

Improving FCC Unit Performance

Mel Larson, Principal Consultant

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Biography

KBC Advanced Technologies Inc.

15021 Katy Freeway
Suite 600
Houston, TX 77094

Tel +1 281 597 7943
Mob +1 281 831 8202
Fax +1 281 616 0900

MLarson@kbcat.com

Melvin G. Larson
Principal Consultant

Profile

- Principal Consultant at KBC with over 31 years experience as a Chemical Engineer.
- Responsibilities include but are not limited to specialty consulting in FCC, serving as Project Manager on various KBC projects, and as Manager / Principal Advisor on 150 KBPD grassroots refinery build.
- Consulting services specialize in process troubleshooting and profit improvement analysis in the FCC, Unsaturates Gas Plant, Alkylation and Naphtha Reformer areas.
- 10^{+} years refinery hands-on experience with unique awareness to day-to-day operations / troubleshooting.

KBC Experience

- Technical Advisor to National Oil Company's new Latin American refinery project. FEL-0 through FEL III assistance in complete complex and build both strategic and in detailed work assistance with owner, licensors and EPC firm.
- Served as project manager on Profit Improvement Programs with extensive international experience, working in USA, Europe, Australia, South America, South Korea and Japan.
- Worked as key advisor on a grassroots complex refinery build. Personal responsibilities required overall refinery knowledge and capability to manage and coordinate multiple disciplines on both client and company aspects of the work.
- Assisted majors in various troubleshoot operations on FCC, including excessive catalyst losses, the re-optimization of operation for higher conversion with existing equipment.
- Identified and implemented charge rate increase in USGC FCC by 3 kbpd without investment and over 20% additional capacity in Japanese FCC Unit without investment.
- Coordinated FCC and Unsaturate Gas Plant analysis on major Yield and Energy Surveys throughout the world. The unsaturate gas plant analysis often includes rigorous simulation of the facilities.

Education

- B.S. in Chemical Engineering from Rose-Hulman Institute of Technology.

