FCC Spent Catalyst Stripper Technology

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Spent Catalyst Stripper Technology

- Big Picture Overview
- Process Considerations
- Development History
- Key Design Considerations
- *ModGrid™* Stripper Internals Features
- Assessing Performance
- Commercial Examples

FCC Spent Catalyst Stripper - The Big Picture

- 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 Process Considerations

- 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

FCC Process Considerations

- Understanding coke yield and delta-coke from the heat balance is important for evaluating stripper performance

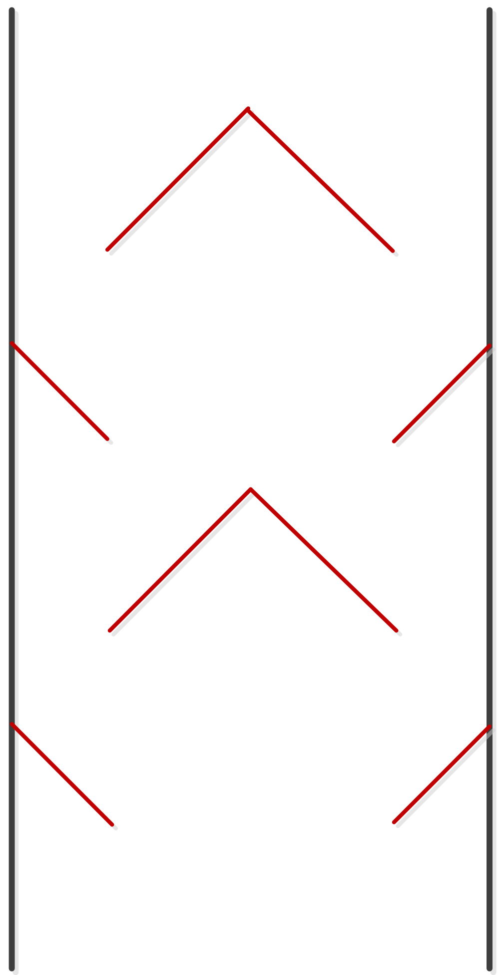
Coke Yield = (Cat-to-Oil) * (Delta-Coke)

$$\textit{Delta-Coke} = (CSC - CRC) \propto (T_{Reg} - T_{Rxt})$$

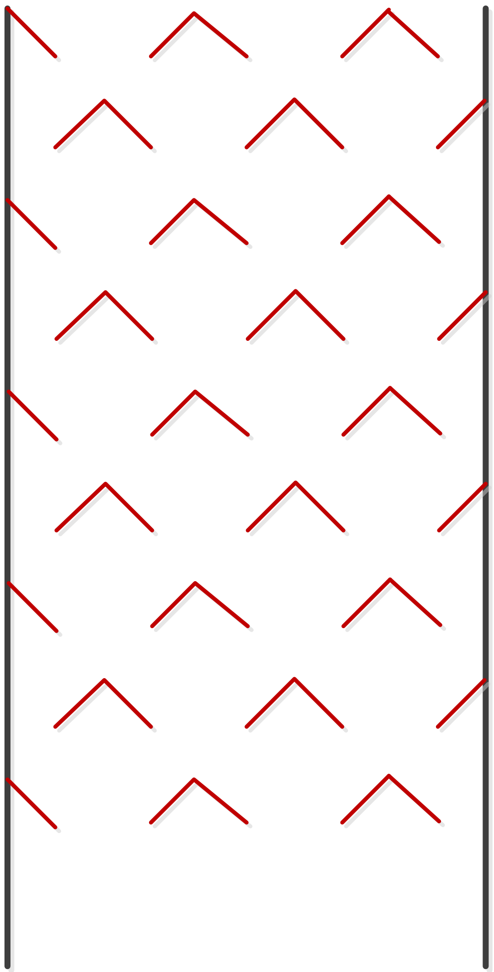
- Coke yield is essentially set by operating conditions
  - Riser outlet temperature, feed preheat temperature, etc.
- Delta-coke improvements required to increase cat-to-oil
- Spent catalyst stripping efficiency directly impacts the delta-coke

