UOP Amine Guard™ FS Technology for Acid Gas Removal

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Agenda

- Overview of the Amine Guard FS process
- UCARSOL™ Solvent characteristics
- Amine Guard FS flow scheme comparison
- Equipment features
- UOP technology transfer
- UOP Experience and Technical Services
- Summary
Overview of the Amine Guard FS Process

- Licensed amine technology
- Removal of CO$_2$ & H$_2$S to low levels or
- Selective H$_2$S Removal
  - Low H$_2$S spec, with as much as 75% CO$_2$ slip
- UCARSOL Formulated Solvent from Dow
- Several flow scheme options available
- UOP MD™ Trays or Raschig Super Rings to maximize performance
### Amine Guard FS Process
Do’s and Don’ts

<table>
<thead>
<tr>
<th><strong>Do’s</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Remove CO₂ &amp; H₂S</td>
</tr>
<tr>
<td>- Selective H₂S removal</td>
</tr>
<tr>
<td>- Natural Gas to pipeline specs</td>
</tr>
<tr>
<td>- Natural Gas to LNG specs</td>
</tr>
<tr>
<td>- Downstream of a membrane for CO₂/H₂S polishing</td>
</tr>
<tr>
<td>- Treat Synthesis gas for H₂, NH₃ or other applications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Don’ts</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mercaptan Removal</td>
</tr>
</tbody>
</table>
Overview of the Amine Guard FS Process

Markets served include:

• Synthesis gas treating for CO$_2$ removal in synthesis gas plants, such as direct iron ore reduction

• Synthesis gas treating for selective H$_2$S removal in integrated gasification combined cycle (IGCC) plants

• Natural gas treating for selective removal of H$_2$S and partial removal of CO$_2$ for pipeline specifications

• High CO$_2$ partial pressure service for reduced energy consumption compared with conventional amines, such as steam reformed ammonia plants
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UCARSOL AP-800 Series Solvent Features:

- State of the art amine technology
- MDEA based solvent with low concentrations of activator
  - Activator accelerates slow overall kinetics of CO$_2$ reaction with MDEA
  - Solvent formulation is chosen to provide the desired amount of CO$_2$ slip
  - AP-814 used for LNG applications to achieve very low residual H$_2$S & CO$_2$ content of product gas
  - Activator significantly reduces packed heights of towers
UCARSOL AP-800 Series Solvent Features (cont’d):

- High thermal and chemical stability
- Non-corrosive (no corrosion inhibitors needed)
- No solvent reclaiming or purging for typical applications
- Non-foaming
- Inventory stored in worldwide locations
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Amine Guard FS Flow Scheme Options

- Feed CO₂ & H₂S partial pressures vs. product specs
- Higher PP allows exploitation of flash regeneration
- Low level H₂S product specifications require some thermal regeneration
- Each application will have its own optimal flow scheme solution
Four Main Amine Guard FS Flow Schemes

- Flash only
- Conventional (absorber + thermal regeneration)
- 1-Stage (absorber + flash column + thermal regeneration)
- 2-Stage (1-stage system that also includes semi-lean solvent stream)
Flash-Only Flow Scheme - Application

• Simple flowscheme and therefore relatively inexpensive

• Low energy requirements

• Ideal for bulk removal of CO2

• Partial removal of H2S
Conventional and Single-Stage Flow Schemes - Application

- Can achieve CO$_2$ levels below 50 ppm for LNG specifications
- Lower solvent requirements than flash-only system
- Thermal regeneration for higher level of removal
Amine Guard FS Process

2-Stage
Advantages

• Much lower duty requirements than single-stage system

• Flexibility to trade-off solvent flow rate for thermal regenerator duty or vice-versa

Disadvantages

• Solvent requirements always higher than those for single-stage system, resulting in higher capital costs (absorber, pumps, and piping)
Flow Scheme Comparison

**Flash Only Flowscheme**
- Simplest flowscheme and therefore relatively inexpensive
- Low energy requirements
- Ideal for bulk removal of CO2
- Partial removal of H2S

**Conventional and 1-stage Flowschemes**
- Can achieve CO₂ levels below 50 ppm for LNG specifications
- Lower solvent requirements than flash-only system
- Thermal regeneration for higher level of removal

**2-stage Flowscheme**
- Much lower duty requirements than single-stage system
- Flexibility to trade-off solvent flow rate for thermal regenerator duty or vice-versa
### Flow Scheme Comparison - Reboiler Duty

