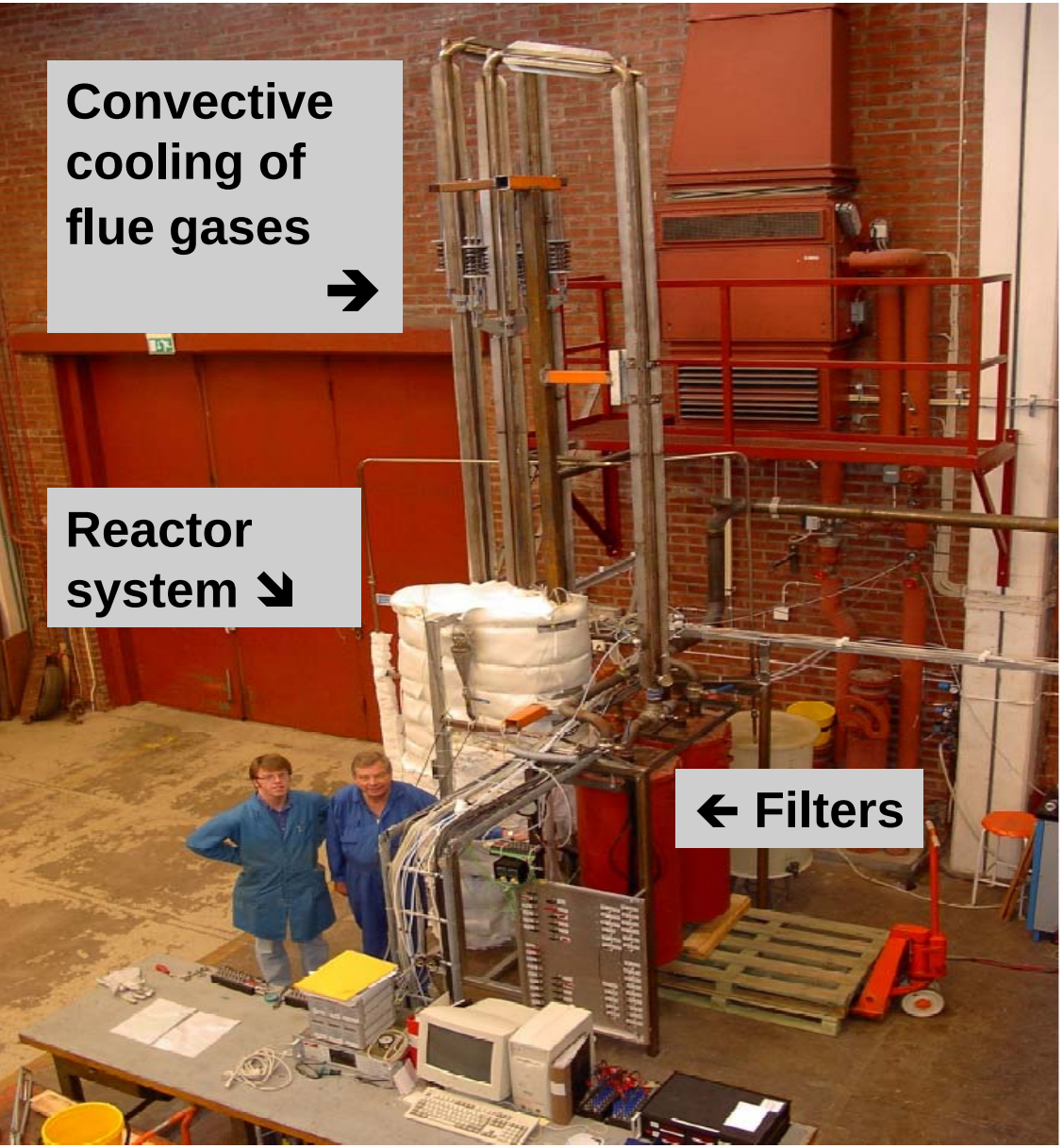


Rate index as a function of crushing strength



Summary (laboratory reactors)