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

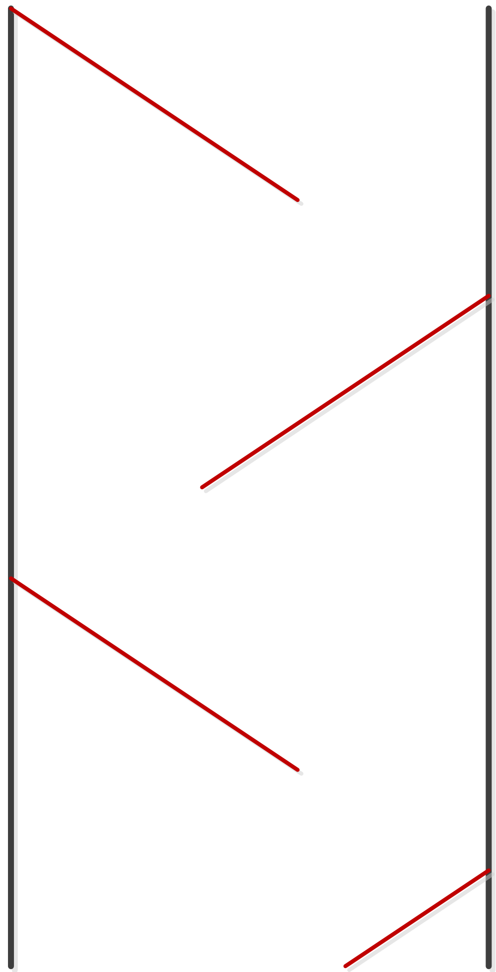


DISK AND DONUT

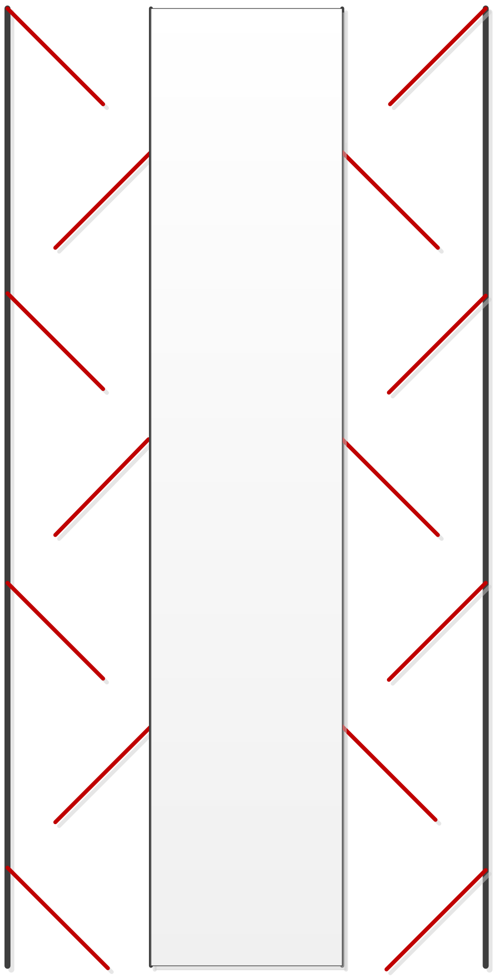


SHED DECK

Development History



BAFFLED



ANNULAR STRIPPER

Stripper Key Design Considerations

- 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

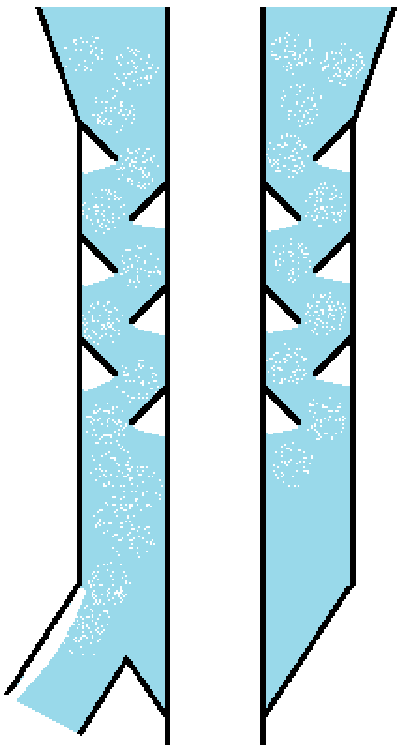
- Manage the catalyst flux through the stripper
  - Provides adequate residence time for stripping
  - Prevents vapor drag into the regenerator
- Optimize the vapor bubble sizes throughout the stripper
  - Large bubbles rise faster and reduce contacting surface area
  - Smaller bubbles improve area but 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

