Amine Guard™ FS Process

Presenters Name Goes Here
Benefits of UOP Amine Guard FS (AGFS) process

Our technologies and products are designed to deliver superior performance, safety and value:

- A state-of-the-art solution tailored to deliver superior lifecycle economics
- Complete process guarantees enabled by licensed technology and key equipment
- Advanced-performance gas treating UCARSOL™ solvents from DOW
- Leveraging world-scale experience meeting the most complex gas treating challenges
- Start-up and after sales service to ensure high plant availability

UCARSOL is a trademark of the Dow Chemical Company
Content

- Overview and Application of AGFS Process
- AGFS Flow Schemes
- Equipment Features
- UCARSOL Solvent Features
- AGFS Experience
- Integrated Solutions for LNG Complex
- UOP Services
Overview of the AGFS Process

• Licensed Technology
  – Enables guaranteeing process performance of the plant

• Process Flexibility
  – Allows for removal of CO2 & H2S to low levels (e.g. ammonia & LNG plants)
  – Selective H2S removal, low H2S spec with up to 75% CO2 slip (e.g. IGCC, NG pipeline specs)

• Process Efficiency
  – 4 typical flow schemes, depending on application and feed gas quality
  – Addresses process efficiency through lower energy consumption

• Special Equipment Supply for Lower Economic Lifecycle Cost
  – Raschig Super Rings, for lower pressure drop and smaller column diameters

• UCARSOL Solvent from DOW
  – Multiple blends designed to meet a variety of gas treating specifications
Applications of AGFS Process

• Pretreatment of LNG feed gas

• Natural gas treating to efficiently meet pipeline specifications

• Steam reformed ammonia plants

• Direct iron ore reduction

• As part of integrated flow schemes to address complex treating challenges
AGFS Flow Scheme Options

- Feed gas quality and product specs
  - Feed CO₂ & H₂S partial pressures
  - Product gas application – pipeline quality gas, NGL, ammonia or LNG
- Higher partial pressure leverages flash regeneration
- Low level H₂S product specs require some thermal regeneration
- 4 typical AGFS flow schemes

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Feed gas quality</th>
<th>Desired product gas quality</th>
<th>Typical application</th>
<th>Reboiler Duty (*MBtu/lbmol CO₂ removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash only</td>
<td>Very high acid gas (&gt;12%)</td>
<td>&gt;2% CO₂</td>
<td>Pipeline NG</td>
<td>8-10</td>
</tr>
<tr>
<td>Conventional</td>
<td>Low acid gas (&lt;7%)</td>
<td>50ppm CO₂</td>
<td>LNG</td>
<td>45-60</td>
</tr>
<tr>
<td>1-stage</td>
<td>High acid gas (7%-12%)</td>
<td>50-1000ppm CO₂</td>
<td>LNG, NGL</td>
<td>32-40</td>
</tr>
<tr>
<td>2-stage</td>
<td>Very high acid gas (&gt;12%)</td>
<td>500ppm CO₂</td>
<td>Ammonia</td>
<td>12-18</td>
</tr>
</tbody>
</table>
Amine Guard FS Process
*Flash Only*

Configuration Suitable for Pipeline Quality Natural Gas

- Simple flow scheme and therefore relatively inexpensive
- Low energy requirement
- Ideal for bulk removal of CO$_2$
- Partial removal of H$_2$S

Diagram:
- Sweet Gas
- Amine Absorber
- Feed Gas
- Make-Up Water
- Rich Solution Heater
- Flash Gas to Fuel Header
- Acid Gas Cooler
- Acid Gas KO Drum
- Filtration System
- Re却 Pump
-Lean Solution Pump
- Rich Flash Drum or Column
- Reflux Pump
- Make-Up Water
- Rich Flash Drum
- Acid Gas
- Make-Up Water

Legend:
- XXXXXX
Amine Guard FS Process
Conventional

Configuration Suitable for LNG and NGL

Achieves CO₂ level below 50ppm

Lower solvent requirements than flash-only system

Achieves H₂S level below 4ppm
Amine Guard FS Process
1-Stage

Achieves CO₂ level below 50ppm
Lower energy requirement than conventional system
Achieves H₂S level below 4ppm

Configuration Suitable for LNG and NGL
Amine Guard FS Process
2-Stage

- Sweet Gas
- Make-Up Water
- Lean Solution Pump
- Lean Solution Cooler
- Acid Gas
- Acid Gas KO Drum
- Filtration System
- Make-Up Water
- Acid Gas Cooler
- Flash Gas to Fuel Header
- Rich Flash Column
- Reflux Pump
- Rich Flash Drum
- Semi-Lean Solution Pump
- Make-Up Water
- Rich Solution Pump
- Lean Solution Pump
- Lean/Rich Exchanger
- Lean Solution Booster Pump
- Amine Reboiler
- Amine Stripper

