PRAXAIR

Achieving Near Zero Emissions via Oxy-Combustion

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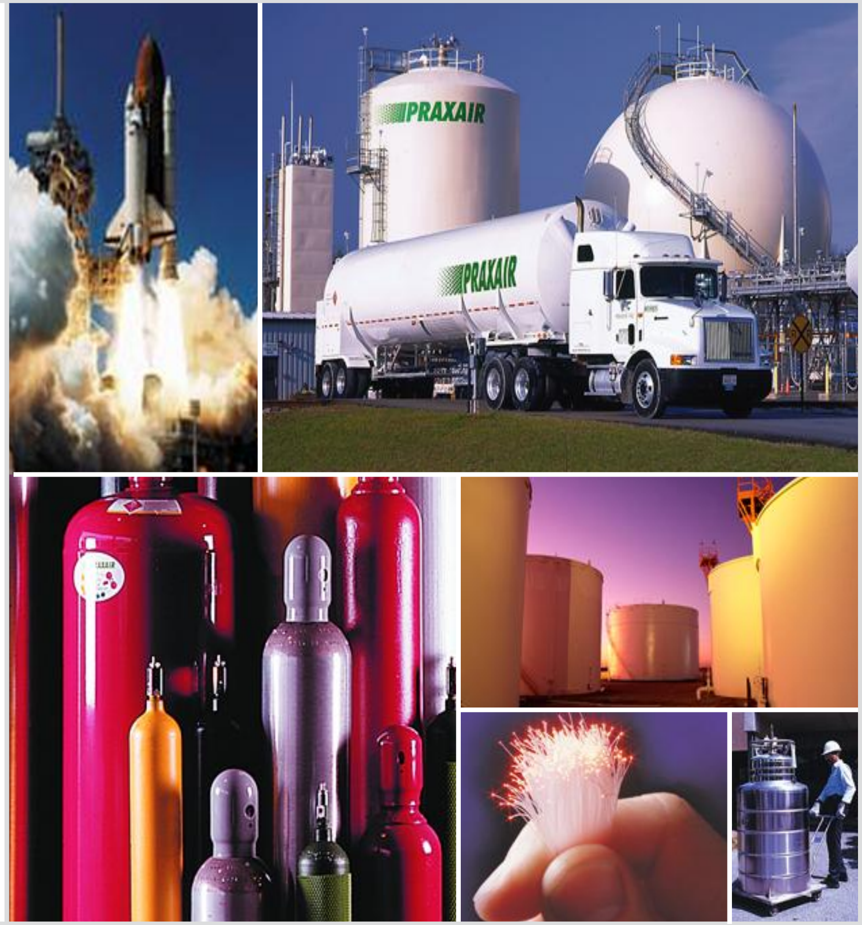
McIlvaine Webinar - Update on Oxyfuel Combustion

August 12, 2010



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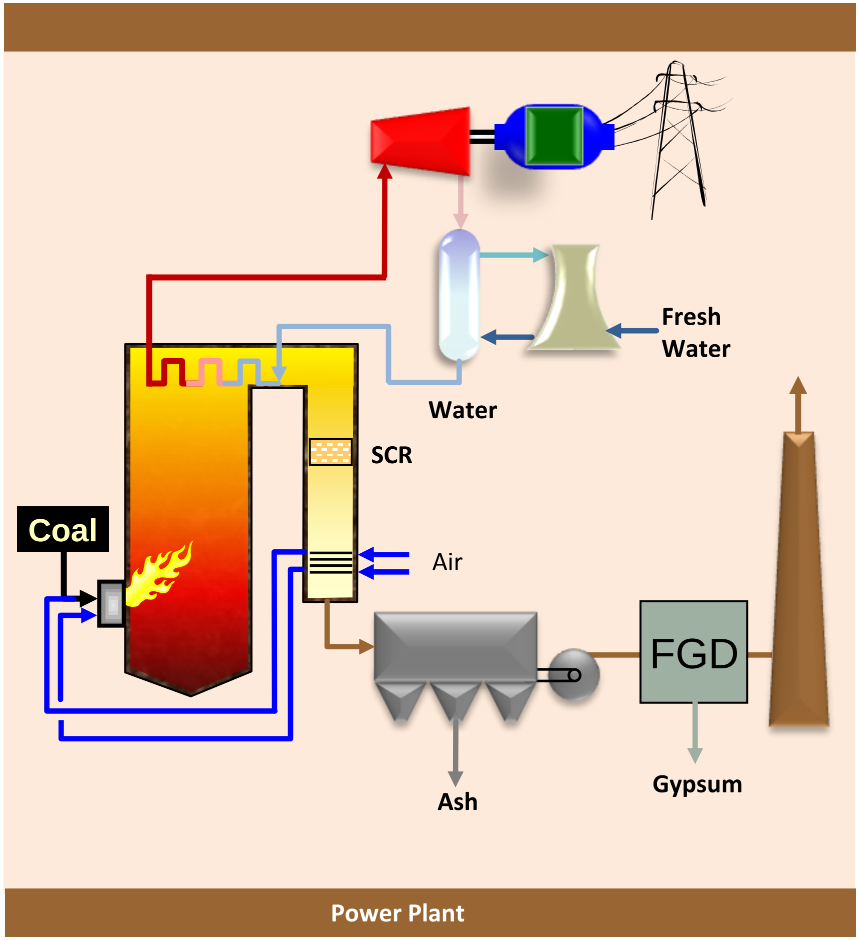
Oxy-Fuel Technology Programs at Praxair