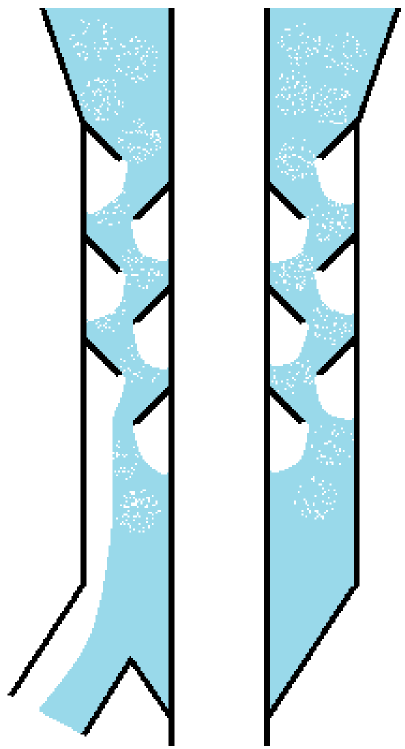
Stripper Efficiency Comparison

Baffles
Low Catalyst Flux



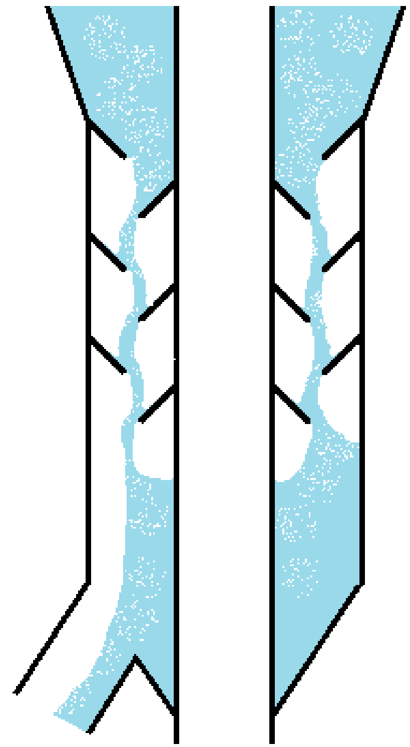
Good tray operation - most steam flows upward

Baffles
Medium Catalyst Flux



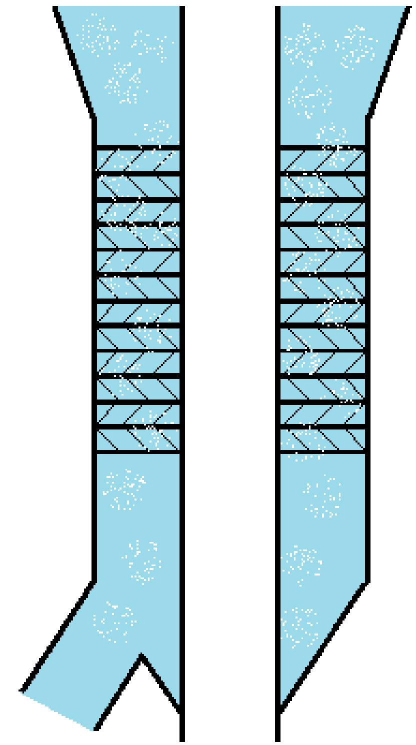
Partially flooded trays - significant steam flows into regenerator

Baffles
High Catalyst Flux



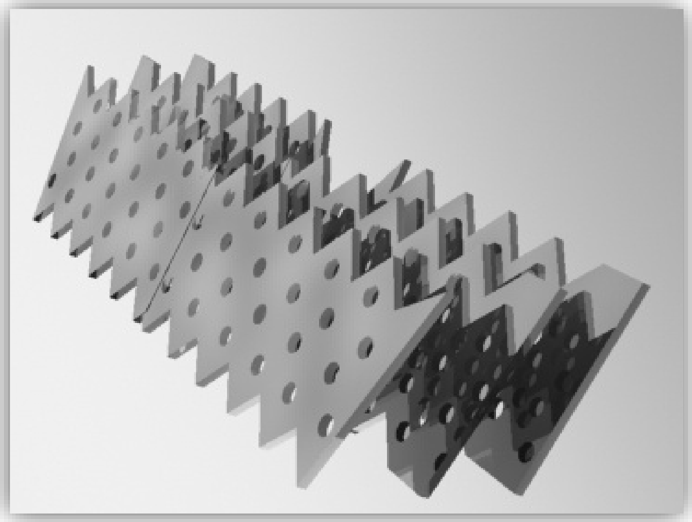
Flooded tray operation - majority of steam flows into regenerator

