Agenda

• Integrated onshore and offshore gas pretreatment upstream of LNG unit
  – Hg Management
  – Molecular Sieves
  – UOP Separex™ Membrane
  – UOP Amine Guard™ FS Process
  – Ortloff NGL/LPG Technology
Integrated LNG Pretreatment
Offshore Application

**UOP GB-562**
Absorbent Mercury Removal Unit

**UOP Separex**
Membrane System

**UOP Amine Guard FS**
Process Unit

Feed Gas

Mercury

Permeate Gas
\[ CO_2 + H_2S \]

Sour Gas
\[ CO_2 + H_2S \]

**UOP MOLSIV™**
Dehydration Unit

**Ortloff NGL/LPG**
Technology

Treated Gas to LNG

Water

LPG/NGL

Treated Gas to LNG
### Gas Composition Variations in Key Areas

<table>
<thead>
<tr>
<th></th>
<th>Middle East</th>
<th>Africa</th>
<th>Pacific Rim</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$S, mol-%</td>
<td>0.1 - 2.9</td>
<td>0 - 0.2</td>
<td>0 - 0.02</td>
</tr>
<tr>
<td>CO$_2$, mol-%</td>
<td>2 - 7</td>
<td>2 - 7.5</td>
<td>9 - 45</td>
</tr>
<tr>
<td>RSH, ppmv</td>
<td>0 – 400+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>COS, ppmv</td>
<td>1 - 40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hg, μg/Nm$^3$</td>
<td>0 - 50</td>
<td>1 - 130</td>
<td>200 - 2000</td>
</tr>
</tbody>
</table>

Different locations require different processing schemes.
# Typical Product Specifications

<table>
<thead>
<tr>
<th></th>
<th>Treated Gas Specs For:</th>
<th>Liquid Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pipeline</td>
<td>LNG</td>
</tr>
<tr>
<td>$\text{H}_2\text{S}$, ppmv</td>
<td>&lt;4</td>
<td>&lt; 2 – 4</td>
</tr>
<tr>
<td>Total Sulfur, ppmv</td>
<td>&lt; 20 - 50</td>
<td>&lt; 10 - 50</td>
</tr>
<tr>
<td>$\text{CO}_2$</td>
<td>&lt;2% – 8%</td>
<td>&lt; 50 ppmv</td>
</tr>
<tr>
<td>$\text{Hg}$, $\mu$g/Nm$^3$</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}$, ppmv</td>
<td>&lt;7 lb/MMSCF</td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>
RasGas 3, 4, 5 Design Basis - Onshore
UOP Integrated Flowscheme – Block Flow Diagram

**Acid Gas** to Claus SRU
Limit on Hydrocarbon

**Product Gas Specifications**
- ppm level of CO₂, Total Sulfur & H₂S,
- Very low levels of H₂O & Hg

**Feed**
- 750 MMSCFD
- CO₂, H₂S
- High RSH content, Hg

**Acid Gas Removal Unit**
(UOP Amine Guard™ FS Unit)

**Dehydration, RSH, & Hg Removal**
(UOP Molecular Sieve System)

**RSH Removal**
(UOP Selexol™ Unit)

**Sweet Gas**
- to Fuel
- ppm level of RSH

**Acid Gas**
- to Claus
- Limit on RSH

**Integrated Flow Scheme**
UOP 5241D-05
RasGas Trains - Ras Laffan, Qatar

Train 6 – Started Up
Train 7 – Near Mechanical Completions

Source: Presentation at LNG 15, The Value of Replication, RasGas Experience in the Execution of LNG trains 3, 4 and 5
FLNG Vessel Topsides
Fitting in the Pretreatment Section

Mooring System

Inlet Separation/Field Specific

Gas Pretreatment (UOP)

Liquefaction/Unloading

LNG Storage

Utilities/Control/Fire Safety/Security (Honeywell-HPS)

Natural Gas Reserves

Sub-sea Gas Pipeline

UOP can be single source for gas pretreatment

UOP 5304-07
**Pretreatment Considerations**

- Wide range of feed conditions
- Removal of mercury, acid gases and water
- Modular equipment design
- Weight, footprint, and center of gravity optimized to overall ship design
- Feed flow to pretreatment sized for one to several trains of liquefaction
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• **Mercury Removal** – to prevent damage to aluminum heat exchanger in LNG or NGL cold boxes. Specification typically < 0.01 μg/Nm³