Abstract

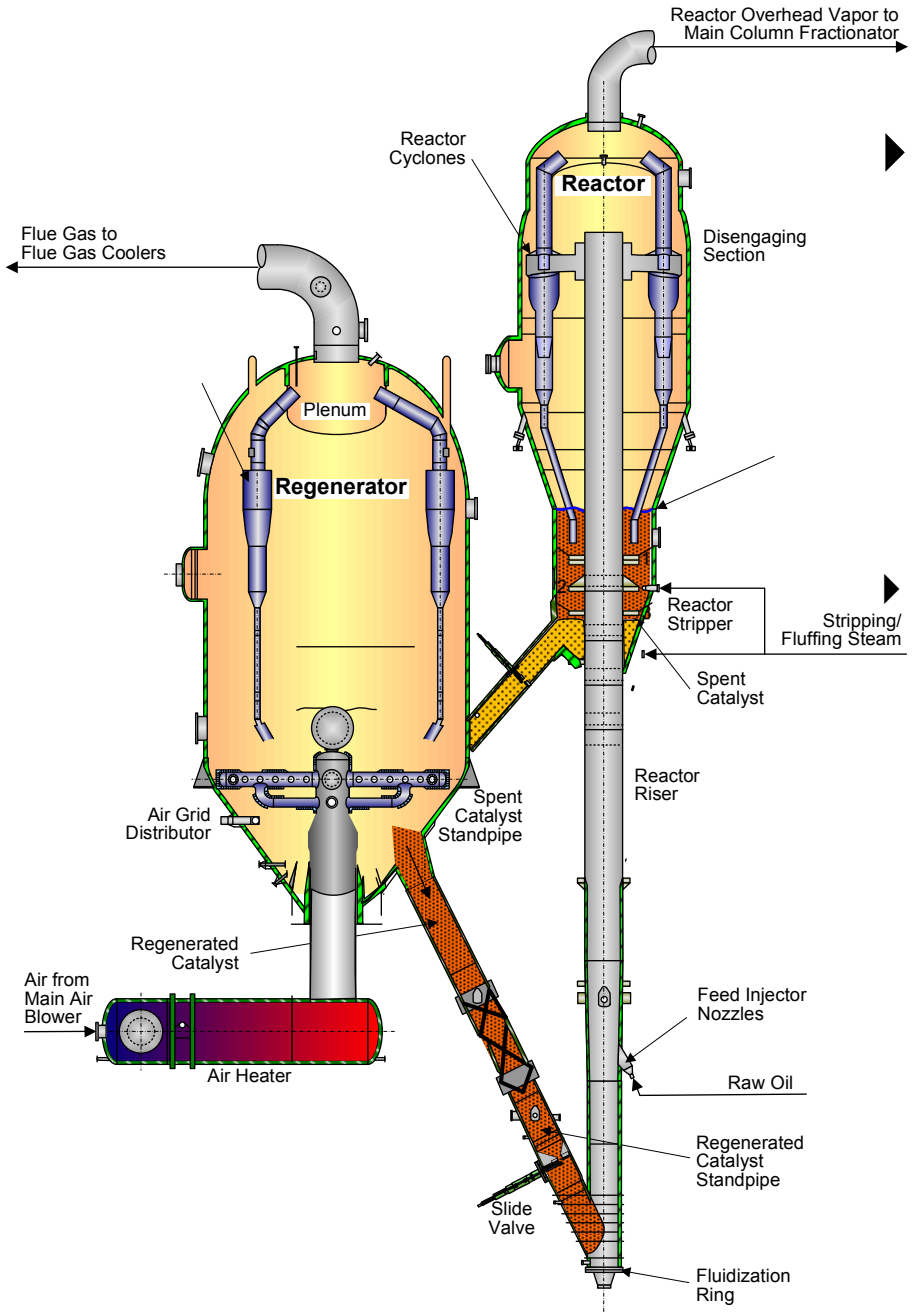
- The FCC has been the centroid of the US refining gasoline production business for the last 60 yrs.
- New regulatory and emissions targets such as 2017 Tier 3 sulfur targets and the proposed FCC Flue gas emissions values are the latest challenges for the refiner.
  - If post treating of FCC cat gasoline is required the loss of octane will put a constraint on meeting the regulatory requirements.
- The value of the FCC is to maximize the yield of “profitable” components of C3 through LCO.
- This presentation will cover a range of options for the FCC plant to consider in in maximizing the profit of the plant with every effort to maximize the volume of most profitable products.

Outline

- **Maximizing Volume and Profit**
  - ✓ What is the definition of maximum volume in the FCC?
- **Maximizing Profit**
  - ✓ Profit regionally defined
  - ✓ Refinery profit balance
  - ✓ What are the value added products
  - ✓ Options to Maximize profit on the main column
- **Adjustments to Consider**
  - ✓ Operational thoughts
  - ✓ Additives and Catalyst options
  - ✓ Investment Considerations
- **Summary**

“Maximizing Volume and Profit”