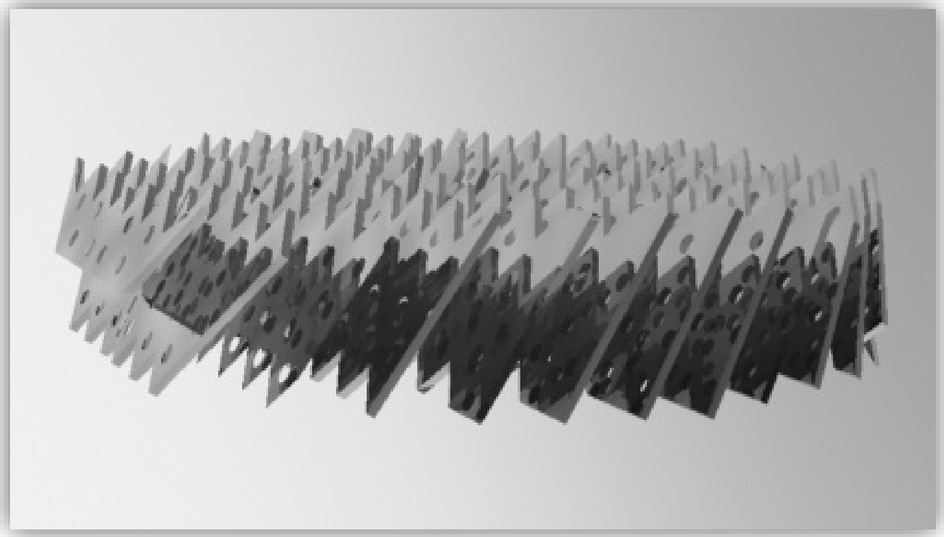
ModGrid™
High Catalyst Flux



Excellent operation - entire stripper volume available for catalyst / steam contacting

ModGrid™ Catalyst Stripper Internals from CB&I

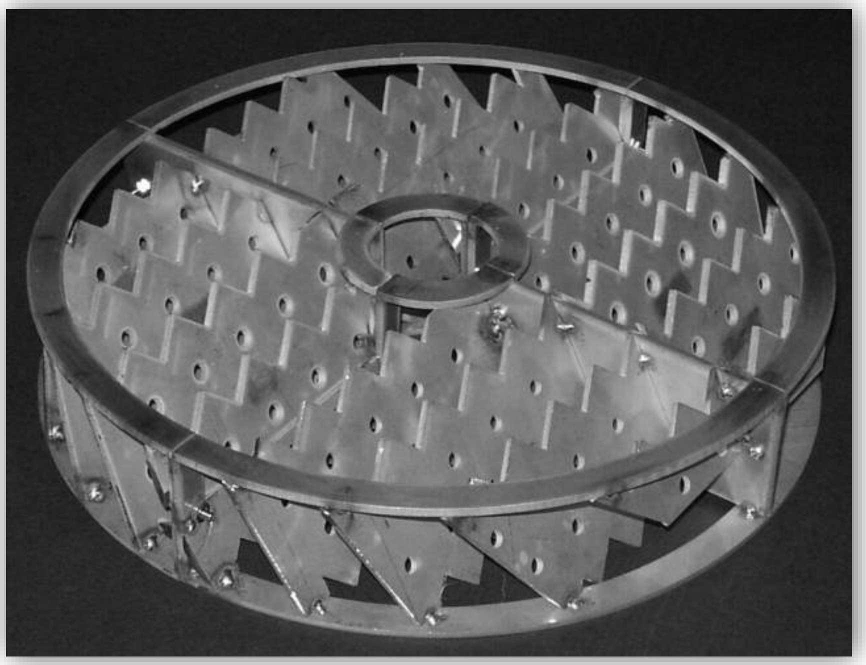




Baffles angled and oriented such that:

- 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

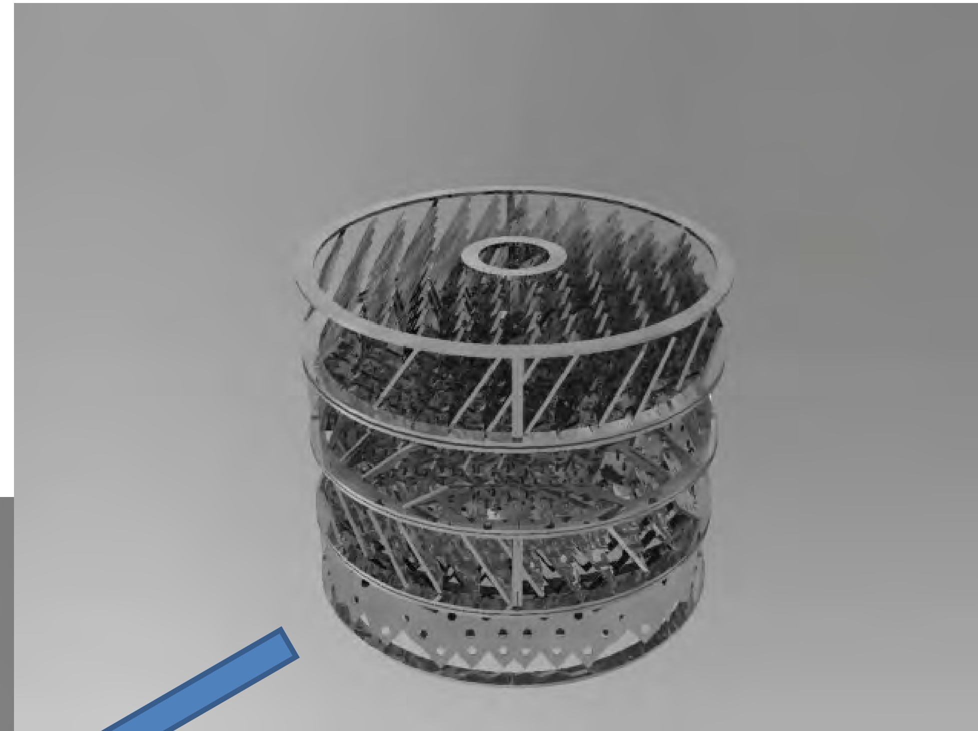
ModGrid Catalyst Stripper Internals

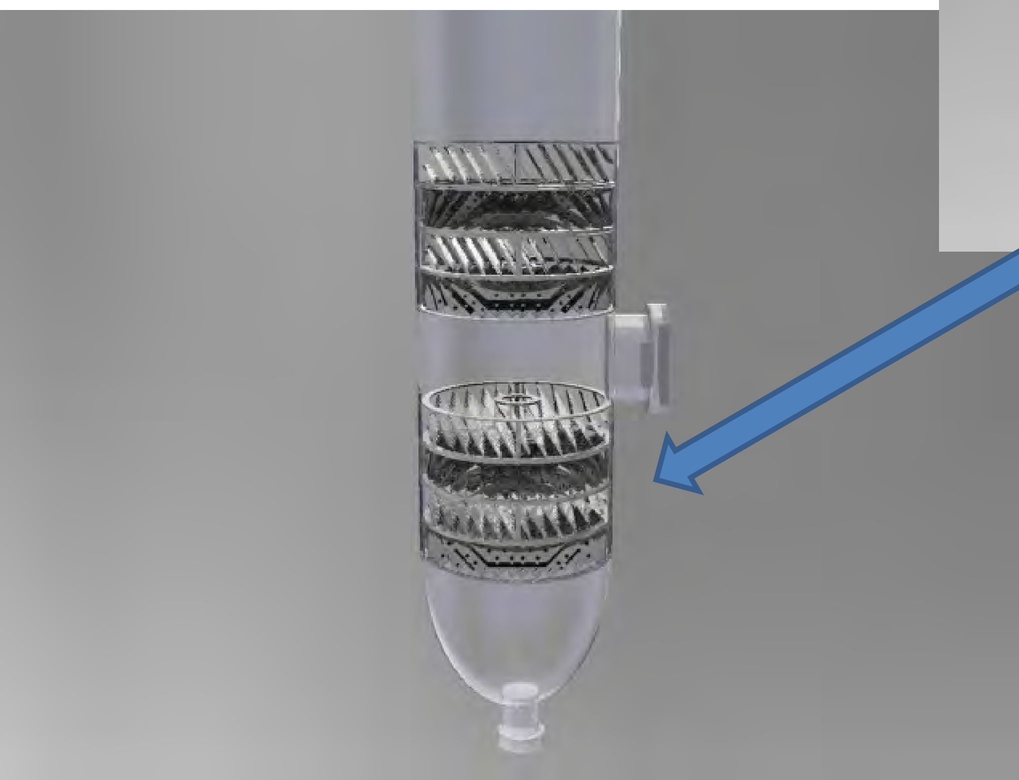


Baffles organized and constructed as modular grids to provide:

- Easy installation and removal
- Adaptability to different unit configurations
- Structural stability

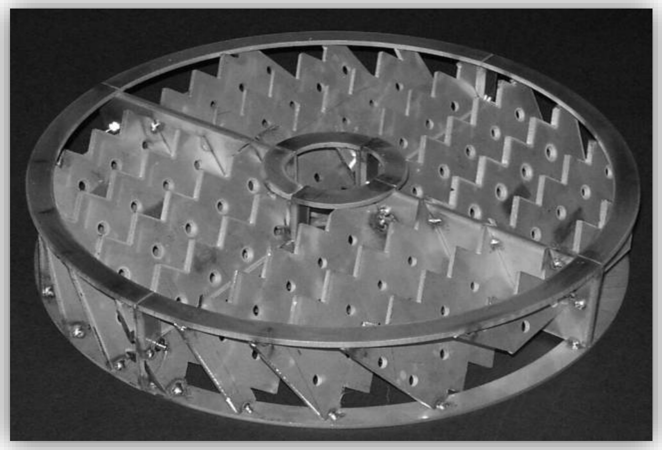
ModGrid Catalyst Stripper Internals





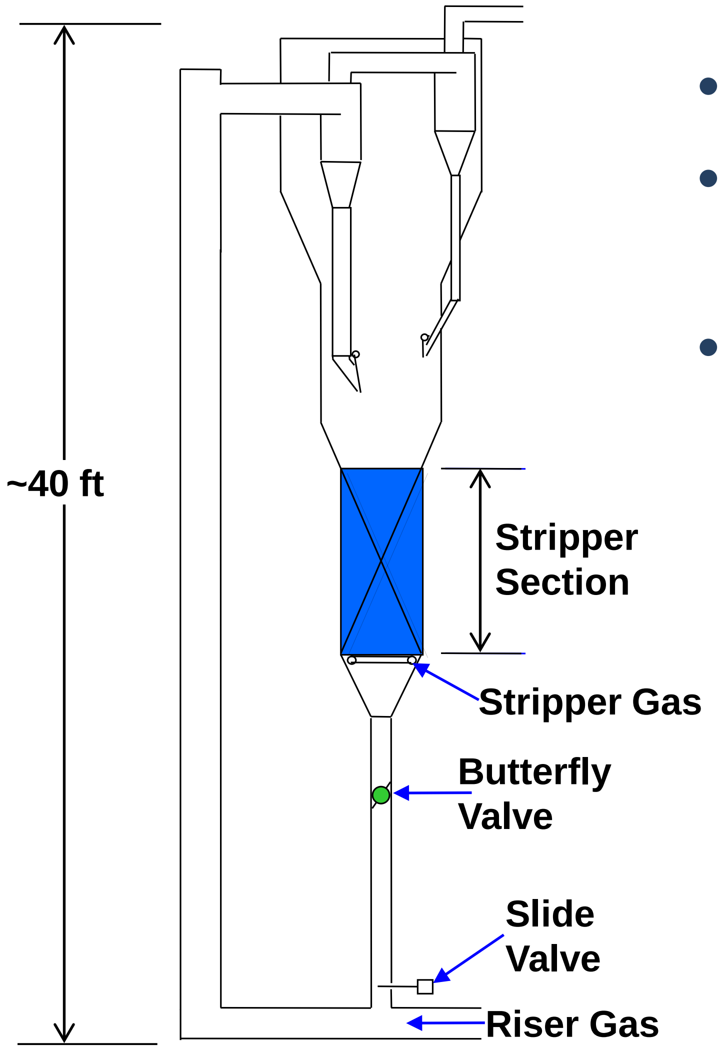
Modular grids are stacked in such a way that catalyst takes 360 deg. turn as it moves down a stack of four grids

