Fluor’s Econamine FG Plus℠ Technology

An Enhanced Amine-Based CO₂ Capture Process
Presentation Outline

- Econamine FG\textsuperscript{SM} Technology
- Econamine FG Plus\textsuperscript{SM} Technology Features
- Heat Integration with the CO\textsubscript{2} Producing Process
- Comparison to other Amine Scrubbing Technologies
The following technologies, described in this presentation, are protected by existing or pending patents owned by Fluor:

- Econamine FG℠
- Econamine FG Plus℠ (all components)
- Heat integration with a power plant or process facility

Additional details of the process can be made available after a secrecy agreement has been signed.
Econamine FG℠ Process

- CO₂ capture via monoethanolamine (MEA) solution with proprietary inhibitor

- Technology permits the economical extraction of CO₂ from oxygen-containing streams, such as flue gas

- Post combustion CO₂ capture system
  - Applicable to existing facilities
  - CCGT and coal-fired power plants are candidates

- Large-scale CO₂ recovery plants are possible
  - 40 to 50 ft. diameter absorbers are considered feasible
  - CO₂ recovery up to 8,000 Te/d per absorber
Example of 40-Foot Diameter Absorber

Fluor-built Saudi Aramco Econamine (DGA) Plant
Uthamaniyah, Saudi Arabia
Econamine FGSM Features

- Econamine FGSM inhibitor protects the amine and the equipment
  - Allows CO₂ removal from oxygen-containing streams by preventing amine degradation
  - Allows conventional materials of construction, mostly carbon steel, by preventing corrosion

- Similar to generic gas treating processes employed for many years
  - Only simple, reliable equipment used in the process
Commercial Plant Example:
FPL Facility at Bellingham, MA

- The only commercial-scale CO₂ recovery unit in the world operating on gas turbine flue gas
  - Only 2.8 - 3.1 vol% CO₂ in flue gas
  - Over 13 vol% O₂ in flue gas
- Recovery is 360 STPD (327 Te/d) of carbon dioxide
- Continuously operating since 1991
- Produces carbon dioxide product suitable for use in the food and beverage industry
  - Better quality than needed for CO₂ sequestration
- Designed and constructed by Fluor
  - Used by Fluor to develop know-how on amine degradation and corrosion prevention strategies
Bellingham Plant Ground View

- Stripper
- Reclaimer
- Absorber
- DCC
- Reboiler
Fluor has developed an improved Econamine FG\textsuperscript{SM} process, called Econamine FG Plus\textsuperscript{SM}.

- Process designed for lower energy consumption

Econamine FG Plus\textsuperscript{SM} process enhancements include:
- Improved solvent formulation
- Split flow configuration
- Stripping with condensate flash steam
- Absorber intercooling
- Integrated steam generation

Plant specifics dictate which features are included, thereby creating a customized and optimized facility.
New Solvent Formulation

- Remains MEA-based

- Increased reaction rates
  - Decreased absorber size

- Higher solvent capacity for CO₂
  - Lower circulation rate than standard Econamine FGSM solvent
  - Lower energy demand for regeneration
Split Flow Configuration

- Rich solvent split into two streams for parallel regeneration
  - One stream fed to stripper to generate lean solvent
    • Used for trim absorption in the top absorber bed
  - Second stream by-passes stripper and is preheated against process streams and flashed to generate semi-lean solvent
    • Used for bulk absorption in the bottom absorber bed

- Total circulation rate increases, but less energy is required
  - Increase in solvent rate is substantially mitigated with the implementation of the reformulated solvent
Stripping with Condensate Flash Steam

- Steam condensate (saturated) from the reboiler is let down to semi-lean flash drum pressure

- Condensate flash vapor (i.e., steam) is injected into the semi-lean flash drum as stripping medium, reducing semi-lean loading

- Requires lower circulation rate than split flow configuration alone

- Reboiler duty is further reduced
Absorber Intercooling

- Semi-rich solvent flowing from the top (trim) bed is extracted from the column and is mixed with semi-lean solvent and cooled

- Cooled solvent is returned to the bottom (bulk) bed of the absorber

- Lower temperature increases the absorption rate
  - Decreased absorber size

- Increases rich solvent loading
  - Decreases circulation rate
  - Reduces energy requirement
Absorber Temperature Profile with Intercooling

Top of Packing (Lean Inlet)

Bottom of Packing (Rich Outlet)

With Intercooling

Without Intercooling
Integrated Steam Generation

- Flue gas can be used to generate all steam requirements for the Econamine FG Plus\textsuperscript{SM} plant.

- If flue gas temperature is high, steam can be raised from heat recovery alone.

- In addition, duct firing can be employed to raise additional steam:
  - Added benefit of increasing CO\textsubscript{2} concentration to absorber.

- Option: generate power by raising high-pressure steam.
Econamine FG Plus™ Benefits

- Low cost carbon steel materials of construction used for most equipment items

- MEA is the lowest cost amine and is readily available world-wide
  - Annual inhibitor cost adds only approximately 20% to the MEA cost

- Lowest heat requirement for competing MEA-based processes

- Lowest solvent circulation rate for competing MEA-based processes
Heat Integration with CO$_2$ Producing Process

- Heat integration with power/refinery/petrochemical process units is feasible

- Excellent integration opportunity with a power plant
  - Econamine FG Plus$^\text{SM}$ process cooling can be carried out with vacuum condensate
    - Stripper overhead condenser and absorber coolers provide heat to steam turbine vacuum condensate
  - Minimize steam and cooling water consumption
  - Substantial energy savings
Amine Scrubbing Experience

- **Fluor Econamine FG℠ and Econamine FG Plus℠**
  - Relatively high MEA concentration in solvent
    - Allows for reduced circulation rate and reboiler duty
  - 23 commercial plants, including:
    - Only commercial-scale CO₂ absorption plant on gas turbine flue gas
    - 1,000 Te/d CO₂ recovery plant for EOR

- **ABB Lummus; Kerr McGee Technology**
  - Lower MEA concentration than Econamine FG Plus℠
  - Three commercial plants

- **MHI/KEPCO**
  - KS-1 hindered amine solvent
  - One commercial plant
Case Study: Comparison of Econamine FG PlusSM to MHI/KEPCO KS-1

- Basis is flue gas from Petronas Fertilizer Co. CO₂ capture plant in Malaysia
  - Only KS-1 commercial installation
  - MHI has published papers on its performance

- Flue gas source is steam reformer
  - 10.4 vol% (dry) CO₂
  - 1.1 vol% (dry) O₂

- CO₂ recovery is 160 Te/d
  - 90% recovery of incoming CO₂
### Comparison of Econamine FG Plus™ to MHI/KEPCO KS-1

<table>
<thead>
<tr>
<th>Units</th>
<th>Econamine FG Plus™</th>
<th>KS-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reboiler Steam Consumption</td>
<td>Btu/lb CO₂</td>
<td>1395</td>
</tr>
<tr>
<td>Solvent Replacement Cost</td>
<td>US$/Te CO₂</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Steam consumption is within 1.5% of each other

Solvent replacement costs are nearly identical

KS-1 reported solvent loss is nearly 4.3 times less than Econamine FG Plus™

**BUT** KS-1 purchase price is approximately 4.3 times more than Econamine FG Plus™
Summary

- The Econamine FG Plus<sup>SM</sup> process has reduced energy consumption.

- If integrated with power/refinery/petrochemical process units, there can be further considerable saving in energy.

- Econamine FG Plus<sup>SM</sup> technology allows CO<sub>2</sub> removal with low capital cost, low energy consumption and simple equipment.