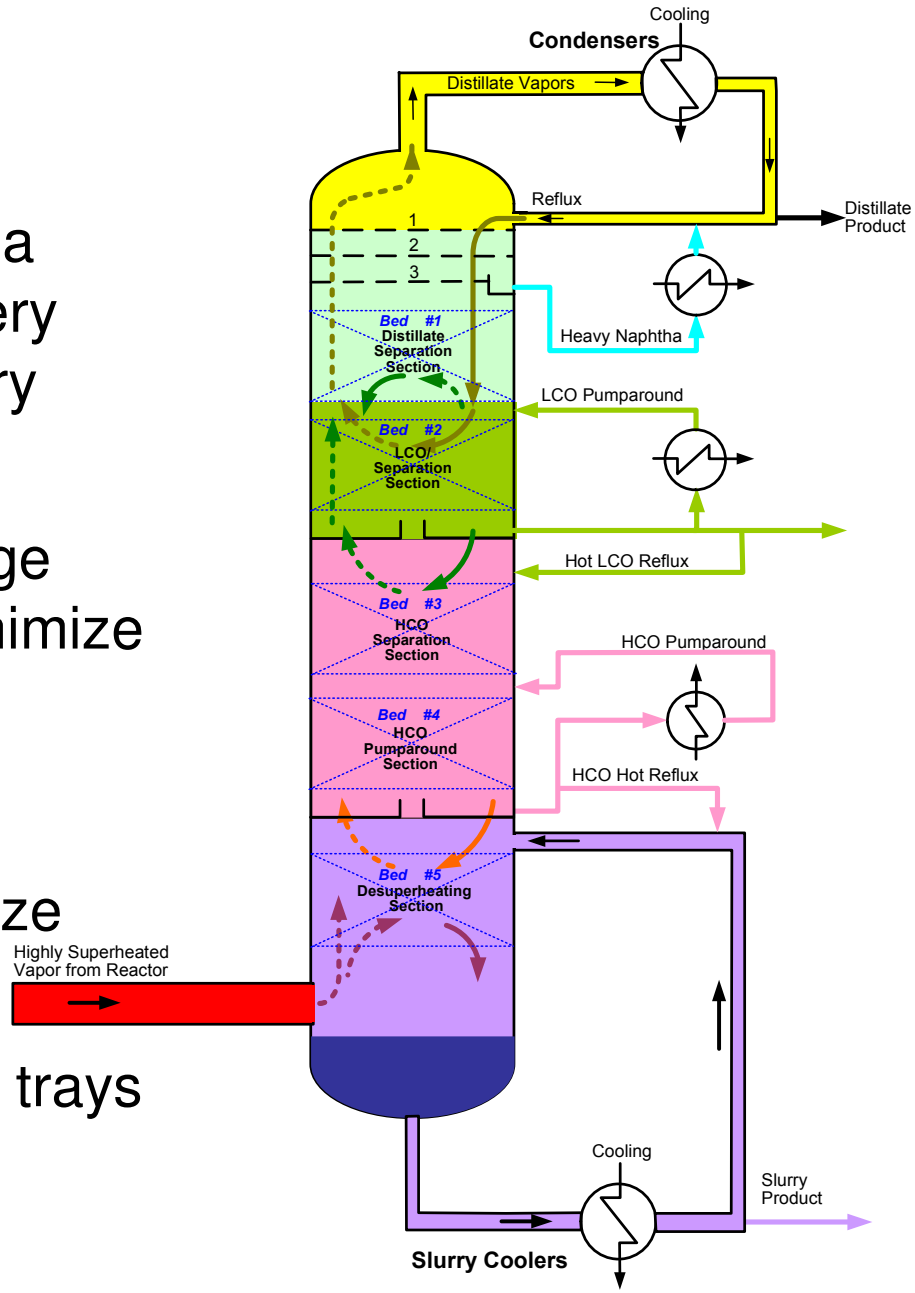
Volume "Swell" or Expansion



- Historically, in the USA one of the key metrics is looking at the C3+ volume expansion.
  - Simply defined (LPG+Gasoline+LCO+Slurry)/Feed
- Consider reactor yields and the recovery of these molecules
  - Recovery considers
    - C3 out of fuel gas
    - C3s in C4s, C4s in C3s
    - Overlap or Gap between Naphtha and LCO, LCO / Slurry

Volume "Swell" or Expansion

- **Fractionation Efficiency Matters**
  - Optimizing Column performance is a critical criteria in maximizing recovery and the highest value for the refinery
  - Operation of the main column is a balance of heat loads / sinks, sponge oils, and internal tower traffic to minimize down grading value.
- Guides
  - Minimum LCO in Slurry, i.e. maximize the temperature below grid
  - Insure sufficient liquid traffic i.e. dry trays below draws are not unusual



Maximizing Profitability

Profit – Regionally Defined

- Maximizing recoverable volume is the first priority within the context of the region or location of the unit.