1000’s BTU/lbmol CO₂ Removed

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Duty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>45-60</td>
</tr>
<tr>
<td>1-stage</td>
<td>32-40</td>
</tr>
<tr>
<td>2-stage</td>
<td>12-18</td>
</tr>
<tr>
<td>Flash only</td>
<td>8-10</td>
</tr>
</tbody>
</table>

*Higher feed CO₂ PP yields lower duty*
## Flow Scheme Comparison – Example 1

<table>
<thead>
<tr>
<th></th>
<th>1-Stage</th>
<th>2-Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed gas rate (MM SCFD)</td>
<td></td>
<td>250</td>
</tr>
<tr>
<td>$\text{CO}_2$ and $\text{H}_2\text{S}$ in feed (mole %)</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Absorber pressure (psi)</td>
<td></td>
<td>600</td>
</tr>
<tr>
<td>Lean solvent rate (gal / min)</td>
<td>2280</td>
<td>1378</td>
</tr>
<tr>
<td>Semi-Lean solvent rate (gal / min)</td>
<td>-----</td>
<td>7924</td>
</tr>
<tr>
<td>Total pump electricity usage (kW)</td>
<td>1010</td>
<td>3372</td>
</tr>
<tr>
<td>Thermal regenerator duty (MM Btu / hr)</td>
<td>101</td>
<td>59</td>
</tr>
<tr>
<td>Absorber diameter large section (ft)</td>
<td>9.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>

UOP 5241B-19
Flow Scheme Comparison – Example 2

<table>
<thead>
<tr>
<th></th>
<th>1-Stage</th>
<th>2-Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed gas rate (MM SCFD)</td>
<td></td>
<td>410</td>
</tr>
<tr>
<td>CO₂ and H₂S in feed (mole %)</td>
<td></td>
<td>18.0</td>
</tr>
<tr>
<td>Absorber pressure (psi)</td>
<td></td>
<td>1070</td>
</tr>
<tr>
<td>Lean solvent rate (gal / min)</td>
<td>6251</td>
<td>2835</td>
</tr>
<tr>
<td>Semi-Lean solvent rate (gal / min)</td>
<td></td>
<td>9676</td>
</tr>
<tr>
<td>Thermal regenerator duty (MM Btu / hr)</td>
<td>235</td>
<td>125</td>
</tr>
<tr>
<td>Total pump electricity usage (kW)</td>
<td>4071</td>
<td>7389</td>
</tr>
<tr>
<td>Absorber diameter large section (ft)</td>
<td>12.0</td>
<td>14.0</td>
</tr>
</tbody>
</table>
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Amine Guard FS Process  
Equipment Features

- Raschig Super-Rings packing or MD Trays for absorber, flash, and thermal regenerator internals to minimize tower diameter and pressure drop

- Welded plate and frame heat exchangers for Lean/Rich exchanger typically specified
  - Conventional design is Shell and Tube exchangers
  - P&F is lower cost, smaller plot space
  - P&F also tighter approach temperature, for additional heat integration

- Power Recovery Turbines

- UOP specialists assess the optimal equipment for each application
Exchangers – recent example

- S&T design required 8 shells
  - TIC - $6MM
- P&F, with tighter approach, 2 in parallel plus 1 warehouse spare
  - TIC - $1.4 MM (with spare)
  - Also, 10% reduction in reboiler duty
    - $1.3MM/yr in steam savings
Power Recovery Turbines

- Large Natural Gas Applications may be able to justify Power Recovery on Amine pressure let down from high pressure absorber to low pressure regenerator
- Recovered mechanical power can justify investment through power consumption savings
- Recent example – 2200 kW savings
  - $700,000/yr electrical savings
  - PRT equipment cost - $400,000
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Engineering With YOU
Every Step of the Way

Experience IS the Difference
Engineering With YOU
Every Step of the Way

Experience IS the Difference

Project Time Line
20+ Years

Planning
Licensor Selection
Basic Design
Training
Detailed Design
Construction
Inspection
Catalyst Loading
Startup
Test Run
Operation

Process Estimates, Plant Visits
Schedule A
Consultation and Review
Startup Services
Ongoing Services
The Schedule A Package

- First step in comprehensive transfer of technology
- Design data to YOUR preferred contractor
- Ensures your unit is:
  - Bid accurately
  - Constructed as designed
  - Reliable

*Experience IS the Difference*
UOP Schedule A Package

**Equipment Specifications**
- Columns, Vessels, and Reactors
- Fired Heaters
- Exchangers
- Pumps and Compressors
- Instruments
- Piping
- Hydraulics
- Operating manual

