ENCAP SP5:
High temperature oxygen generation for power plant cycles

Ilaria Ciattaglia and Frank Fitch

THE LINDE GROUP

CASTOR-ENCAP-CACHET-DYNAMIS
Common Technical Training Workshop

22 - 24 January 2008, IFP-Lyon

encapco2

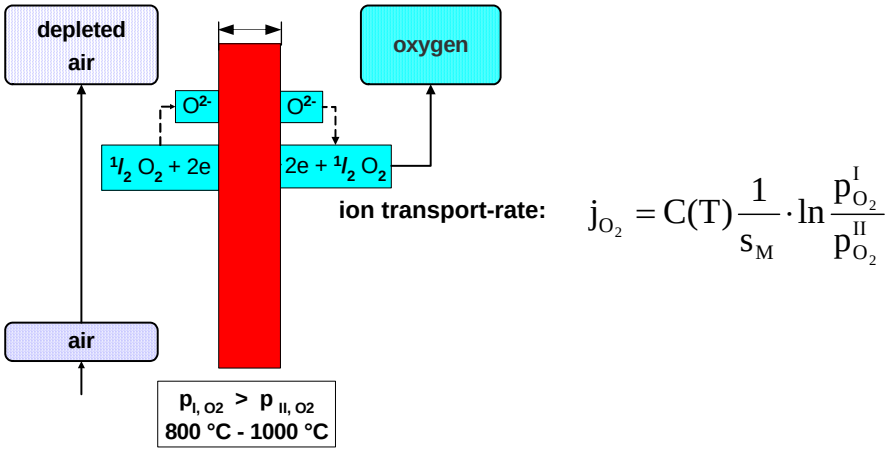
Motivation for the work in SP5

- New technologies are based on use of oxygen (no N_2, better CO_2 separation downstream).
- The cost of oxygen contributes a significant part of the cost of power.
- SP5 looks at alternative technologies for cost-effective oxygen generation:
  - high-T (600°C -1000°C) oxygen generation systems integrated in power plants (IGCC/IRCC in SP2, Oxyfuel in SP3).
  - Systems: ceramic structures with either O_2-transport or storage properties.

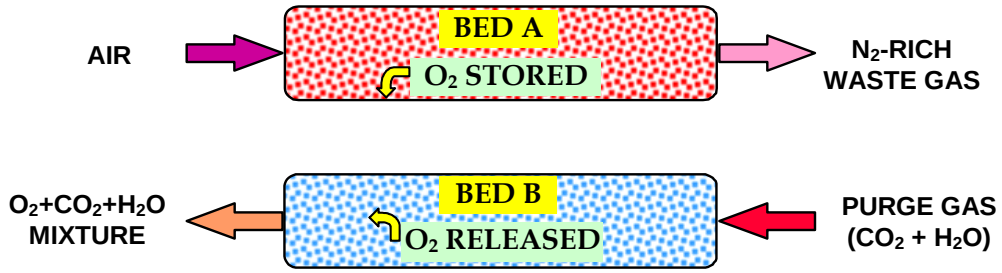
Objectives of the work in SP5

- Phase I (first 18-months):

  investigation and comparison of different high-T oxygen generation systems.



ion transport-rate: $j_{O_2} = C(T)\frac{1}{s_M}\cdot \ln\frac{p^{I}_{O_2}}{p^{II}_{O_2}}$



O_2-production by a pressure-driven ceramic membrane

O_2-production by CAR process

Objectives of the work

- Phase II (start:month 19): further validation of the selected option = CAR technology.
  - Selection based on maturity degree/near future scale-up chances.