And

- Maximum profit means yielding the highest volume of the most valuable products.
  - Typically, in the gasoline centric market of the USA, maximum volume generally means maximum conversion without "overcracking" of naphtha to LPG.
- Regional Sensitivity (one example)
  - USGC – Propylene to Alky Feed Differential 10-14$/bbl
    - Chemical value exceeds propylene alkylation
  - MidContinent – Propylene costly to get into PetChem Market

Profit – Balance

- Reality Check
  - Maximizing profit is a blend of feed rate and quality with the specific hardware constraints of a given unit.
  - Gasoil allocation and product market is an input to operation
- Competitive Yield / Markets

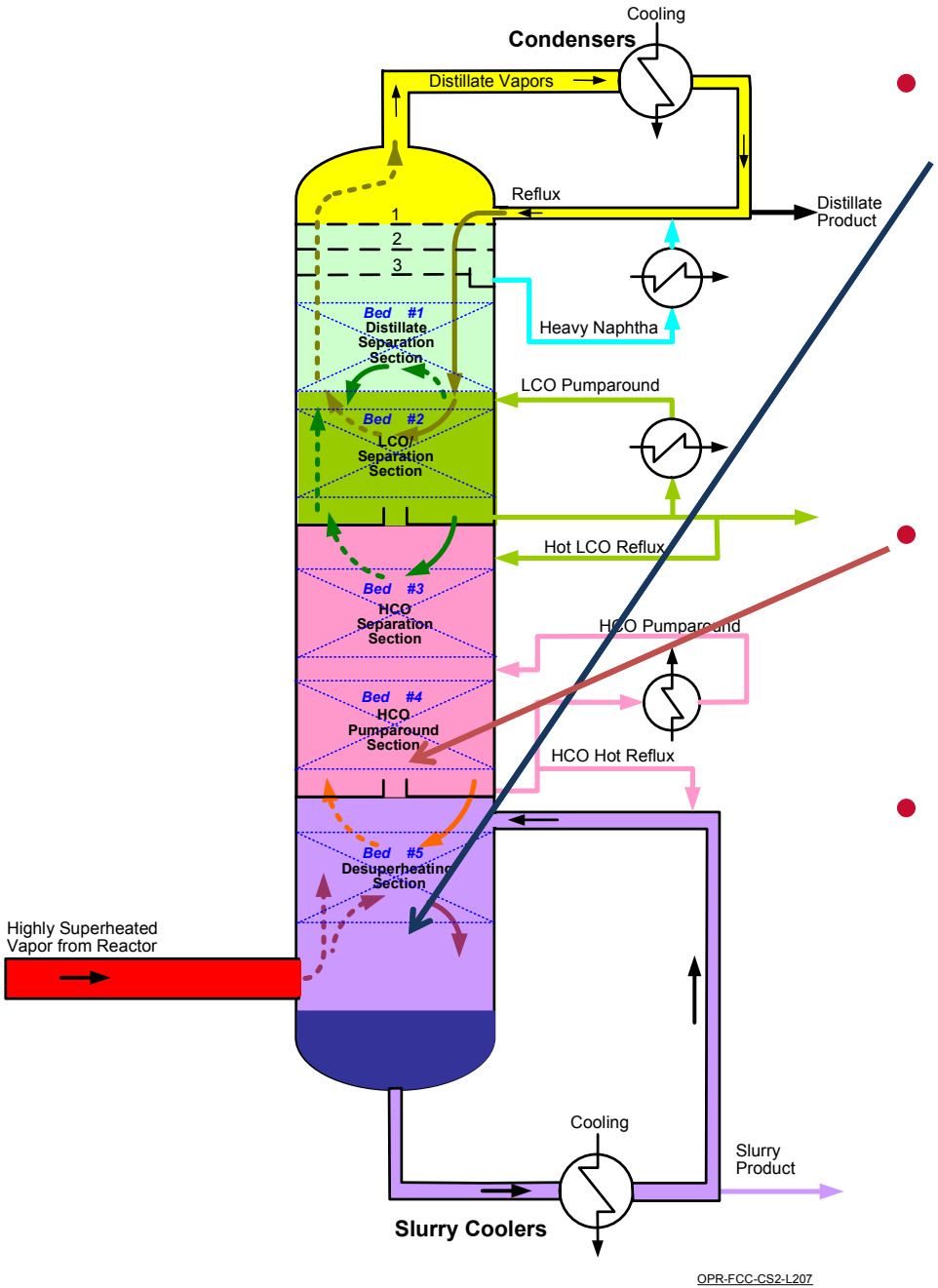
Unit	C3+Volume Exp	Mid-distillate Selectivity
Hydrocracker	120 LV%	70-80%
FCC	110-115 LV%	15-30%