• **Dehydration** – feed gas dried to < 0.1 ppmv of H₂O to avoid freezing in LNG or NGL unit

• **Desulfurization** – removal of mercaptans and other sulfur compounds to meet product specifications. Specifications typically 10 to 50 ppm total sulfur

• **CO₂ Removal** – viable if feed gas < 2 % CO₂. Specifications typically < 50 ppm
Mercury Removal Unit

Feed Gas

Fixed-Bed Non-Regenerative MRU with GB-562

Particle Filter
UOP Molsiv™ Adsorbent Technology

Natural Gas Dehydration

Feed → Dehydration → Product Gas

Typical Op. Parameters:
• Temperature: 25 – 30 °C
• Product Spec.: < 0.1 ppmv H₂O

Natural Gas Dehydration & Sweetening

Feed → Dehydration → Sulfur Compounds → Mercury → Product Gas

Typical Op. Parameters:
• Temperature: 25 – 30 °C
• RSH up to 400 ppmv in feed
• Product Spec.: < 0.1 ppmv H₂O
  < 14 ppmv TSx
  < 1 ppmv H₂S

Multiple adsorbent layers are used to remove different components
UOP HgSIV™ Adsorbent

- Regenerative Hg removal adsorbent
- Simultaneous removal of water and mercury
- Achieves 0.01 ug/Nm3 specification
- Standard Molecular Sieve characteristics
- Original installation in 1989
- Treating 5 BCFD of natural gas in > 50 units
- Typically no impact on unit size
- In combination with non-regenerative GB absorbents mercury sequestration is possible
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Separex™ Membranes

- Not a filtration process
- Solution-Diffusion based separation process
  - Components dissolve into membrane surface and diffuse through it
  - More soluble components permeate quicker
  - Smaller components permeate quicker

Membranes are characterized by permeability (flux) and selectivity
Compact Module Design for Offshore
Separex Membrane: Key Features

- Bulk CO$_2$ removal
- Modules allow very low installation cost
- Easy to start-up, operate, turndown and shutdown
- High reliability and on-stream time
- Weight and space efficiency
- Operates dry - no flammable liquid inventories, refrigerants or chemicals
- Meets offshore requirements for deinventory during ESD
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What is the Amine Guard FS Process?

• Amine Guard Formulated Solvent (AGFS) technology with process guarantees
• Allows removal of CO₂ and H₂S to very low levels
• Sourced from UCARSOL™ line of solvents
• Low energy options
• Extensive commercial experience in LNG applications
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Ortloff: NGL/LPG Recovery
Sulphur Recovery (SRU – Claus)

- Ortloff Engineers, Ltd. (1960 - 2009)
- Over 17 Patented NGL/LPG Recovery Technologies
- Experience
  - 94 NGL/LPG Recovery Units (57 New, 37 Retrofits)
  - 76 Sulfur Recovery Plants

NGL/LPG Recovery

- Ortloff Technology Can Provide
  - Increased recovery with *no* increase in horsepower
  - Increased capacity with *no* increase in horsepower
  - Lower capital cost

- Improved Plant Reliability
  - Better CO₂ tolerance
  - Eliminates critical phase envelope problems

- Improved Plant Operating Flexibility
  - Ethane recovery / rejection mode of operation

Example: Gas Subcooled Process (GSP)

Ortloff also provides Claus (SRU) technology
Integrated LNG Pretreatment
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UOP MOLSIV Dehydration Unit

Orloff NGL/LPG Technology

Water

LPG/NGL

Treated Gas to LNG
Advantages – Single Source Pretreatment Supplier

- Consistent engineering design work between UOP technology groups
- Eliminates schedule delays as design iterations between process units are efficiently closed out
- Supply of specialty equipment with lower cost and higher performance
- Single source for operator training, commissioning and start up support
- Single source for continuing technical services
- Single source for OVERALL performance guarantee
Typical UOP Scope of Supply

- **Mercury Removal Unit (MRU)**
  - Size vessel and amount of absorbent & support media. Provide vessel sketch and can review vessel fabrication drawing if requested

- **Separex Membrane**
  - Delivered as fully fabricated skid complete with instrumentation and skid-edge piping

- **Amine Guard FS Process**
  - Basic Engineering Package, Proprietary Equipment, and Initial fill of solvent

- **MOLSIV**
  - Same as MRU

*Alternatively UOP can supply Pretreatment as an Integrated Equipment Module*
Q & A