Amine Plant Energy Requirements & Items impacting the SRU

10 October 2016
AGRU energy needs

Amine energy requirements
  – Regeneration
  – Processing effects
Leanness required
  – Determine required leanness
  – Over stripping
Energy sources
  – In amine system
  – Sulphur conversion waste heat loss due to AGRU

SRU energy supply

Waste heat
  – Reactor
  – Incinerator
in excess of SRU/TGT needs,
Is there more to save?

Optimisation dependent on operating conditions
All quoted figures are indicative
Amine closed system – chemical reaction

The amine solvent loading is set by temperature and partial pressure of H₂S and CO₂ in a certain %wt amine solvent, determined by equilibrium, kinetics and the mass transfer between gas and liquid phase.

Regenerator temperature, typical 115 °C < T < 140 °C
Regenerator pressure, typical 1.5 < p < 2.5 bara

Absorber temperature, typical 30 °C < T < 65 °C
Absorber pressure, typical 1.1 < p < 100 bara
Amine energy consumers

Solvent regeneration heat

Reboiler steam 75 – 95% of energy consumption in amine system

- Several components require energy (heat)
  - Desorption
  - Heating of solvent to regenerator bottom condition
  - Internal generation of steam in regenerator reboiler

Heating medium: low pressure steam, also because of the constraint of thermal degradation of the amine at high temperature

Solvent circulation pumps

Remainder of total energy consumption depending on pressure differential and solvent properties

Air cooling is a minor energy consumer compared to other energy consumers
Amine – energy generation

Typical amine solvent

<table>
<thead>
<tr>
<th>Amine type</th>
<th>kJ/kmol H₂S</th>
<th>kJ/kmol CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%wt DGA</td>
<td>54</td>
<td>99</td>
</tr>
<tr>
<td>50%wt MDEA</td>
<td>40</td>
<td>70</td>
</tr>
</tbody>
</table>

Equilibrium partial pressure of H₂S

Energy balance absorber
Absorber Heat (Enthalpy) Balance

Heat of absorption (energy make) determined by:

- Solvent type
  - \(C_p\) (for energy balance)
- Amine type
- Solvent %wt amine
- Type of treating
  - selectivity
  - other components removal
- Feed gas pressure
- Feed gas composition - \(C_p\)
- Lean solvent temperature
  - prevention HC condensation criteria
- Feed gas acid content
- Sweet gas specification

In principle independent of type of internals unless heat distributions is hampered
The maximum temperature is usually above the bottom tray

Heat of absorption is larger when the loading is smaller, thus not a constant!
Amine – energy consumption for regeneration

Equilibrium partial pressure of H₂S

Typical amine solvent

<table>
<thead>
<tr>
<th>Amine type</th>
<th>kJ/kg H₂S</th>
<th>kJ/kg CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%wt DGA</td>
<td>1570</td>
<td>1972</td>
</tr>
<tr>
<td>50%wt MDEA</td>
<td>1045</td>
<td>1340</td>
</tr>
</tbody>
</table>

Energy balance regenerator

Solvent loading (mol/mol)
Amine Regeneration (Heat) Enthalpy balance

Heat for regeneration determined by:

- Solvent type
  - \( C_p \) (for energy balance)
- Amine type
  - Rich solvent loading and temperature after flash and L/R HE
- Solvent %wt amine
  - Solvent boiling temperature reboiler
- Type of treating
  - selectivity
  - other components removal
- Regenerator bottom pressure
  - Downstream unit pressure drop
  - Type of internals
  - Sweet gas specification
- Reflux temperature

Hydraulic constraint at regenerator inlet due to flashing and flow pattern may limit

Overstripping causes corrosion/erosion
Steam requirements regenerator

The required solvent leanness is determined by the sweet gas specification

\[ S_s = \text{sensible heat} \]
heating solvent to bottom temperature

\[ S_r = \text{heat of reaction} \]
chemical desorption of H₂S, CO₂, other

\[ S_t = \text{top steam} \]
for sufficiently low acid partial pressure in the lean solvent at feed tray, minimum applied by process vendors

\[ S_b = \text{bottom steam (kg/m}^3\text{)} \]
\[ = S_t + S_s + S_r \]
minimum applied by process vendors
Regenerator Bottom Temperature