- Typical FCC hardware constraints
  - Air blower (coke), wet gas compressor (dry gas yield), and Column limits (Main, absorber, debutanizer etc.) flooding

What are the Valuable Products

- Looking forward to post 2017
  - C3/C4s (alky feed) > LCO > FCC naphtha > Slurry or gas
  - USGC Alkylate is 15-25$/bbl over RUL
    - With Tier 3 and octane losses Alkylate will be valued HIGHER
  - Globally diesel market is higher than gasoline thus LCO that can be treated into Diesel market great value
- Current and future adjustments
  - Cut FCC Naphtha lighter (higher octane) lower octane debit
  - 370-430ºF FCC Naphtha into diesel pool up to cetane limit
    - Increased value of FCC moving to 30% diesel selectivity
  - Maximize LCO out of Slurry
    - Operate desuperheat section hotter allowing more LCO recovery with potential of coking off the grid section

Options to Maximize Value



OPR-FCC-CS2-L207

- Maximizing the temperature at the bottom of the grid to 725-735ºF (Max LCO)
  - Pool temperature 700ºF with quench stream
- Keep trays wet
  - Dry trays cause endpoint excursions in LCO
- Consider yielding a HCO cut for hydroprocessing
  - CFHT or Hydrocracking
  - Minimize Slurry

