FCC Spent Catalyst Stripper Technology

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Coking and CatCracking Conference

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• Big Picture Overview
• Process Considerations
• Development History
• Key Design Considerations
• ModGrid™ Stripper Internals Features
• Assessing Performance
• Commercial Examples
• Critical component of the FCC reaction system
• Designed to recover hydrocarbon vapors entrained with catalyst via steam stripping
  – Reduces secondary thermal and catalytic cracking reactions
  – Reduces coke loading to the regenerator
• Significantly affects profitability of the unit
• Easy to operate and monitor
• Typically easy to revamp and upgrade
  – Relatively low investment cost and quick payouts
• Should always be evaluated when making modifications to any portion of the reactor/regenerator circuit
Effect on FCC Performance

• Directly impacts the feed conversion and overall yield selectivity from the unit

• Poor performance can result in:
  – Downgrade of valuable products
  – Increased delta-coke or coke on the catalyst
  – Increased regenerator temperature
  – Increased dry gas production
  – Loss of feed processing capacity
  – Catalyst deactivation

• Directly impacts unit steam usage / sour water production
• Key contributor to pressure build upstream of the SCSV
• Efficiently removing the hydrocarbon vapors can significantly improve the unit profitability
• FCC unit performance is dictated by a delicate coke and heat balance

• Heat produced from combustion of coke in regenerator supplies heat to operate the unit

• Four types of coke:
  – Contaminant coke from feed quality
  – Catalytic coke from feed conversion
  – Additive coke from feed metals
  – Cat-to-oil coke from entraining hydrocarbon leaving the stripper (interstitial and trapped within pores)

• Contaminant / catalytic / additive coke are functions of feed quality, catalyst type, and reactor temperature

• Cat-to-oil coke largely a function of spent catalyst stripper performance
• Understanding coke yield and delta-coke from the heat balance is important for evaluating stripper performance

\[ \text{Coke Yield} = (\text{Cat-to-Oil}) \times (\text{Delta-Coke}) \]

\[ \text{Delta-Coke} = (\text{CSC} - \text{CRC}) \alpha (T_{\text{Reg}} - T_{\text{Rxt}}) \]

• Coke yield is essentially set by operating conditions
  – Riser outlet temperature, feed preheat temperature, etc.
• Delta-coke improvements required to increase cat-to-oil
• Spent catalyst stripping efficiency directly impacts the delta-coke
Development History

- Spent catalyst stripper technology has continually evolved over several decades
- Open strippers (no internals)
- Disk and donut baffles
- Shed deck baffles
- Modifications to include holes and tubes in the baffles
- Structured packing
- Accommodation to annular stripper configurations
Development History

DISK AND DONUT

SHED DECK
Development History

BAFFLED ANNULAR STRIPPER
• Maximize cross-sectional area of the vessel available for catalyst and steam to flow through it
  – Utilize the full diameter of the stripper available
• Maximize surface area available for mass transfer per unit volume of the stripper vessel
  – Enhances mass transfer for efficient stripping and hydrocarbon recovery
• Provide thorough and uniform contact of the catalyst with the stripping steam
  – Further enhances mass transfer
• Provide uniform catalyst fluidization
  – Minimizes stagnant zones that reduce stripping efficiency and promote coke formation
  – Minimizes channeling and bypassing
Stripper Key Design Considerations

• Manage the catalyst flux through the stripper
  – Provides adequate residence time for stripping
  – Prevents vapor drag into the regenerator

• Optimize the vapor bubble sizes throughout the stripper
  – Large bubbles rise faster and reduce contacting surface area
  – Smaller bubbles improve area but can be pulled down

• Maximize pressure build through the stripper
  – Provides flexibility for increased cat-to-oil
  – Closely tied to catalyst fluidization

• Optimize location of the stripping steam distributor
  – Provide ideal steam coverage entering the stripper internals
  – Minimize steam drag to the regenerator

• Minimize stripping steam requirement
  – Reduces sour water production and cyclone velocities
Stripper Key Design Considerations

