Power Generation and Utility Fuels Group

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Gasification

Background and Process Description
Combustion vs. Gasification

**Combustion with oxygen**

\[ C + O_2 \rightarrow CO_2 \]

\[ H_2 + \frac{1}{2} O_2 \rightarrow H_2O \]

Generate: \( CO_2 + \text{water} \)

\[ \text{Heat} \]

\[ \text{Ash} \]

**Partial combustion with oxygen and reactions with water**

\[ C + \frac{1}{2} O_2 \rightarrow CO \]

\[ CO + H_2O \rightarrow CO_2 + H_2 \]

\[ CO + H_2O \rightarrow CO + H_2 \]

Generate: \( \text{Syngas} \)

\[ \text{Syngas} \]

\[ \text{Less Heat} \]

\[ \text{Slag} \]
Gasification Utilization Strategies

FEEDS
- Alternatives:
  - Asphalt
  - Coal
  - Heavy Oil
  - Petroleum Coke
  - Natural Gas
  - Wastes
  - Clean Fuels
  - Biomass

GASIFICATION
- Oxygen
- Gasifier
- Byproducts: Solids (ash)

GAS CLEANUP
- Sulfur Removal
- Syngas
- Marketable Byproducts: Sulfur

END PRODUCTS
- Combined Cycle Power Block
- Electricity Steam
- Alternatives:
  - Hydrogen
  - Ammonia
  - Chemicals
  - Methanol
  - Fuels

Source: The Department of Energy’s (DOE) National Energy Technology Laboratory (NETL) / GE Texaco
OMB Gasification

- OMB Enhances the Mixing and Resonance Time Distribution
- High-Temperature Reaction Reduces/Eliminates Tar Formation
- High Performance (98% carbon conversion)
- High Availability (98% as a stretch goal)
- High Load Flexible (40%-120%)
- Industrial process technology
- 38 projects (Including 1 in US), 109 gasifiers
- Total capacity > 130,000 Tons coal per day
Gasification Operation Pictures

- Ignition
- 145°C
- 450°C
- 600°C
- Injection of CWS in Burner C, D (Burner A, B with NG on)
- 2 Burner CWS gasification (Burner A, B with NG on)
- 4 Burner CWS gasification (Lens of endoscope fouled)

• Gasifier installed and currently being tested
• Downstream components online soon
Future Research Areas

1.) Host site for technology development around CTL
   • Gasification
   • Carbon Capture
   • FT
   • WGS and Refining

2.) Gasification Technology
   • High concentration CWS
   • Increase H/CO ratio and Reduce Downstream Clean-up
      • In-situ WGS with warm sulfur removal
      • Collaboration with Catalyst group, ECUST
   • Coal/Biomass Blending Gasification Research
   • Dynamic Modeling and Controls

3.) Carbon Capture
   • New Solvents
   • New catalysts
   • New processes and technologies

4.) Gas Conversion by F-T Synthesis
   • Catalysts (Co, Fe, etc.)
   • Types of F-T reactors
   • Fine tuning based on selectivity of desired product(s)
Carbon Capture

Background and Process Description
Why CO$_2$ Capture?

The Earth's carbon cycle

- Carbon contained in the atmosphere (760 billion tons) Annual increase (3.4 billion tons/yr.)
- Emissions from fossil fuels (6.4 billion tons/yr.)
- Absorption by oceans (1.6 billion tons/yr.)
- Emissions from changes in land use (1.6 billion tons/yr.)
- Absorption by forests, etc. (2.6 billion tons/yr.)
- Volume absorbed by on-land ecosystems (400 million tons/yr.)
- Balance absorbed by on-land ecosystems (1.4 billion tons/yr.)
- Carbon contained in plants and soil (2.26 trillion tons)
- Carbon contained in the oceans (38 trillion tons)
- Carbon contained in fossil fuels (3.7 trillion tons)

Ref: The IPCC Fourth Assessment Report
CO₂ Capture Possibilities and Utilization

CO₂ capture technologies

- Postcombustion
  - PSA
  - TSA
  - VSA
- Precombustion
  - Membranes
  - Fixed bed reactors
  - Moving bed reactors
  - Fluidized bed reactors

Oxycombustion
  - Polymer networks
  - Activated carbon
  - Metal oxides
  - Ionic liquids
  - Zeolites
  - MEAs
  - MOFs
  - ZIFs

CO₂-to-X Technologies

- Photochemical
- Electrochemical
- Chemical processing
- Biochemical processing

Biorefinery

Biofuels Biomaterials

Atmospheric CO₂

Stationary CO₂ point sources

Natural gas wells

Power plants

Cement plants

Other industrial plants

Geological CO₂ sequestration

Enhanced oil recovery

Deep sea CO₂ sequestration

Renewable energy sources

Water

Microalgae cultivation

Liquid fuels Value-added chemicals
Technology Development Pathway

- **Proof of Concept**
  - Fundamental Thermodynamic and Kinetic Studies

- **Concept**
  - 1.5” ID
  - Bench-scale Unit

- **Molecular and Process Modeling and Simulations**

- **Lab-scale Unit**
  - 0.02 MWe
  - (0.1 MWth)

- **Pilot-scale Unit**
  - 0.7 MWe
  - (2 MWth)

- **Demonstration Unit**
  - 10-25 MWe

- **Full-scale Unit**
  - 100-500 MWe

- **Shengli Power Plant**
  - Shandong, China
  - 1.0 M tons/yr
  - US-China Climate Change Working Group
  - MoU Signed July 8, 2014

**PGUF Overview**

January 2017
CO$_2$ Capture Chemistry

Amine (MEA) + Carbon Dioxide

Monoethanolamine (MEA) + O=C=O $\rightarrow$ HEAT

HO$\rightarrow$NH$_2$ + O=C=O $\rightarrow$ HEAT

2 eq

Monoethanolamine (MEA)
Typical CO$_2$ Capture Flow Diagram

Key Equipment:
1) Absorber
2) Stripper
3) Heat Exchangers
What Happens in the Absorber?

**Absorber** – the equipment that captures CO$_2$ using a chemical solvent

**Carbon Rich Stream** – the chemical solvent after it has absorbed the CO$_2$

- Exothermic chemical absorption
- Counter current
- Careful liquid and gas distribution
- Structured packing
What Happens in the Stripper?

Stripper – the equipment that regenerates the solvent and liberates the captured CO$_2$

Carbon Lean Stream – the chemical solvent after it has been regenerated and contains very little CO$_2$

- Heat is added with the reboiler
- Reverse the exothermic chemical absorption reaction
- Structured packing
What is Involved in the PGUF Group?

Process Modeling and Simulation
Chemical Engineering
Chemical Process Development
Mechanical Engineering
Equipment and Structural Design
Analytical Chemistry
Emissions Studies
Solvent Chemical Changes
Materials Science
Metallurgy
Corrosion Studies
Energy Efficiency