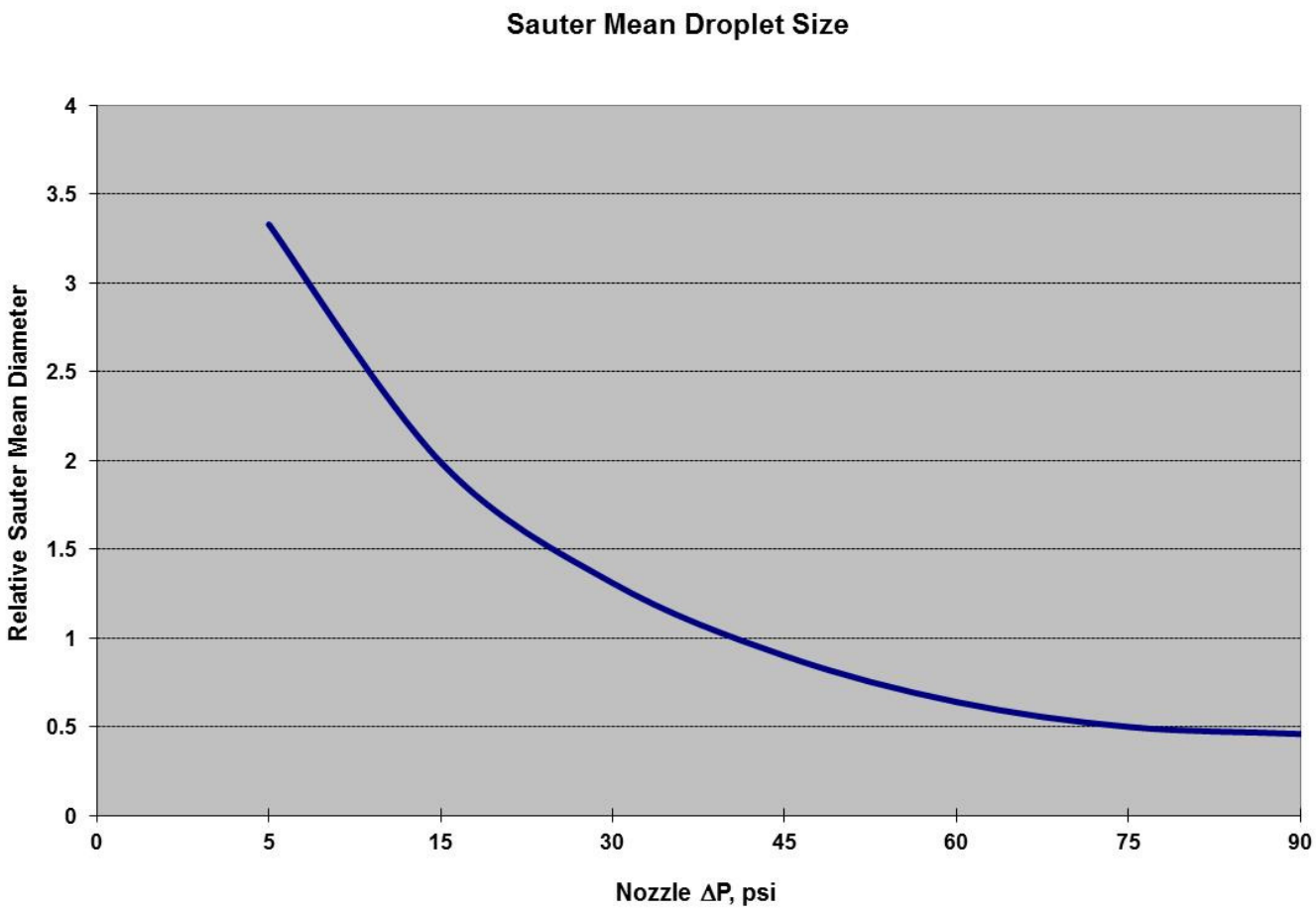
Adjustments to Consider

Operational Considerations

- Reactor / Regenerator Operational Considerations
  - In general maximizing Cat/Oil benefits liquid recoverable yield
  - Reactor Temperature set by
    - Propylene, Alky feed, and Debutanized octane requirements
  - Minimizing thermal reactions can benefit yield selectivity
- Naphtha in Riser
  - Naphtha in the riser acts like a “cat cooler”
    - Lower thermal conditions at the point of contact with gasoil
    - Higher C/O at constant coke
    - Naphtha priority (Coker, FCC heartcut)
    - Naphtha will crack with about 20-30% converted to mixed C3/C4s typical of FCC distribution (minimal coke and gas yield)