- The regenerator bottom temperature is determined by the amount of steam generated in the reboiler, which is a boiling aqueous amine at the bottom pressure:
  - The more steam is generated, the higher the pressure drop ($\Delta P$) across the regenerator trays, more gas phase
  - The higher the pressure drop, the higher the regenerator bottom pressure ($P_0 + \Delta P$)
  - The higher the bottom pressure, the higher the bottom temperature

- NB similar effect due to the stripping of acid gas in the reboiler is very small, because the solvent leanness should be met at the stripping stage

- Reboiler external steam $\neq$ regenerator steam
**AGRU internal energy saving**

Inside AGRU  **Turbo expander**

- High pressure absorber only
- Not on one shaft with solvent pump
- Saving on pump power dependent on pressure difference
AGRU internal energy saving

Inside AGRU  Lean/rich heat exchanger

Optimisation limited by:
- Regeneration needs (see leanness)
- Type of heat exchanger
- Use of low pressure steam limitation
- Solvent loading (flashing in HE)
- Fouling system
- System configuration (vibration due to 2 phase flow in vertical regenerator inlet piping)
AGRU and SRU interfaces

Outside AGRU affecting SRU

\[ \text{H}_2\text{S} + R_3\text{N} \rightleftharpoons \text{HS}^- + R_3\text{NH}^+ \]

\[ \text{H}_2\text{S} + \frac{1}{2}\text{O}_2 \rightleftharpoons \text{S} + \text{H}_2\text{O} \]
Entrained and soluble hydrocarbon route

When the color is more intensive, there is more entrained than soluble rated hydrocarbon in the stream.
SRU affected by hydrocarbon from amine unit

Hydrocarbon content in SRU feed gas
- Preferably below 1% vol
- Maximum 5% vol
  - Air consumption increase thus
    - Reduction maximum capacity
    - Therefore the overall Sulphur conversion
  - Energy consumption increase

However

<table>
<thead>
<tr>
<th>Hydrocarbon composition fluctuation</th>
<th>Unburned liquid and heavy HC form soot on catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Sulphur</td>
<td>Can even block Sulphur rundown</td>
</tr>
</tbody>
</table>

Fast composition changes cannot be controlled by analysers due to dead time.

This can be handled by Tail gas analyser when change is slow.
Co-absorption of CO₂ – selective treating

\[ \text{Ratio} = \frac{\text{H}_2\text{S}}{\text{CO}_2} \]

\[ \text{H}_2\text{S} + \frac{1}{2}\text{O}_2 \rightleftharpoons \text{S} + \text{H}_2\text{O} \]

\[ \text{H}_2\text{S} + R_3\text{N} \rightleftharpoons \text{HS}^- + R_3\text{NH}^+ \]
**CO₂ co-absorption determining parameters**

CO₂ co-absorption reduction design parameters based on:

- **Chemical** equilibrium differences H₂S and CO₂
  - Meeting equilibrium would require infinite # trays/packing height
  - Competition H₂S and CO₂
  - Equilibrium condition dependent

- **Reaction kinetics**
  - H₂S has a very fast reaction at the gas phase
  - CO₂ has a slow reaction in the liquid bulk, BUT
    - CO₂ accelerator, even in minimum amount, destroys selectivity

- **Gas/Liquid mass transfer**
  - Type of absorber internals – gas/liquid interface, residence time
Reduction of CO$_2$ co-absorption

Optimise **DESIGN/DEBOTTLENECK** based on realistic operating window, may be seasonally different

- Solvent selection and concentration
- Absorber temperature (different effect at high and low pressure)
- Flash vessel temperature and pressure
- Include sufficient on-line stream analysers for main components, include logic in control
  - based on simulations
  - based on operating experience
- Select the best practice internals to reduce entrainment (as with hydrocarbon)

Optimise **OPERATION** within the equipment constraints in an existing plant

- Awareness of the contributing operational conditions
  - is beyond pressure and temperature
  - in an amine unit slow and smooth operational changes can be applied, opening on the run optimisation (based on modeling)
- Check if conditions change (new wells) and find new optimum
  - process simulation may help, but mostly is not refined enough
AGRU operation trends affect energy demand