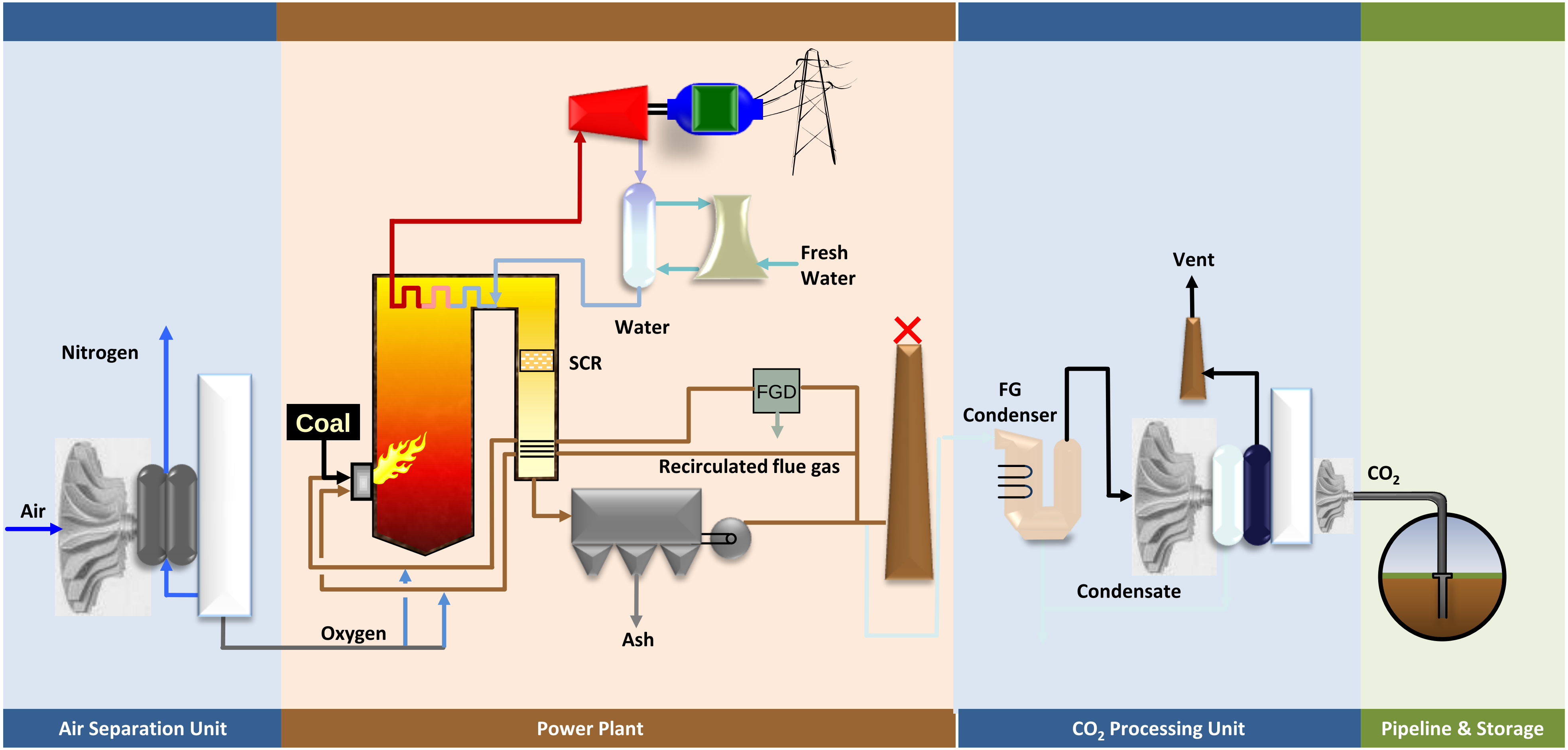
- **Near Zero Emissions Oxy-Combustion Flue Gas Purification**
  - $5.4 MM DOE – funded program (2009 – 2011)
  - Two methods for SOx/NOx removal
  - Technology for achieving up to 99% CO_2 recovery
- **Pilot-scale oxy-combustion testing at U. of Utah**
  - Oxy-fuel PC (1.2 MW_{th})
  - Oxy-fuel CFB (0.3 MW_{th})
- **Oxy-fuel retrofit of NG-based 50 MMBtu/hr steam generator for oil sands planned in 2011-2012**
- **Oxygen transport membrane (OTM) based power cycle**
  - Efficiency penalty for CO_2 capture is only ~ 3 percentage points
  - Bench-scale testing on the OTM reactors completed
  - Pilot-scale OTM units are being designed

