Residue Upgrading Technology Options

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Residue Processing Options

Catalytic

- RFCC
- Hydrocracking
- Developing technologies

Non-Catalytic

- Visbreaking
- Solvent Deasphalting
- Coking

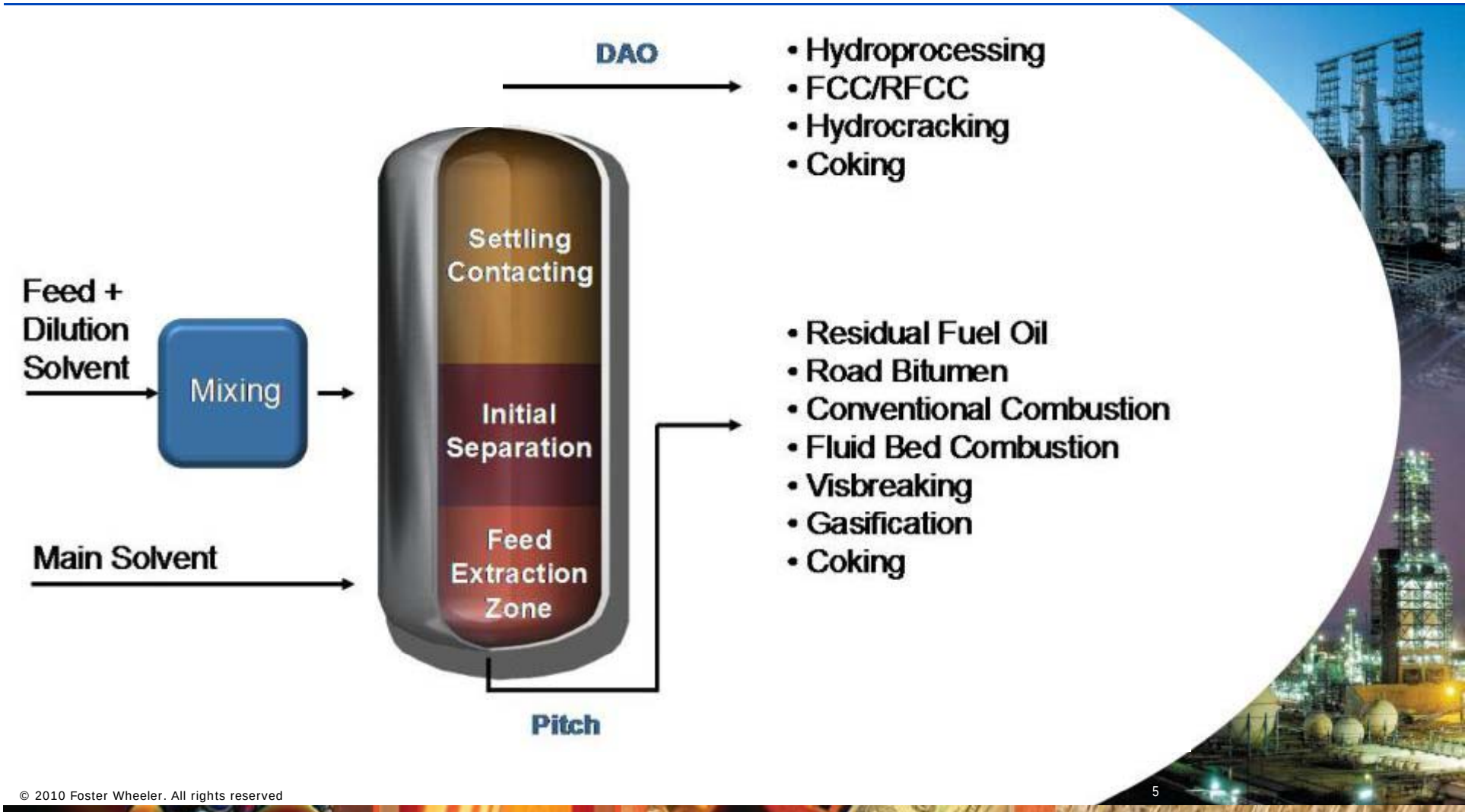
Visbreaking

- Thermal process for mild cracking of residues
- Fuel oil production
- Viscosity reduction
- Reduce cutter stock requirements
- Conversion limited by stability
- Unattractive unless high demand for fuel oil

