Air Products: Success in Advanced Separation and CO$_2$ Processing for EOR

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Air Products Overview

- Multinational corporation producing Industrial Gases, Chemicals, and Energy Systems
  - Sales of $10.3B (FY13)
  - >250,000 customers worldwide
  - Operations in >50 Countries
  - Industry safety leader
  - Leader in sustainability

- World’s largest manufacturer of hydrogen at more than >2 BSCF/day

- World leader in LNG technology

- Pioneer of cryogenic N₂ injection for enhanced oil recovery

- Build, own & operate industrial gas facilities with high reliability
Air Products & CO₂

- Solutions for the EOR Industry
  - Developing, financing, constructing, and operating CO₂ processing facilities
  - Helium Recovery Project
  - Port Arthur CO₂ Project
  - New H₂S Removal Technology, NGL recovery

- Industrial CO₂ business in Americas & Europe
  - Recent purchase of EPCO CO₂ business

- CO₂ Capture R&D
  - Evaluation and development of broad range of CO₂ Capture Technologies
  - Pilot demonstration of CO₂ processing unit for oxyfuel combustion of coal at Vattenfall’s research and development facility in Schwarze Pumpe, Germany
Air Products Technical Capabilities

- Industry Leader in **Safety**
- World Class **Engineering & Construction**
  - R&D, Technology, Engineering, Plant Design
  - Over 1,000 employees in Allentown, London, Shanghai
  - $ 3 billion of projects in execution
  - Project Management, Turnkey Capability
- Global Equipment **Manufacturing**
  - Facilities in Wilkes-Barre PA, Shanghai, Malaysia
  - Manufacturing partners and suppliers globally
- **Operating** Organization
  - Over 8,000 employees (40%) in operations
  - 700+ operating plants around the world
We seek employ the **optimal technical solution**, be it developed by AP or a third party.
Challenging CO₂ Impurities Require Advanced Separation Technology

- **Low-value impurities** include H₂S, N₂, CH₄, SOx, ....
  - Goal is to remove as cost effectively and safely as possible to meet EOR specifications for the CO₂ product
  - Technology minimizes the cost of unlocking CO₂ for EOR

- **High-value “impurities”** include NGL’s and Helium
  - Goal is to recover with optimal cost/recovery tradeoff
  - Technology used to unlock high value for the CO₂ project

- **The Process** – a staged approach

  Setting the premise → Executing the plan

  Setting the premise:
  - Gas Composition
  - Existing Infrastructure
  - Future Growth Plans

  Executing the plan:
  - Product Value
  - Recovery Targets
  - Design Basis
  - Technology Selection
  - Project Development
  - Permits
  - Project Execution
  - Start up & Commissioning
  - Maintenance
  - Reliability
Air Products Port Arthur CO₂ Project

New technology to recover anthropogenic CO₂ for EOR

- Capture and purification of CO₂ from hydrogen plants (syngas) for EOR
- 50 MMSCFD of CO₂ to Denbury’s Green Pipeline for West Hastings oilfield
- Retrofit of 2 Steam-Methane Reformers (SMR) that sit in the middle of a refinery
- Technology developed by Air Products
- 90%+ capture of CO₂
- 30 MWe Cogeneration unit to generate power and make-up steam
- Total project $431 MM
- DOE Share: $284 MM (66%)
Project Overview:
State-of-the-Art Carbon Capture from Two Port Arthur, TX SMRs

- American Recovery and Reinvestment Act Funding
  - 1 of 8 Large CO₂ Capture Projects Supported by the US DOE
- ~1 million tons of CO₂ to be recovered and purified annually starting late 2012
- Valero providing land, rights-of-way, utilities
- AP supplying compressed and purified CO₂ to Denbury for injection into TX oilfields for enhanced oil recovery
Simplified CO₂ Capture Block Flow Diagram

PORT ARTHUR 2

Natural Gas
Utilities
HP Steam Export
Power Export

Existing Stream

New Stream

Revised Stream

EXISTING SMR

Purge Gas

Syngas

Syngas (CO₂ Removed)

Export Hydrogen

Export CO₂

NEW COMPRESSOR / DRIER

Wet CO₂

CO₂

H₂

PORT ARTHUR 1

Natural Gas
Utilities
HP Steam Export
Power Export

Existing Stream

New Stream

Revised Stream

EXISTING SMR

Purge Gas

Syngas

Syngas (CO₂ Removed)

Export Hydrogen

Export CO₂

NEW VSA

Wet CO₂

CO₂

H₂
Vacuum Swing Adsorption Process for CO₂ Separation

Flow

SMR CO₂ Rich Syngas

H₂ CO₂

Sweet Syngas to Existing H₂ PSA

To Feed

CO₂
Key Project Components
Capturing CO₂ for Denbury’s “Green Pipeline”

- Vacuum swing adsorption (VSA) vessels
- Tri-ethylene glycol (TEG) drier system
- CO₂ export compressor
  - Export pressure over 2000 psig (~140 bar)
- 13 mile (21 km) CO₂ Pipeline connecting to Denbury’s “Green” 300+ Mile (~500 km) CO₂ Pipeline