**Drawings**
- Process Flow Diagrams
- Piping and Instrument Diagrams
- Material Selection Diagram
- Mechanical Equipment
- Typical Plot Plan

**Standard Specifications**
- Additional design information
- Design basis
- Stream and heat transfer data
- Hydraulics
- Operating manual
UOP Engineering Experience

- Schedule A Designs: 150 - 200 per year
- Process Studies: 50 - 75 per year
- Revamps: 100 - 150 per year
Superior Technology Delivery

- Several Study & Design package options as starting points for customizing to best evaluate options & meet project objectives
- Work with EVERY major contractor worldwide
- Gas Processing Operations Experts
- Secure Private On line Transfer Server (SPOTS) enables IMMEDIATE secure transfer of project design data via the web
- UOP leading the industry to the next generation of design systems optimization (ZyCad) ⇒ fastest and lowest cost projects
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- **UOP Experience and Technical Services**
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## Commercial Experience

<table>
<thead>
<tr>
<th>Process</th>
<th>No. of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amine Guard II</td>
<td>220+</td>
</tr>
<tr>
<td>Amine Guard FS</td>
<td>30+</td>
</tr>
<tr>
<td>Dow UCARSOL</td>
<td>550+</td>
</tr>
</tbody>
</table>
## Amine Guard FS Units

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Capacity MMSCFD</th>
<th>Feed CO₂/ H₂S ppmv</th>
<th>Product CO₂/ H₂S ppmv</th>
<th>S/U Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid East</td>
<td>750</td>
<td>23,000/8,000</td>
<td>50/3</td>
<td>2004</td>
</tr>
<tr>
<td>Mid East</td>
<td>195</td>
<td>72,000/15,000</td>
<td>500/50</td>
<td>2002</td>
</tr>
<tr>
<td>Far East</td>
<td>51</td>
<td>30,000/60</td>
<td>80/4</td>
<td>2002</td>
</tr>
<tr>
<td>Mid East</td>
<td>520</td>
<td>83,000/10</td>
<td>29,000/4</td>
<td>2000</td>
</tr>
<tr>
<td>Mid East</td>
<td>52</td>
<td>143,000/17,900</td>
<td>5,000/4</td>
<td>1999</td>
</tr>
<tr>
<td>Mid East</td>
<td>122</td>
<td>52,000/540</td>
<td>30,000/8</td>
<td>1994</td>
</tr>
<tr>
<td>Mid East</td>
<td>93</td>
<td>40,000/6,000</td>
<td>100/4</td>
<td>1998</td>
</tr>
</tbody>
</table>

**Operating**
### Amine Guard FS Units

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Capacity MMSCFD</th>
<th>Feed $\text{CO}_2/\text{H}_2\text{S}$ ppmv</th>
<th>Product $\text{CO}_2/\text{H}_2\text{S}$ ppmv</th>
<th>S/U Date</th>
</tr>
</thead>
</table>
| In Design / Construction
| Mid East         | 750 x 2         | 23,000/8,000                           | 50/3                                    | 2005      |
| Mid East         | 750             | 23,000/8,000                           | 50/3                                    | 2006      |
| Far East         | 425             | 230,000/55                             | 40,000/5                                | 2005      |
| Mid East         | 1,262           | 40,000/10,300                          | 5,500/20                                | 2006      |
| Mid East         | 3,200           | 23,100/8,000                           | 8,000/3                                 | 2006      |
| Mid East         | 128             | 80,000/75                              | 50/7                                    | 2006      |
| Mid East         | 1,530 x 2       | 25,200/8,220                           | 25/2                                    | 2007      |
| Mid East         | 794             | 46,000/30,000                          | 9,400/20                                | 2007      |
| Far East         | 800             | 230,000/38                             | 3,000/1                                 | 2008      |
Technical Service

Guaranteed Performance

Before
- Design Checks
- Training
- HAZOP

During
- Unit Checkout
- On-Site Training
- Test Run

After
- Continuing Services
- Data Link Access to Process Experts
  - Remote Process Monitoring
  - Analytical Support
- Symposia
- Process Training
- Turnaround Service
- Inspection
Amine Guard FS Process Summary

- UOP has extensive commercial experience and technology expertise for acid gas removal
- Amine Guard FS utilizes state of the art UCARSOL Formulated Solvent
- Applicable to a wide variety of applications including natural gas and synthesis gas
- The Amine Guard FS process is a proven licensed technology
- Licensed approach provides ongoing technical service
- UOP Schedule A is an efficient and proven technology transfer system
- UOP can assist you in optimizing and maximizing the value of your project
Q&A