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

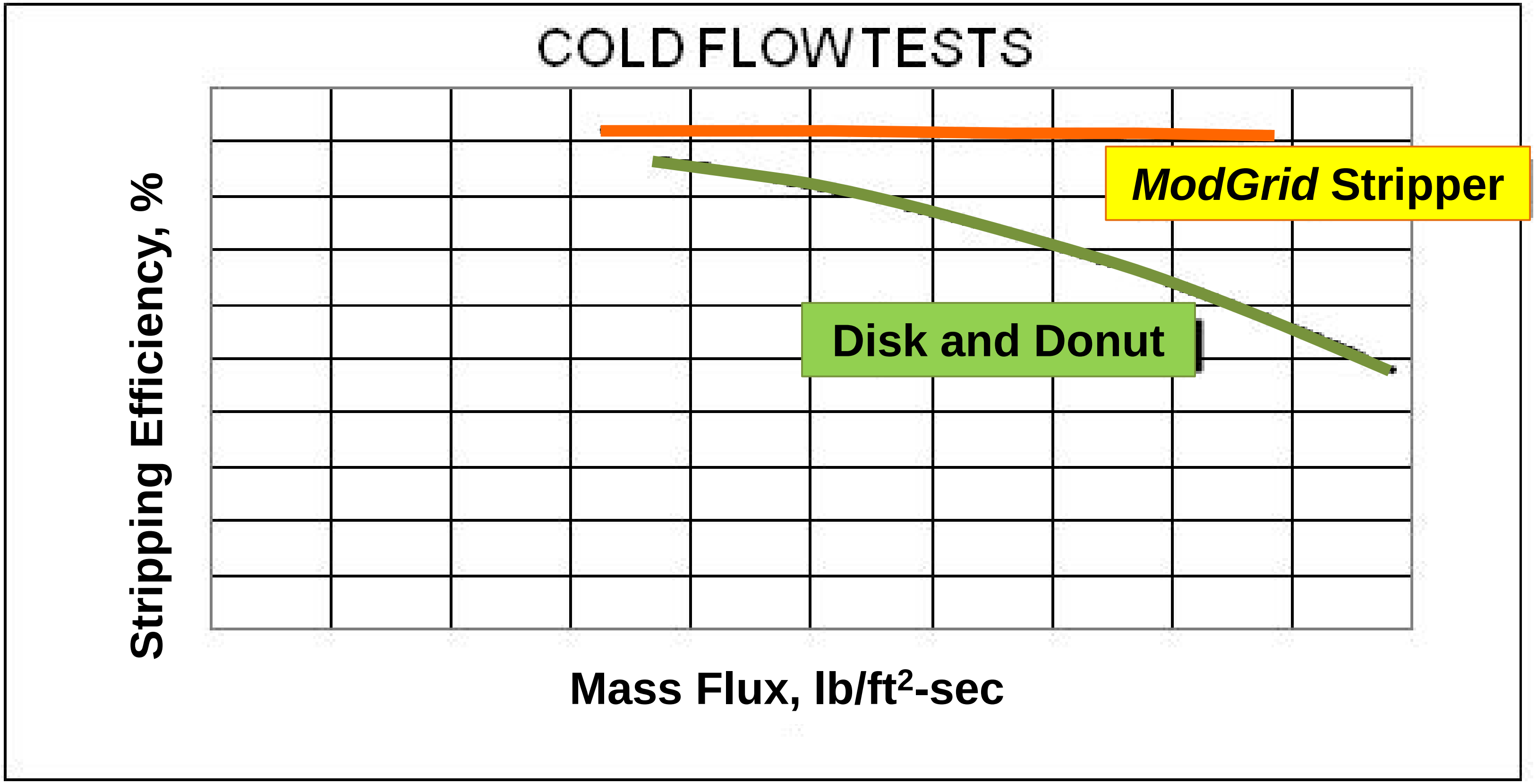
ModGrid Stripper Cold Flow Model Testing