Much lower duty requirements than 1-stage system
Flexibility to trade-off solvent flow rate for thermal regenerator duty or vice-versa

Configuration Suitable for LNG and Ammonia
## Flow Scheme Comparison

<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>250</td>
<td></td>
</tr>
<tr>
<td>CO₂ and H₂S in feed (mole %)</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Absorber pressure (psi)</td>
<td>600</td>
<td></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>
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<tr>
<td>Total pump electricity usage (kW)</td>
<td>1010</td>
<td>3372</td>
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<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>

**Solvent Requirements Higher than those for Single-Stage System, Resulting in Higher Capital Costs**
Amine Guard FS Process
Equipment Features

- Internals
  - 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
  - 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 Turbine option

- UOP specialists assess the optimal equipment for each application
Raschig Super-Ring Applications

- Gas Processing Licensed Units
  - Amine Guard FS Process
  - SeparALLTM Process
  - BenfieldTM Process

- Typical GP Unit columns
  - Absorbers (CO2 & H2S)
  - Regenerators
  - HP & LP Flash columns
  - Concentrators

- 120+ applications in GP Units

Commercial Successes in Multiple UOP Technologies
Raschig Super-Ring Value

For a customer that needs a highly efficient and cost effective random packing in UOP’s AGFS technology, RSR provides TIC savings in the AGFS columns in the range of 10-20% which translates into savings of over $1M. These savings are achieved by:

- Higher solvent loading capacity
- Reduced column diameters

![Graph showing TIC savings and additional packing cost]
## AGFS LNG Case Study #2 (RSR vs. ALTP)

<table>
<thead>
<tr>
<th>AGFS LNG Case Study</th>
<th></th>
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<tbody>
<tr>
<td>Feed Gas Rate</td>
<td>1035</td>
<td>MMSCFD</td>
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<tr>
<td>Solvent Circulation Rate</td>
<td>2469</td>
<td>gpm</td>
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<tr>
<td>Feed CO2</td>
<td>2.0</td>
<td>mol %</td>
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</table>

<table>
<thead>
<tr>
<th>Column Dimensions</th>
<th>Absorber</th>
<th>Regenerator</th>
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</thead>
<tbody>
<tr>
<td>Column Diameter, RSR vs. ALTP, ft</td>
<td>RSR#2</td>
<td>ALTP#50</td>
</tr>
<tr>
<td>Column Diameter, RSR vs. ALTP, ft</td>
<td>15.5</td>
<td>17</td>
</tr>
<tr>
<td>Column Diameter, RSR vs. ALTP, ft</td>
<td>20 (Bottom)</td>
<td>20 (Bottom)</td>
</tr>
<tr>
<td>Column T/T, RSR vs. ALTP, ft</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>Packing Height, ft</td>
<td>2 x 25 + 1 x 3.25</td>
<td>2 x 20</td>
</tr>
</tbody>
</table>

### Cost Comparison

<table>
<thead>
<tr>
<th>Cost Comparison</th>
<th>RSR</th>
<th>ALTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop Floor Column Cost</td>
<td>80.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Packing Cost</td>
<td>110.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total Installed Column Cost</td>
<td>83.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total Savings</td>
<td>16.5%</td>
<td></td>
</tr>
</tbody>
</table>
Amine Guard FS Process

Equipment Features

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)
  – 10% reduction in reboiler duty
    • $1.3MM/yr in steam savings

• Power recovery turbines

• Large NG applications … justifies power recovery on amine pressure let down from HP absorber to LP 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
DOW UCARSOL Solvent

BENEFITS

• Utilizes advanced amine formulation technology for enhanced performance
• High thermal and chemical stability; non-corrosive
• No foaming problems
• Inventory maintained worldwide
• An MDEA based solvent requiring only low concentrations of activator
  – Activator accelerates slow overall kinetics of CO2 reaction with MDEA
  – Solvent formulation is tailored to deliver the desired amount of CO2 slip
  – AP-814 formulation for LNG applications achieves very low residual H2S & CO2 content in product gas
  – Activator enables reduced packed heights of towers
<table>
<thead>
<tr>
<th>Process</th>
<th>No. of Projects</th>
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<tr>
<td><strong>Amine Guard Process</strong></td>
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<tr>
<td>Amine Guard I, II, III and IV</td>
<td>215</td>
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<tr>
<td>Amine Guard FS</td>
<td>35</td>
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<tr>
<td>Total</td>
<td>240</td>
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<tr>
<td><strong>UCARSOL Solvents</strong></td>
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<tr>
<td>UCARSOL AP Series</td>
<td>235</td>
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<tr>
<td>UCARSOL HS Series</td>
<td>245</td>
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<td>Total</td>
<td>480</td>
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## Amine Guard FS Units