- A large number of oxygen carriers have been tested at Chalmers using different fuels
- In general Ni- has the highest reactivity with methane compared to Mn and Fe-based oxygen carriers
- For syngas Mn and Fe-based particles showed promising reactivity
- Of the 300 oxygen carriers particles tested in laboratory , many are feasible for CLC with respect to reactivity, crushing strength and fluidization behaviour



Chalmers

10 kW Chemical-looping combustor 2003

Conclusions:10 kW unit (Ni-based carrier)

No CO_2 from air reactor →

- No leakage between reactors
- No significant carbon formation
- 100% CO_2 capture

- Almost pure CO_2 possible
  1.2% H2, 0.6% CO with NiO
- Conversion of fuel: 99.5% at 800°C

Operation

- Stable and easy to control
- 105 h operation CLC (13 days) without change of particles
- ~300 h circulation

Investigation of particles after 105 h

- No loss in reactivity
- No loss in particle strength
- Loss of fines very low:
- Particle lifetime >40,000 h (?)

Low particle cost:

- <1 €/ton CO_2 (lifetime 4,000 h)

300 W Chemical-Looping Combustor, 2004

$NiO/MgAl_2O_4$ (40 h)

$Mn_3O_4/Mg\text{-}ZrO_2$ (70 h)

Fe_2O_3/Al_2O_3 (40 h)

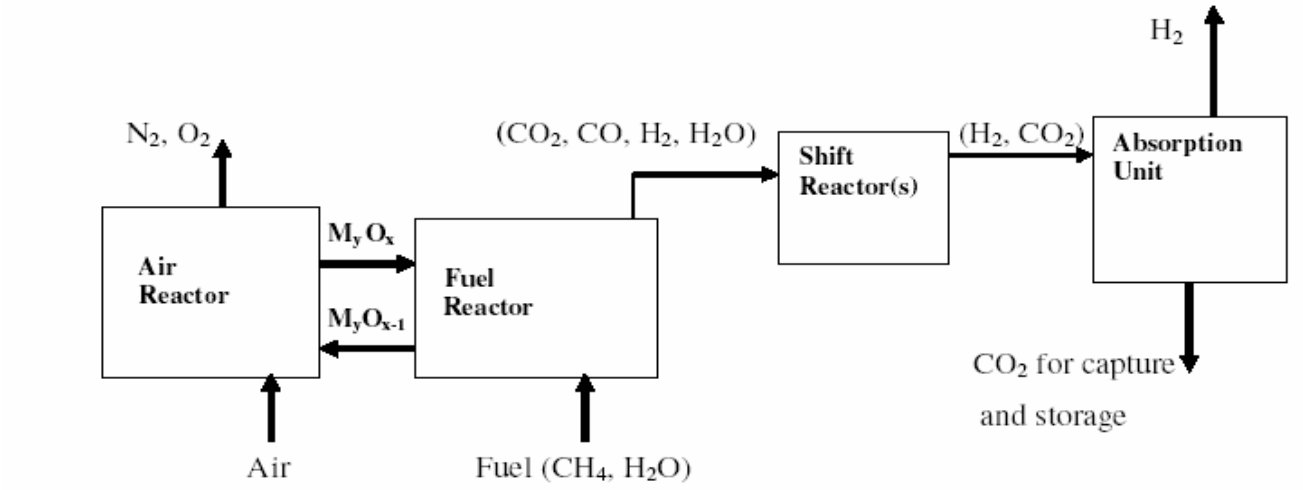
Fuel: CH_4 and Syngas

Temp: 800-950°C

- almost complete fuel conversion
- No loss in reactivity
- No agglomeration

Other applications of CLC

- H_2 production (chemical-looping reforming)



- Combustion of solid fuels e.g. coal and pet coke

Summary

CLC Reactor system (fluidized beds):

- Well established
- Commercially available
- simple
- Moderate costs

Oxygen carriers

- Very encouraging results
- Scale up of particle manufacture
- Raw materials
- Long term testing is needed

Thank you very much

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