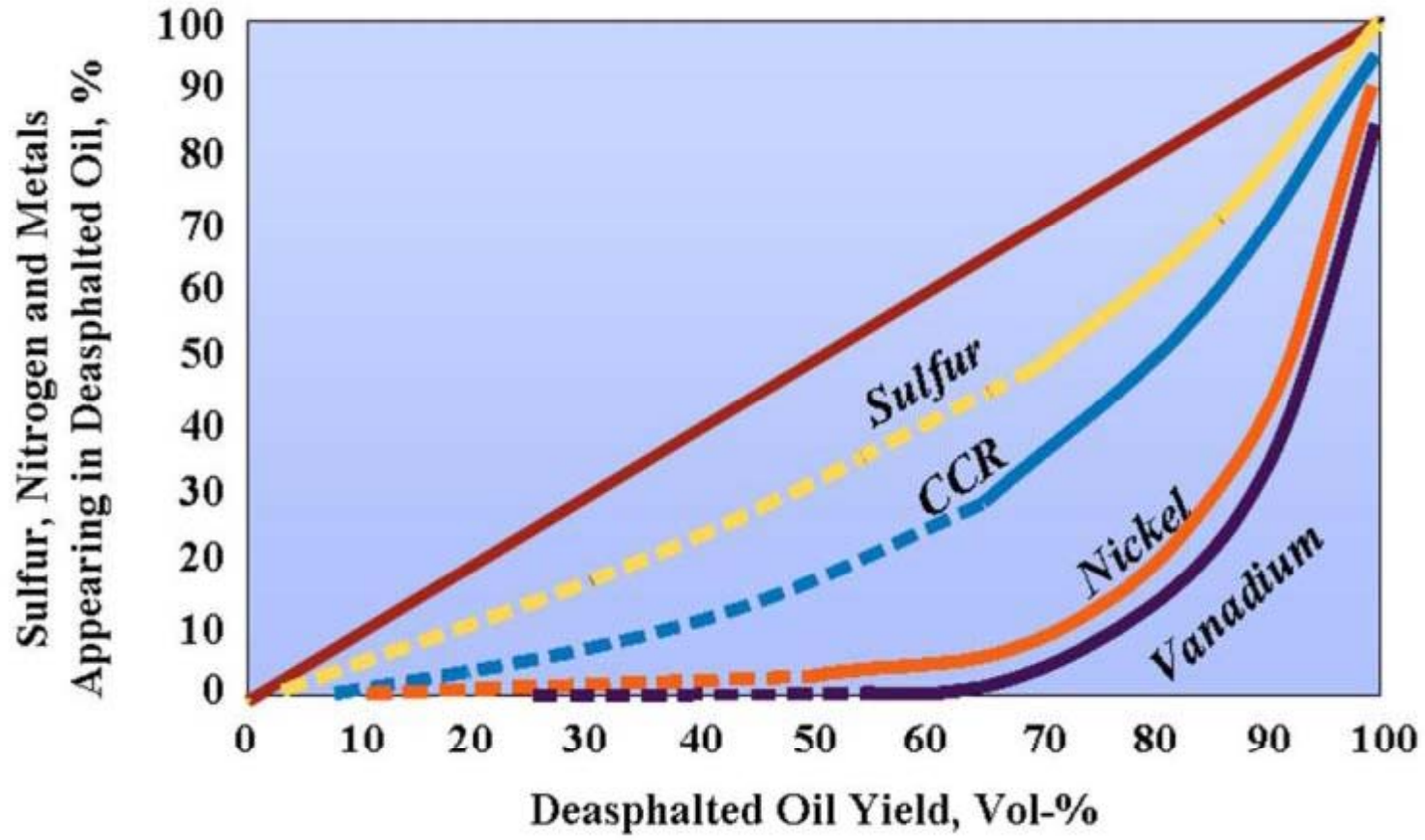
Solvent Deasphalting

- Physical separation process
  - Deasphalted oil (DAO)
  - Asphaltene rich product (pitch)
- Light paraffin solvent
- Solvent recovery
  - Sub critical
  - Super critical
- Applications
  - Lubes
  - Fuels
- Can be combined with other processes