<table>
<thead>
<tr>
<th>Location</th>
<th>Solvent Series</th>
<th>Plant Capacity</th>
<th>Feed Gas Composition</th>
<th>Treated Gas Specification</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PPMV CO₂</td>
<td>PPMV H₂S</td>
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<tr>
<td>Middle East</td>
<td>UCARSOL</td>
<td>122</td>
<td>52000/540</td>
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<tr>
<td>Middle East</td>
<td>UCARSOL</td>
<td>52</td>
<td>143000/17900</td>
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<tr>
<td>Middle East</td>
<td>CR Series</td>
<td>93</td>
<td>40000/6000</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>195</td>
<td>72000/15000</td>
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<tr>
<td>SE Asia</td>
<td>AP-800</td>
<td>51</td>
<td>30000/60</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>750</td>
<td>23000/8000</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>750</td>
<td>23000/8000</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>750</td>
<td>23000/8000</td>
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<tr>
<td>SE Asia</td>
<td>AP-800</td>
<td>425</td>
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<td>SE Asia</td>
<td>AP-800</td>
<td>324</td>
<td>80000/30</td>
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# Amine Guard FS Units

<table>
<thead>
<tr>
<th>Location</th>
<th>Solvent Series</th>
<th>Plant Capacity</th>
<th>Feed Gas Composition</th>
<th>Treated Gas Specification</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PPMV CO₂</td>
<td>PPMV CO₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PPMV H₂S</td>
<td>PPMV H₂S</td>
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<tr>
<td>N. America</td>
<td>AP-800</td>
<td>45</td>
<td>715000/4100</td>
<td>157000/850</td>
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<tr>
<td>Middle East</td>
<td>HS Series</td>
<td>188</td>
<td>54400/83000</td>
<td>30000/5</td>
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<td>Asia</td>
<td>AP-800</td>
<td>68</td>
<td>217000/0</td>
<td>104000/0</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>2500</td>
<td>23100/8000</td>
<td>8000/3</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>128</td>
<td>80000/75</td>
<td>50/7</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>1262</td>
<td>40000/10300</td>
<td>5500/20</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>794</td>
<td>46000/30000</td>
<td>9400/20</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>1530</td>
<td>25200/8220</td>
<td>25/2</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>1530</td>
<td>25200/8220</td>
<td>25/2</td>
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<tr>
<td>Middle East</td>
<td>AP-800</td>
<td>1530</td>
<td>25200/8220</td>
<td>25/2</td>
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<tr>
<td>SE Asia</td>
<td>AP-800</td>
<td>800</td>
<td>2300000/38</td>
<td>3000/1</td>
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</tbody>
</table>
UOP Integrated Solution

