Résumé of the 10-year joint development program of BASF, Linde and RWE Generation at the post-combustion capture pilot plant at Niederaussem –

\( \text{OASE}^\text{®} \text{blue: } 2.5 \text{ GJ/t}_{\text{CO}_2}, <300 \text{ g}_{\text{solvent}}/\text{t}_{\text{CO}_2}, \text{effective emission control} \)
The holistic approach of the development program

10 years of development

Solvent screening, Mini Plant testing

Construction pilot plant at Niederaussem

MEA benchmark and new solvent testing

OASE® blue long-term testing, emission reduction

OASE® blue process optimisation, mitigation of aerosol-based emissions, reclaiming test
Post-combustion capture pilot plant at Niederaussem

- Flue gas: 1,550 Nm³/h; CO₂ product: 7.2 t CO₂/day; capture rate 90%
- Commissioning and start-up 2009, availability ~97%
- 285 online measuring points and 18 material testing points
OASE® blue - testing for >55,000 hours under real power plant conditions

OASE® blue testing time [h]

Captured CO₂

Solvent flow

Capture time

Gas turbine simulation

CO₂ capture time OASE blue blue [h], Solvent flow [-]
**OASE® blue - 2.5 GJ/t\textsubscript{CO2}**

solvent performance and advanced process concept

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**Basic process design**

- Reduction in circulation rate and energy (by 20%) (simple configuration): 2.8 GJ/t\textsubscript{CO2}

**Advanced process concept**

- Reduction of specific energy demand by around 0.3 GJ/t\textsubscript{CO2}: 2.5 GJ/t\textsubscript{CO2}
- Low additional CAPEX
Challenge: Investigation of aerosol formation and effect of countermeasures

Operation time

Organic Acids Concentration

OASE® blue - < 300 g/t CO₂
solvent consumption and high degradation stability

Low solvent losses and degradation

Reclaiming: The ion exchanger is effectively removing heat stable salts
Aerosol formation – bimodal particle size distribution of solid aerosol nuclei
Investigation of aerosol formation and development of effective countermeasures

1. ESP - particulate removal, SO₃ formation
2. FGD - cooling/H₂O saturation, SO₂/SO₃ removal, particulate removal
3. WESP - particulate removal, aerosol formation, SO₃ formation
4. DCC - cooling, SO₂/SO₃ removal
5. Fan - heating, H₂O undersaturation
6. Absorber - heating/cooling, organic compounds removal
7. Acid wash - cooling and organic compounds removal
8. Water wash - cooling and organic compounds removal
9. Countermeasure „Pre-Treatment“
10. Countermeasure „Dry Bed“
Optimal emission reduction measures: “Pre-treatment” and “Dry Bed”

**Water wash**

- Absorber
- Flue gas
- Water

**Acid wash**

- Absorber
- Flue gas
- Acid
- Water

**Dry bed**

- Absorber
- Flue gas
- Water

**Pre-treatment**

- Absorber
- Flue gas
- Water

**WESP**

- Absorber
- Flue gas
- Water

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**Graphs:**

- **Carbon Dioxide Absorber [CO₂]**
  - Normal operating conditions
  - No counter measures
  - Aerosol mitigation by pre-treatment and Dry Bed configuration
  - Normal operating conditions

- **WESP operating voltage [V]**
  - Factor 30

- **Amine concentration in flue gas downstream CO₂ absorber [%]**

- **Time [hours]**
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
  - 12
  - 14
  - 16
  - 18

- **Flue gas flow [m³/h]**
  - 150
  - 300
  - 450
  - 600
  - 750
  - 900
  - 1050
  - 1200
  - 1350
  - 1500
  - 1650

- **Flue gas temperature [°C]**
  - 100
  - 150
  - 200
  - 250
  - 300
  - 350

- **Module active**
- **Module non-active**

**Legend:**
- Amine
- WESP operating voltage

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5th - 8th September 2017 
Birmingham, Alabama, USA - PCCC4, Moser et al.
Optimal emission reduction measures: “Pre-treatment” and “Dry Bed”

Testing time [h]

- THC concentration
- Amine concentration
- Lean solvent temperature
- WESP operating voltage
- Wash water temperature

5th - 8th September 2017        Birmingham, Alabama, USA        PCCC4, Moser et al.
Improved packing for scale-up

Implementation of new high performance packing

Reduction in:

- Pressure drop by up to 50%
- Absorber diameter up to 14%

1,100 MW_{el} Plant:
Up to 2 m reduction in diameter
Equipment specific material selection

- Flanges, tubes, gaskets
- Concrete module
- Coupons

Diagram showing a process flow for pre-scrubber, absorber, desorber, caustic soda, drain, make-up water, CO₂-lean flue gas, CO₂ from regeneration, and solvent flue gas.
### Scale-up risks handled

#### Solvent specific's tested
- performance (specific energy consumption, recovery rate, loading, circulation rate) ✓
- impact from real flue gas (foaming, impurities) ✓
- degradation, $O_2$ stability, emissions $\rightarrow$ solvent losses ✓
- long term behavior/stability ✓

#### Equipment specific’s tested
- packings (height, pressure drop) ✓
- emission control system (design, performance optimization) ✓
- heat exchanger type and performance ✓
- materials of construction (equipment, piping, seals, gaskets) ✓

#### Design verification finalized
- verification of process simulation tools ✓
- consideration of design ranges based on test results ✓
- Design tools for scale-up developed ✓
Commercial designs are developed

- Customized designs for different applications are developed
  - Feed gas sources from coal and gas fired power plants and from steam reformer
  - Absorber design depending on flue gas flow (2 parallel trains if required)
  - Material concept depending on flue gas source
  - Designs available for water cooling or air cooling application
Summary and conclusions

- BASF, RWE and Linde have jointly developed an energy efficient process for PCC from coal fired power plants.
- An outstanding test period of >55,000 hours was reached for OASE® blue solvent.
- Process and solvent are applicable for a wide range of different flue gas sources.
- Emission control for environment protection and low amine losses.
- New approaches for installations with substantial Capex reduction tested.

→ PCC process is commercial available
  - for delivery of large amounts of CO₂ for EOR and storage (> 1000 MTD)
  - as CO₂ source for chemical use in small and midsize scale (200 – 2000 MTD)
  - as CO₂ source for CO₂ food grade in smaller scale (< 500 MTD)
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