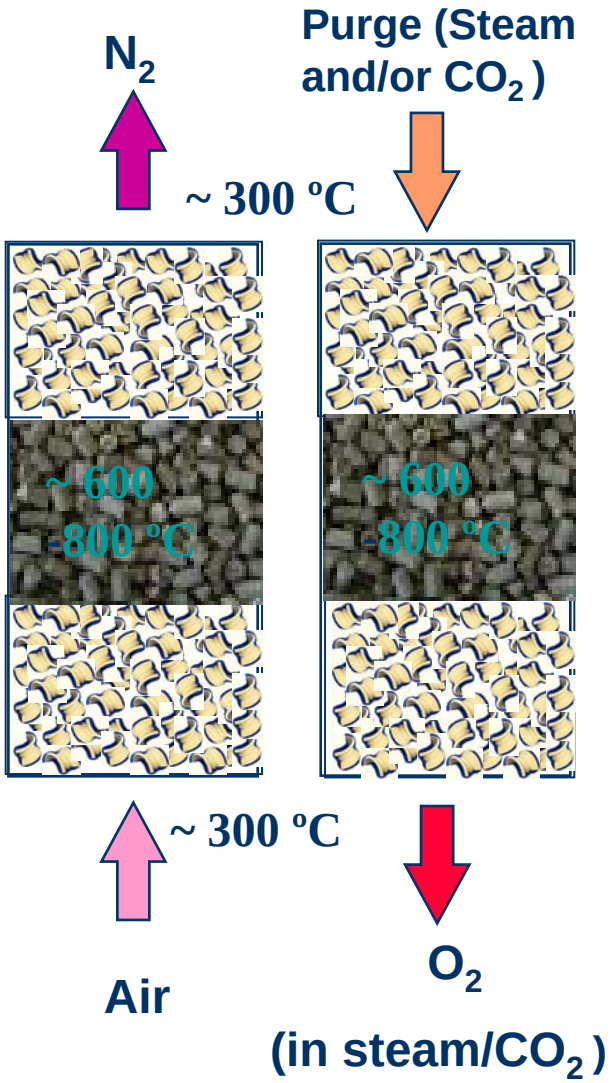
SP5 Partners

Phase I: Linde, RWE, Siemens, Statoil, BOC, Alstom Power-CH, SINTEF, TNO, University of Twente

Phase II: Linde, Linde-BOC, Alstom Power-CH, SINTEF, TNO, University of Twente (UT)

CAR (Ceramic Auto-thermal Recovery)

- Process Features
  - Uses oxygen “storage” property of perovskites at high temperatures.
  - Highly selective O_2 extraction.
  - Based on conventional pelletized materials
  - Cyclic steady state process.
  - Perovskite alternately exposed to feed air and regeneration gas flows.
  - Partial pressure swing (using a sweep gas) enables production of an O_2-enriched stream
  - Internal regenerative heat transfer

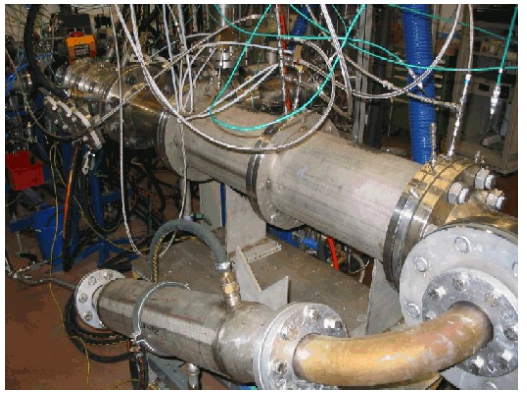


SP5: CAR sorbent successfully scaled-up

- The CAR sorbent powder composition and pellet geometry were selected based on the trade-off between performance, mechanical strength and manufacturability.
- Pilot scale quantities of perovskite powder were toll-synthesized and made into pellets using a commercial tool.
- These pellets were then used in pilot-scale process trials in the ENCAP and DOE-funded CAR programmes.
- Large scale manufacturing procedures and costs have been established.

SP5 Pilot-Scale Process Demonstration

- ENCAP Pilot scale trial completed by Alstom Power Technology Centre, CH
  - CAR process shown to transfer sufficient O_2 from air for CO_2/steam expansion turbine based oxyfuel combustion power applications.



- DOE-funded 2-bed Pilot Plant trial run by Linde/WRI (outside scope of ENCAP).
  - Start-up and continuous oxygen production demonstrated in 2-bed cyclic CAR process.
  - System now linked to combustion test facility (CTF) to allow flue-gas purge trials to be made.

ENCAP SP5: Impact of Process Gas Impurities

- Selected CAR-materials were exposed to SO_2 and to flue gases from the CTF at WRI (Linde outside ENCAP-scope).
  - The performance of CAR sorbent pellets were found to be significantly effected by flue-gases with high SO_2 levels (100s – 1000s of ppm).
- Impact of typical flue-gas impurities on properties and stability of selected CAR materials is being studied in SP5 (UT/Linde).
  - O_2 exchange properties of selected perovskite powders being measured before and after exposure to CO_2, SO_2 or flue-gas.
  - Preliminary results indicate significant impact of CO_2 on O_2 exchange rates.
- The use of steam as purge would avoid any problems with SO_2 and other flue-gas impurities, but
  - Oxy-fuel boiler process simulations show this would be more expensive than the ASU-boiler baseline case (Linde).

Main conclusions ENCAP SP5

- The CAR oxygen production process has been successfully demonstrated at pilot scale, but is not yet optimized.
- Commercial procedures have been established for the manufacture of the standard sorbent material.
- For steam-purge CAR option to be attractive, need either
  - Lower purge requirement or lower process temperature.

- Challenges that must be addressed before a larger scale CAR demonstration plant can be designed, include:
  - Current sorbent performance is at low end of acceptable range.
  - Need better control of heat losses.
  - Need better understanding of impact of impurities in flue-gas.