• Provide wide range of operation
  – Maintain performance from turndown to max throughput
• Ensure catalyst is properly fluidized for entry into spent catalyst standpipe
  – Proper fluidization exiting the stripper is critical
• Provide structural integrity to handle normal and upset operations
  – Handle reversals and other severe events
• Provide flexibility to accommodate all unit configurations
• Minimize overall weight of the internals
• Provide flexibility for ease of fabrication, installation, and future inspection
Stripper Efficiency Comparison

**Baffles**
- Low Catalyst Flux

**Baffles**
- Medium Catalyst Flux

**Baffles**
- High Catalyst Flux

*ModGrid™*
- High Catalyst Flux

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- **Good tray operation** - most steam flows upward
- **Partially flooded trays** - significant steam flows into regenerator
- **Flooded tray operation** - majority of steam flows into regenerator
- **Excellent operation** - entire stripper volume available for catalyst / steam contacting
Baffles angled and oriented such that:

- Cross sectional area of stripper vessel available for catalyst flow is maximized
- Surface area available for mass transfer is maximized
- Flows of catalyst and steam, and their contact, are uniform
- Ideal bubble sizes are produced
Baffles organized and constructed as modular grids to provide:

- Easy installation and removal
- Adaptability to different unit configurations
- Structural stability
Modular grids are stacked in such a way that catalyst takes 360 deg. turn as it moves down a stack of four grids.
ModGrid Catalyst Stripper Benefits

- Reduced delta-coke
  - Reduced regenerator temperature
  - Ability to process heavier feed
- Increased cat-to-oil ratio
  - Higher conversion
  - Improved liquid yields
- Enhanced recovery of hydrocarbon vapors entrained with the catalyst
  - Lower dry gas yield
  - Reduced product downgrade
- Improved pressure build and slide valve pressure differential
- Reduced steam consumption
• Extensive cold flow testing
• Disc and donut baffle tested for comparison
• Under all conditions, the ModGrid design exhibited:
  – Higher capacity
  – Higher efficiency
  – Efficiency nearly constant over wide range in catalyst flux
ModGrid Stripper Efficiency Comparison

COLD FLOW TESTS

Stripping Efficiency, %

Mass Flux, lb/ft²·sec

ModGrid Stripper

Disk and Donut
• Hydrogen-in-coke has traditionally been used to assess stripper performance
  – Requires a very reliable flue gas analysis to provide accurate hydrogen-in-coke values
  – Calculated number -- difference between two relatively large numbers
  – Often leads to scatter in the data analyses
  – Small changes in flue gas CO₂ content can lead to large changes in the hydrogen-in-coke calculation

• Hydrogen-in-coke can still be used as a secondary indicator of stripper performance

• Typical values range from 6.0 – 9.0
  – Lowest value possible from ideal stripping is 5.5 – 6.0%
A CO$_2$ concentration of 16 mol% instead of 15 mol% changes the Hydrogen-in-Coke value by 3 wt%
• Recommend using primary process variables to assess stripper performance (before and after revamp)
  – Regenerator dense bed temperature reduction for a given set of riser outlet and preheat temperatures
• Delta-coke reduction
• Combustion air reduction at a given oxygen concentration in flue gas
• Normalization of feedstock properties to negate feed effects
• Match catalyst properties and contaminant levels to negate catalyst effects
• Use cut point corrected product yields for consistency
## ModGrid Stripper Revamp Results

### Refinery A

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<tr>
<th></th>
<th>Pre-revamp</th>
<th>Post-revamp</th>
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<tbody>
<tr>
<td>Feed Rate</td>
<td>Base</td>
<td>+12%</td>
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<tr>
<td>Stripping Steam</td>
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<tr>
<td>Coke, wt%</td>
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<tr>
<td>Dry Gas, wt%</td>
<td>Base</td>
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<tr>
<td>Gasoline, wt%</td>
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<tr>
<td>LCO, wt%</td>
<td>Base</td>
<td>+1.4</td>
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### Refinery B

<table>
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<tr>
<th></th>
<th>Pre-revamp</th>
<th>Post-revamp</th>
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</thead>
<tbody>
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<td>Feed Con Carbon, wt%</td>
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<td>Feed Ni+V, ppmw</td>
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<td>Reactor Temp, F</td>
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<td>Regenerator Temp, F</td>
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</tbody>
</table>
Thank You!

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