- 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

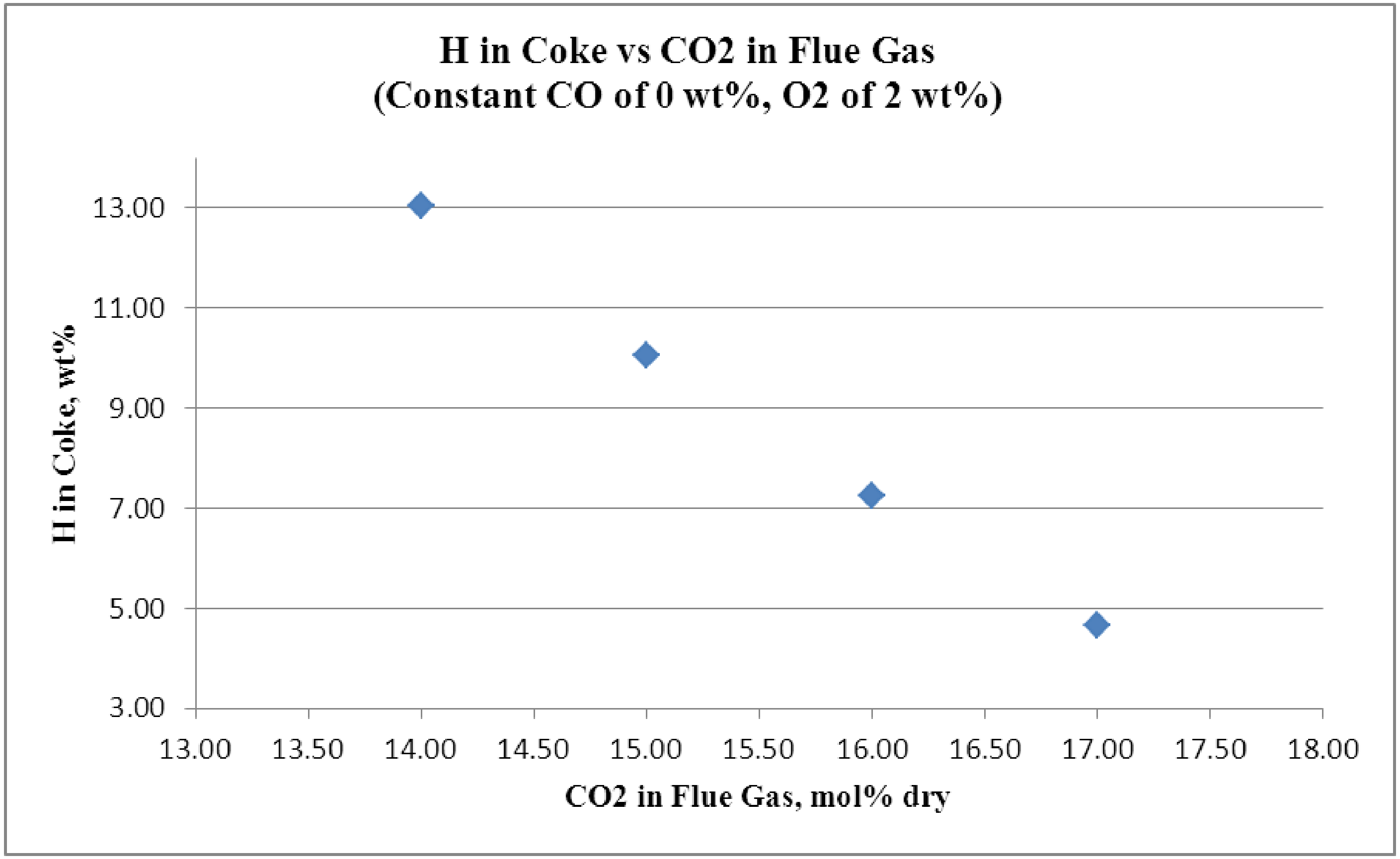
ModGrid Cold Flow Model Snapshot

ModGrid Stripper Efficiency Comparison



Assessing Performance

- 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 CO_2 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%

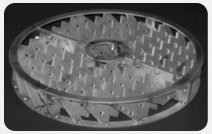
Assessing Performance

- 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

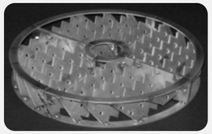
	Pre-revamp	Post-revamp
Feed Rate	Base	+12%
Stripping Steam	Base	-30%
Coke, wt%	Base	-0.5
Dry Gas, wt%	Base	-0.9
Gasoline, wt%	Base	+0.9
LCO, wt%	Base	+1.4



ModGrid Stripper Revamp Results

Refinery B

	Pre-revamp	Post-revamp
Feed Rate	Base	+6%
Feed Con Carbon, wt%	Base	+0.4
Feed Ni+V, ppmw	Base	+2.6
Feed Iron, ppmw	Base	+2.1
Reactor Temp, F	Base	+9
Regenerator Temp, F	Base	No change



Thank You!

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