Power Plant without CCS



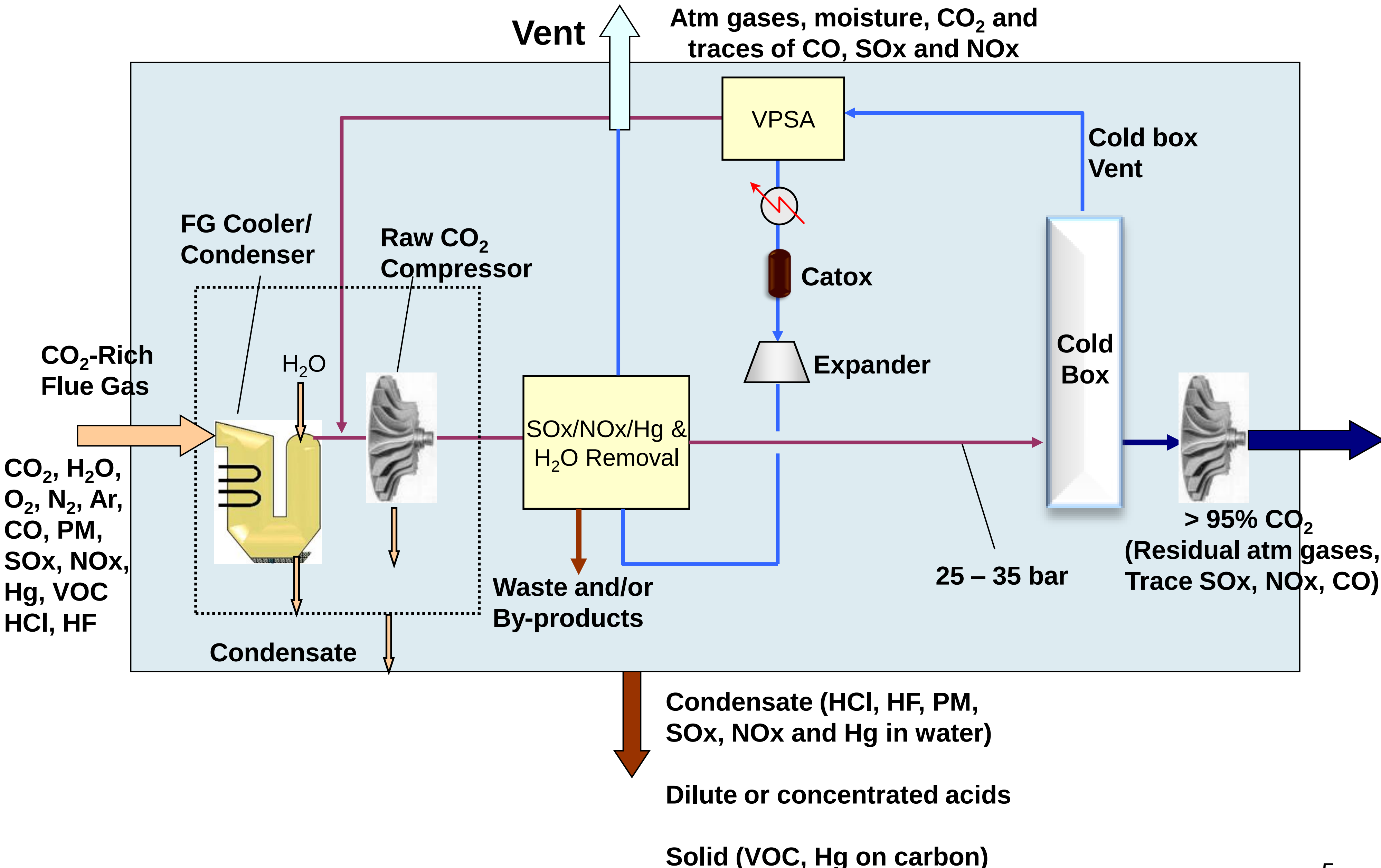
- Flue gas flow from 500 MW (net) subcritical plant is ~ 5 MM lb/hr