Inside AGRU

Parameter trends in next slides
## Energy influencing trends

<table>
<thead>
<tr>
<th>Solvent variables</th>
<th>%wt amine, heat of reaction</th>
<th>Feed gas H₂S and CO₂</th>
<th>Accelerator CO₂ removal</th>
<th>Accelerator effectiveness</th>
<th>Deeper spec H₂S</th>
<th>Deeper spec CO₂</th>
<th>Integration AGRU/TGT/AGE</th>
<th>%wt amine, C₀</th>
<th>Mercaptan removal</th>
<th>Hybrid solvent swap</th>
<th>Type of amine, prim, sec, tert</th>
<th>No trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy influencing trends</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

- **%wt amine, heat of reaction**: Increase
- **Feed gas H₂S and CO₂**: Increase
- **Accelerator CO₂ removal**: Increase
- **Accelerator effectiveness**: Increase
- **Deeper spec H₂S**: Increase
- **Deeper spec CO₂**: Increase
- **Integration AGRU/TGT/AGE**: Decrease
- **%wt amine, C₀**: Increase
- **Mercaptan removal**: Increase
- **Hybrid solvent swap**: No trend
- **Type of amine, prim, sec, tert**: No trend
<table>
<thead>
<tr>
<th>Operating variables</th>
<th>AGRU</th>
<th>TGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating pressure absorber</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Trays or packing regenerator</td>
<td>↑</td>
<td>Trays</td>
</tr>
<tr>
<td>Operating pressure absorber</td>
<td>↑</td>
<td>TGT</td>
</tr>
<tr>
<td>Lean solvent temperature</td>
<td>↑</td>
<td>Total removal, High pressure</td>
</tr>
<tr>
<td>Lean solvent temperature</td>
<td>↑</td>
<td>Selective H2S removal, Low pressure</td>
</tr>
<tr>
<td>Operating pressure regenerator</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Pressure drop regenerator</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Rich solvent inlet temperature</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Regenerator limit bottom</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>External steam flow</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>External steam temperature</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>High Sulphur Recovery (TGT)</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Foaming tendency</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Retrograde HC condensation</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Solvent quality</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>STEADY OPERATION</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Solvent rich loading</td>
<td>↑</td>
<td>Bottom limit</td>
</tr>
<tr>
<td>Material integrity (corrosion)</td>
<td>↑</td>
<td>Case dependent</td>
</tr>
<tr>
<td>Regenerator overhead temperature</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Regenerator reflux temperature</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

Energy influencing trends

Risk of overstripping
Risk of overstripping and degradation
### Energy influencing trends

#### Hardware

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trays or packing absorber</td>
<td>Tray</td>
</tr>
<tr>
<td>Trays or packing regenerator</td>
<td>Tray</td>
</tr>
<tr>
<td>Isometrics, pressure drop</td>
<td>Tray</td>
</tr>
<tr>
<td>Turbo expander</td>
<td></td>
</tr>
<tr>
<td>Header system between processes</td>
<td></td>
</tr>
<tr>
<td>Type of HE, pressure drop</td>
<td>Case dependent</td>
</tr>
<tr>
<td>Trays or HE, approach</td>
<td></td>
</tr>
<tr>
<td>Effective mechanical filter</td>
<td></td>
</tr>
<tr>
<td>Effective activated carbon filter +</td>
<td></td>
</tr>
<tr>
<td>mechanical after filter</td>
<td></td>
</tr>
</tbody>
</table>

#### More, other?

Plant and condition specific

#### Operational models can help explore options
Conclusion

AGRU design, operation and installed hardware should take into account its impact on the SRU.

Amine units have many parameters to optimise its operation. Indicative trends are presented and can be used without violating Amine unit specification.

Integrated design and operation offer energy saving options.

Know your processes – trends depend on conditions.
Discussion

Which do you use?
Thank you
Reaction heat quotes averaged from

- Oilfield Processing of Petroleum, Natural Gas, Volume 1