Map shows Denbury’s Green CO₂ Pipeline. Data source is Denbury, December 2011, CO₂ Flooding Conference
Overview of Project Site, Port Arthur II

Source: Air Products and NETL

Air Products and Chemicals, Inc: Port Arthur 2
Close-up View

Eight-stage, integrally-geared centrifugal CO₂ compressor

CO₂ surge tank delivery

CO₂ VSA Vessels
Validation of Design

CO₂ Product Purity

CO₂ Recovery

Port Arthur II Operation
February 2013

Design Operating Curve
Port Arthur CO$_2$ Project
Operational Update

- Project Timeline:
  - Phase 2 awarded – June 2010
  - FEED complete - Nov 2010
  - Foundations – September 2011

- CO$_2$ Capture On-stream:
  - PA-II SMR – December 2012
  - PA-I SMR – March 2013

- Full capacity achieved **April 2013**

- CO$_2$ delivered: 500,000 tons
  - Through the end of September 2013

- Retrofit within an operating facility

- Integration with existing hydrogen business
Do you know what’s in your gas??

- **Helium** recovery from CO$_2$ provides opportunity
  - Unlocks value when recovered from CO$_2$ currently processed
  - Helium can improve economic viability of new CO$_2$ sources

- **Air Products** is a global leader in helium supply
  - Pioneered many of the helium extraction, production, distribution and storage technologies used in the industry today and operates numerous facilities around the world.
Why is Helium important?

Demand growth of 3-5% annually

Fiber Optics

Balloons & Lifting

Cutting and Welding

Electronics

Pressurizing/Purging

Medical Imaging (MRI)

Source: 2012 Gasworld
Where does Helium come from?

- By-product of gas production
- Formed by the decay of elements in the earth’s crust (Uranium and Thorium)
  - Only found in certain gas fields
  - Where gases formed together and capped by impermeable rock
  - New helium supplies are required to meet demand
Doe Canyon CO$_2$ Source Field

- Kinder Morgan CO$_2$ Source in Dolores County, SW Colorado
- Expanded to 170 MMSCFD CO$_2$ capacity
- ~0.3% helium
Helium Extraction from CO₂

- Helium is in the CO₂ stream
- This project will extract the helium from the CO₂ stream and return the CO₂ to the pipeline
- Helium will be liquefied and then transported from the site in tanker trucks
- First commercial recovery of helium from pure CO₂ stream
Proprietary Helium Recovery Technology

**Feed**
- 170 MMSCFD
  - CO₂: 97%
  - N₂: 2.6%
  - He: 0.3%

**CO₂ Product**
- 169.5 MMSCFD
  - CO₂: 97.3%
  - N₂: 2.6%
  - He: 0.0%

**Pure He To Liquifier**
- He: 99.9%

**He Polishing**

**Heat Exchanger Network**

**Distillation Column**

**Compression**

**Dehy**

**H₂O**

**Network**

**Polishing**
Project Details

- First commercial project to recover helium from pure CO₂
- CO₂ product is used as refrigerant (auto-refrigerated process)
- No CO₂ is lost in the helium recovery system
- >98% helium recovery
- No combustion sources / no process vents
- 230 MMSCF/y of helium replaces 15% of BLM supply volume
Air Products Helium Extraction Facility

- Site preparation / civil work has commenced
- First helium production: Spring 2015
What’s Next in CO₂ Purification?

- **H₂S and CO₂**
  - A common impurity in CO₂ sources
  - A difficult challenge (they like each other!)

- There are good solutions for low-levels of H₂S (100’s of ppm)

- At higher levels of H₂S there are fewer options
  - **Ryan Holmes Processes** – an option if C₄+ hydrocarbons are present in the feed
    > Energy/CAPEX intensive
  - **Solvent Processes** – an option where sulfur production is desired, energy is cheap, or syngas/methane content is high
    > H₂S is removed at low pressure, high compression power for CO₂
  - **Distillation Process** – an option where CO₂ and H₂S are needed at high pressure
CO₂/H₂S Distillation Technology to Address Challenges at high H₂S levels

- Air Products has developed a technology to separate EOR-grade CO₂ from H₂S that provides advantages over solvent-based processes
  - Draws upon Air Separation / Hydrocarbon Experience
- Process designed for efficiency and reliability:
  - Conserves feed pressure
  - Uses CO₂ as its own refrigerant
  - No fuel or steam necessary, no solvents
  - CO₂ recoveries of up to 98.5% are practical
  - Studies show substantial advantages when H₂S >0.5%
  - H₂S spec in CO₂ of 100 ppm is typical starting point, lower levels are possible
Closing Thoughts

• New gas separation challenges in CO₂
  - Complex projects take a disciplined approach
• Technology choices are specific to type and disposition of impurities, leveraging existing infrastructure
• High-value impurities like Helium offer an opportunity to provide value back to CO₂ producers
• Setting the correct project premise is key
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