Oxy-Coal Power Plant with CCS



- **With oxy-combustion, flue gas flow is reduced to ~1.3 MM lb/hr**
- **Flue gas is sent to CO_2 processing unit (CPU)**
- **After separating CO_2, vent gas is only 0.11 MM lb/hr**

Near Zero Emissions CO_2 Processing Unit



Sulfuric Acid Process for SOx/NOx Removal

- **Converts SOx and NOx into saleable H_2SO_4 and HNO_3**
  - Flue gas contacted with circulating H_2SO_4 at elevated pressure
  - >99% SOx removal and > 90% NOx removal
- **Process also removes Hg and moisture**

- **Benefits:**
  - Retrofitting existing plants – reduce FGD opex and eliminate SCR opex
  - New CCS plants - Smaller FGD; eliminate SCR

- **Current Status:**
  - Bench-scale tests underway; plan to complete in Dec 2010

- **Next Steps/Challenges:**
  - Handling and storage of acid by-products
  - Significant efforts required to scale-up from current stage

Activated Carbon Process for SOx/NOx Removal

- **Converts SOx and NOx into dilute H_2SO_4 and HNO_3**
  - Flue gas contacted with activated carbon at elevated pressure
  - Dual bed system – one on feed while other is being regenerated
  - Mercury removal in a separate carbon bed system
- **Benefits:**
  - Retrofitting existing plants – Smaller FGD; eliminate SCR opex
  - New plants – Smaller FGD; eliminate SCR
- **Current Status:**
  - Bench-scale tests showed >99% SOx removal and >98% NOx removal
  - Continuous operation testing planned in 2011
- **Next Steps/Challenges:**
  - Scale up to handle 10 – 50 tpd CO_2–rich flue gas
  - Demonstrate performance in long-term operation tests

Vacuum Pressure Swing Adsorption (VPSA) for Achieving High CO_2 Recovery

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- **Increases overall CO_2 recovery from 90% to 99%**
  - Upgrades CO_2-lean stream from cold box to CO_2-rich stream
- **Benefits:**
  - Achieves high CO_2 recovery even from plants with high air ingress
  - Reduces overall CO_2 capture cost
- **Current Status:**
  - Pilot-scale testing underway with a typical cold box vent stream
  - 100 tpd unit being commercialized for other CO_2 capture application
- **Next Steps/Challenges:**
  - Technology will be available for 200 – 500 MW scale plants by 2012

Projected Process Performance
Activated Carbon Process + VPSA

- **% reductions in air emissions**
  - Compared to air-fired plant with FGD and SCR

CO_2	> 98.5%
SOx	> 99.5%
NOx	> 96%
Hg	> 99%
CO	> 99.5%
NH_3	100%
HCl	100%
PM	> 99%
VOC	> 99%

% Reductions =

$$\left\{ 1 - \frac{(\text{emissions/net output})_{\text{oxy-fired}}}{(\text{emissions/net output})_{\text{air-fired}}} \right\} \times 100$$

- **CO_2 Purity (by vol.)**

CO_2	> 99.99%
Atm gases	< 100 ppm
H_2O	1 ppm
SOx	7 ppm
NOx	5 ppm
Hg	Nil
CO	< 1 ppm
NH_3	Nil
HCl	Nil
PM	Nil
VOC	Nil