**UOP Amine Guard FS Process**
- Removes CO₂ & H₂S in treated gas.
- Removes most COS & some RSH.

**UOP Molecular Sieve Ethane Treater**
- Removes H₂S, COS and RSH in C₂ to achieve Total S spec.

**UOP Molecular Sieve Propane Treater**
- Removes COS and RSH in C₃ to achieve Total S spec.

**UOP Molecular Sieve Butane Treater**
- Removes RSH in C₄ to achieve Total S spec.

**Orloff NGL Recovery & Fractionation**

**Lean Process Gas**

**Rich Process Gas**

- C₁ to Sales
- C₂
- C₃
- C₄
- C₅⁺ to Sales

**UOP SELEXOL Process**
- Removes RSH, and partial removal of H₂S and COS from regen gas.

**Flash Gas to Fuel Gas**

**Acid Gas containing CO₂, COS and H₂S to SRU**

**Treated Gas Cooler**

**Spent Regen Gas**

**Recycle Gas Compressor**

**Natural Gas Feed**

**Sales Gas**

**Integrated Solution for RasGas Project ...Commercial Success**
## UOP LNG & NGL World Scale Experience

### Integrated Processing Flow Scheme

<table>
<thead>
<tr>
<th>Project Location</th>
<th>Capacity, MMSCF/Day</th>
<th>Technologies</th>
<th>Application</th>
<th>S/U Date</th>
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</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>4 x 625</td>
<td>B, M3</td>
<td>LNG+NGL</td>
<td>80’s</td>
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<tr>
<td>Adgas</td>
<td>2 x 225</td>
<td>B, M3</td>
<td>LNG+NGL</td>
<td>85</td>
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<tr>
<td>Adgas</td>
<td>550</td>
<td>B, M3</td>
<td>LNG+NGL</td>
<td>95</td>
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<tr>
<td>RasGas</td>
<td>3 x 750</td>
<td>A, M, S, O</td>
<td>LNG</td>
<td>04/05/06</td>
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<tr>
<td>RasGas</td>
<td>750</td>
<td>A, M3, S, O</td>
<td>SG</td>
<td>05</td>
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<tr>
<td>Dolphin</td>
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<td>A2, M3</td>
<td>SG+NGL</td>
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<tr>
<td>Gasco</td>
<td>2 x 625</td>
<td>A, O</td>
<td>SG+NGL</td>
<td>08/09</td>
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<tr>
<td>Gasco</td>
<td>2 x 400</td>
<td>A, O</td>
<td>SG+NGL</td>
<td>09</td>
</tr>
<tr>
<td>QatarGas</td>
<td>2 x 1400</td>
<td>M3, S, O</td>
<td>LNG+NGL</td>
<td>08/09</td>
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<tr>
<td>RasGas</td>
<td>2 x 1500</td>
<td>A, M3, S, O</td>
<td>LNG+NGL</td>
<td>09</td>
</tr>
<tr>
<td>RasGas</td>
<td>1600</td>
<td>A, M4, S, O</td>
<td>SG+NGL</td>
<td>09</td>
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<tr>
<td>QatarGas</td>
<td>2 x 1400</td>
<td>M3, S, O</td>
<td>LNG+NGL</td>
<td>09/10</td>
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<tr>
<td>Gasco (SGD)</td>
<td>2 x 900</td>
<td>M, S, O</td>
<td>SG+NGL</td>
<td>12/15</td>
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<tr>
<td>RasGas (Barzan)</td>
<td>3 x 980</td>
<td>A, M, S, O</td>
<td>SG+NGL</td>
<td>12/15</td>
</tr>
</tbody>
</table>

**26.69 Bcf/Day**

A - UOP Amine Guard FS Unit  
B - UOP Benfield Unit  
M - UOP Molecular Sieve System  
O - Ortloff NGL Unit  
S - UOP Selexol Unit  
I - Integrated
UOP LNG Experience

Commercially Successful Solution in World Scale LNG Project
UOP as Your Technology Provider

• Organizational Structure: UOP is focused on processing applications and markets.

• Workforce Stability: UOP’s subject matter experts are recognized authorities and maintain their relevancy by moving the technology forward.

• UOP’s Deliverables: UOP delivers more than technology. UOP delivers technical capability.

• UOP’s support network: UOP’s support personnel are familiar with integration, start-up and operations.

• What drives UOP: For our customer we move the technology forward.
  – Feedback: Lesson Learned and Management of Change

Deep Understanding of Your Process Needs
Single Source vs. Multiple Suppliers

- **Multiple Suppliers (EPC is the process lead and integrator)**
  - EPC Works to pull together technologies
  - EPC defines feed streams to/from each unit
  - EPC engineers the interfaces
    - Guarantees the intermediate streams
    - Manages finger pointing between suppliers

- **Single Supplier (UOP Coordinates with EPC for integration)**
  - No handoff between technology suppliers
  - No delays for process iteration between suppliers
  - Intimate Open conversation on optimization
  - Easy process/heat integration
  - One Single Overall guarantee backed by UOP
  - Single source for training and site services

*Provides Complete Solution to Complex Challenges*
## Technology Providers

<table>
<thead>
<tr>
<th>Technology Provider</th>
<th>UOP</th>
<th>ALT1</th>
<th>ALT2</th>
<th>ALT3</th>
<th>ALT4</th>
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<tbody>
<tr>
<td>Amine for H2S and COS removal</td>
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<td></td>
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<tr>
<td>Molecular sieves for H2O removal</td>
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<td>√</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Molecular sieves for S removal</td>
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<tr>
<td>Regenerative Mercury removal</td>
<td>√</td>
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<td></td>
</tr>
<tr>
<td>Non-regenerative Mercury removal</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>C5+ removal</td>
<td>√</td>
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<tr>
<td>Unknown Contaminant Removal</td>
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</tr>
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</table>

*UOP is the One Stop Shop to Collaborate with Your EPC*
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
To Summarize

- The Amine Guard FS process is a proven licensed technology
- Licensed approach provides ongoing technical service
- Amine Guard FS utilizes state of the art UCARSOL Formulated Solvent
- UOP has extensive commercial experience and technology expertise for acid gas removal
- UOP can assist you in optimizing and maximizing the value of your project

<table>
<thead>
<tr>
<th>AGFS Process</th>
<th>Range of Application</th>
<th>Type of Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selective H₂S removal (CO₂ slippage)</td>
<td>- Natural Gas to Pipeline Specs</td>
</tr>
<tr>
<td></td>
<td>Trim Removal of H₂S and CO₂</td>
<td>- Natural Gas to LNG Specs</td>
</tr>
<tr>
<td></td>
<td>COS Removal</td>
<td>- Syngas for H₂, NH₃ &amp; Chemicals</td>
</tr>
<tr>
<td></td>
<td>Limited RSH removal</td>
<td></td>
</tr>
</tbody>
</table>