Operational Considerations - Steam

- Feed Nozzle performance

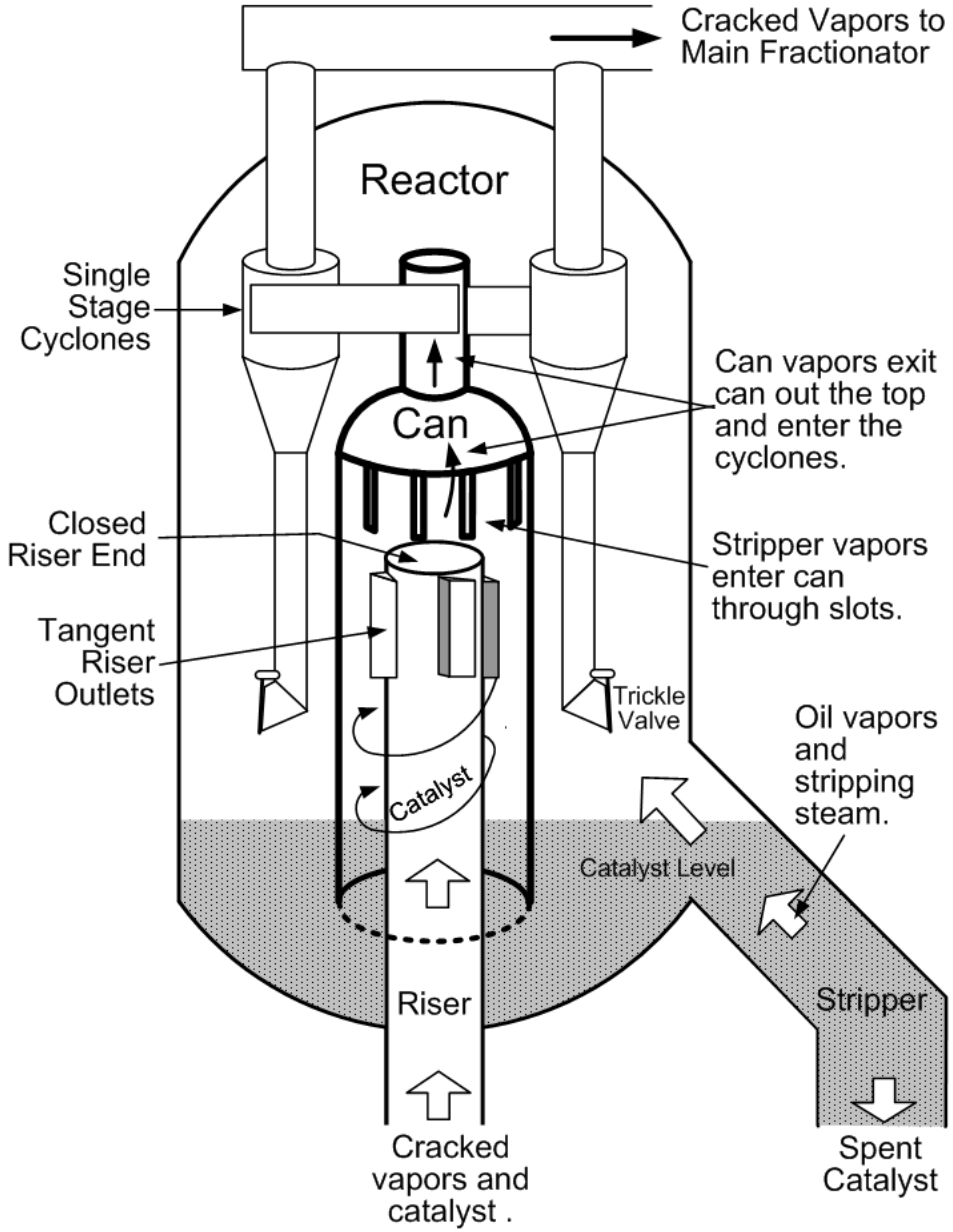


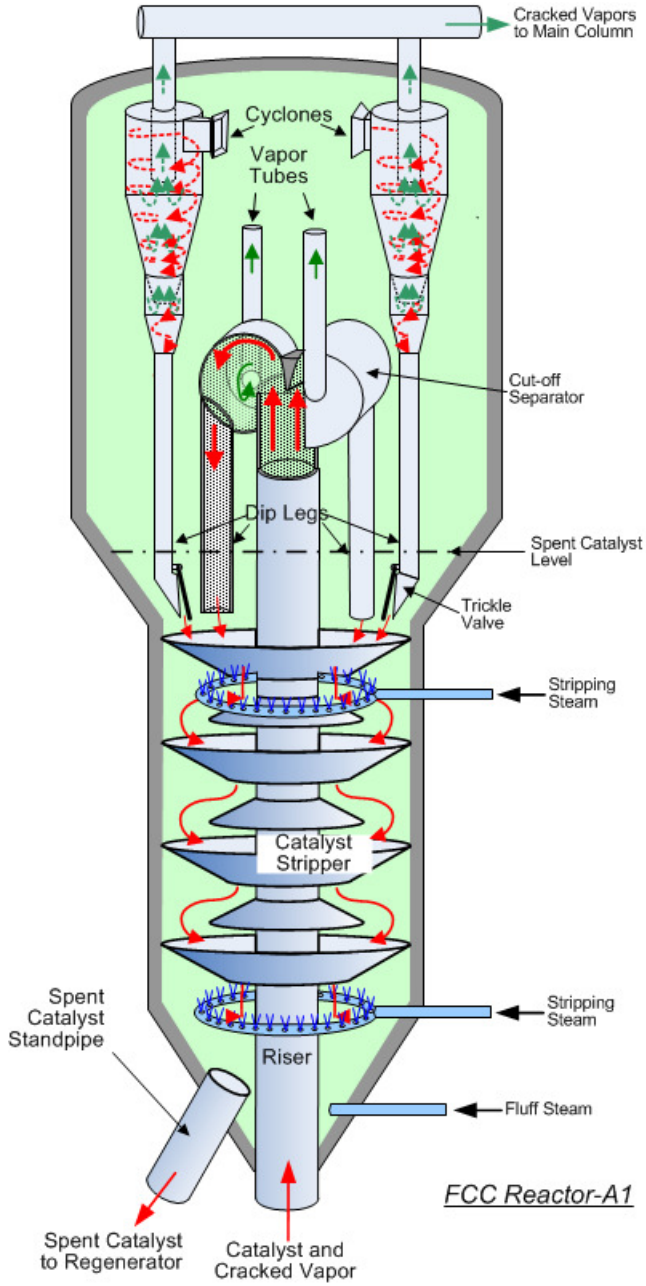
- Droplet size is a function of nozzle ΔP
- The chart provides a reference or index one can use for understanding droplet size
- Increasing steam to the nozzles increases ΔP and tip velocity
- Combined value of lower droplet size is improved gasoil/catalyst mixing and more efficient cracking and lower ΔCoke

Operational Considerations - Steam

- Spent Catalyst Stripping
  - Minimizing hydrocarbon to the regenerator lowers air demand and regenerator bed temperatures
    - The percentage of hydrogen on coke values should be below 7 with pacesetters at 6. Above a value of 7 indicates hydrocarbon slip into the regenerator
      - Some companies using advanced controls use stripping steam as a means to control the regenerator bed temperature.
  - The stripping is partial pressure on hydrocarbon
    - Stripping can be improved by
      - Two stage stripping
      - Grid or other open type of structure to maximize catalyst break up through stripper and using all of the available diameter
      - Minimize hydrocarbon re-contact with top of stripping bed

Minimize Recontacting





Additives and Catalyst Options

- Additives
  - Bottoms upgrading
  - ZSM-5 over more distillate selective catalyst
    - Minimize gasoline to octane value while making diesel and LPG
- Catalyst options
  - Modern FCC catalyst functions well with up to 0.3 wt% CRC
  - Catalyst options are possible considering to meet specific unit requirement
  - Caution - Make sure the unit is optimized in evaluating the benefits of a catalyst change

Investment Considerations

- Spent Cat Stripper upgrade
  - Internals to improve hydrocarbon removal at higher C/O
- Chilling absorption fluids
  - Chilling lean oils / heat removal in recovery system aids in recovery and capacity
- Column operations
  - Packing of the FCC Main Fractionator
  - Monitoring water in the Recovery section
    - Water reduces effective diameter causes flooding or foaming
  - Packing absorbers / Dethanizer strippers
  - High Capacity trays for columns

Summary

- Maximizing Volume and Profit is the balance of feed and hardware
- Identify and understand which products carry the most value from the FCC
  - Seasonality, down stream constraints, system demands all are dynamic and require routine monitoring to maximize the value.
- The investment into the asset can yield the greatest value and flexibility
  - FCC has the ability to produce more or less LPG, octane, and bottoms
- If the FCC has feed capacity, recycling of select streams as a means to further maximize profit

Q&A