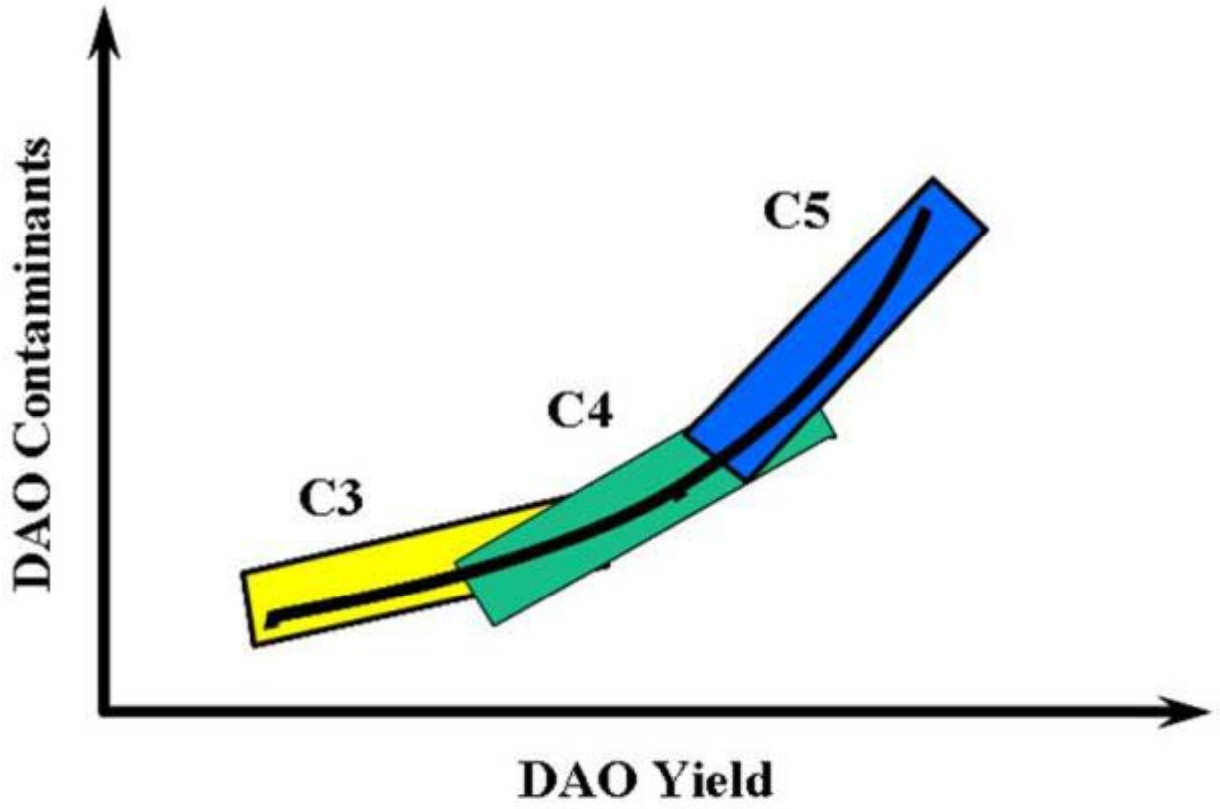
Solvent Deasphalting Process



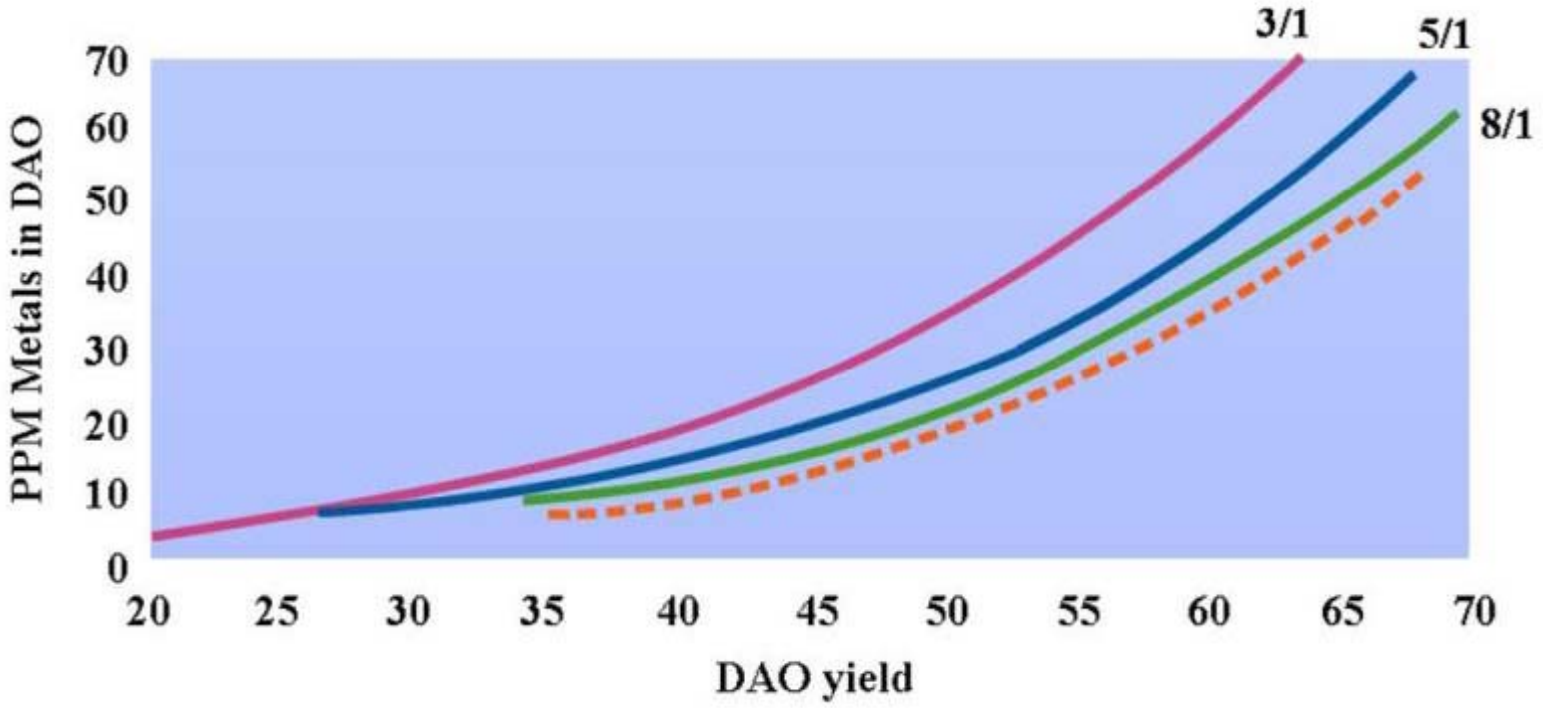
Deasphalting Selectivity



Solvent Selection



Effect of Solvent – Oil Ratio



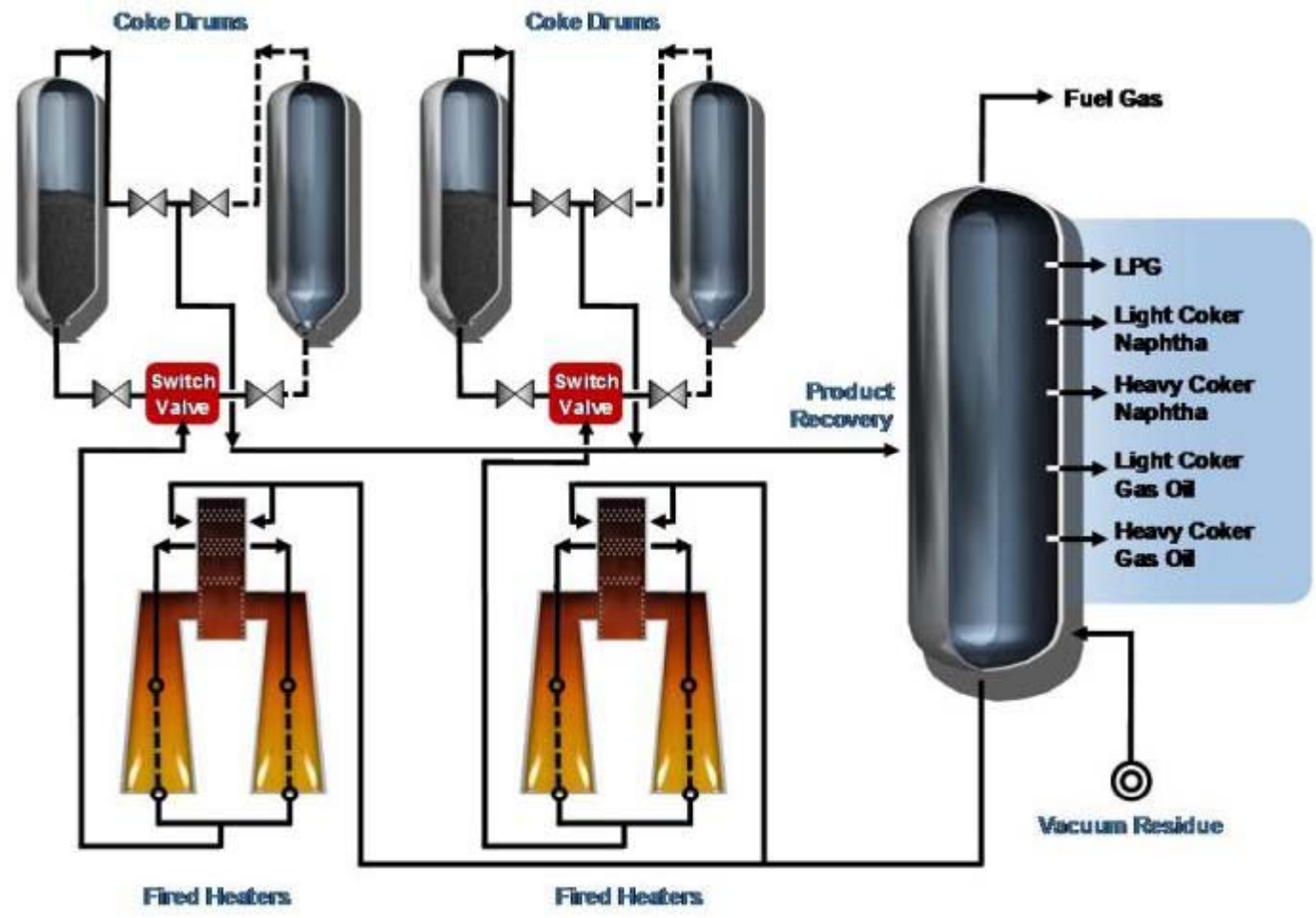
UOP/FWUSA Solvent Deasphalting Process

- Joint technology of UOP and FWUSA
- Access to FWUSA and UOP experts
- Over 70 operating units
- Super critical recovery
- 3 product designs
- Large units a specialty

Delayed Coking

- Most commonly used residue upgrading process
- Very attractive economics
- Complete residue conversion
  - Gas
  - Naphtha
  - Gas oils
  - Coke (disposal not an issue)
- Specialty coke production
- Maximized diesel yield with Hydrocracker integration
- Wide variety of feedstocks

Foster Wheeler SYDEC^{SM} Process



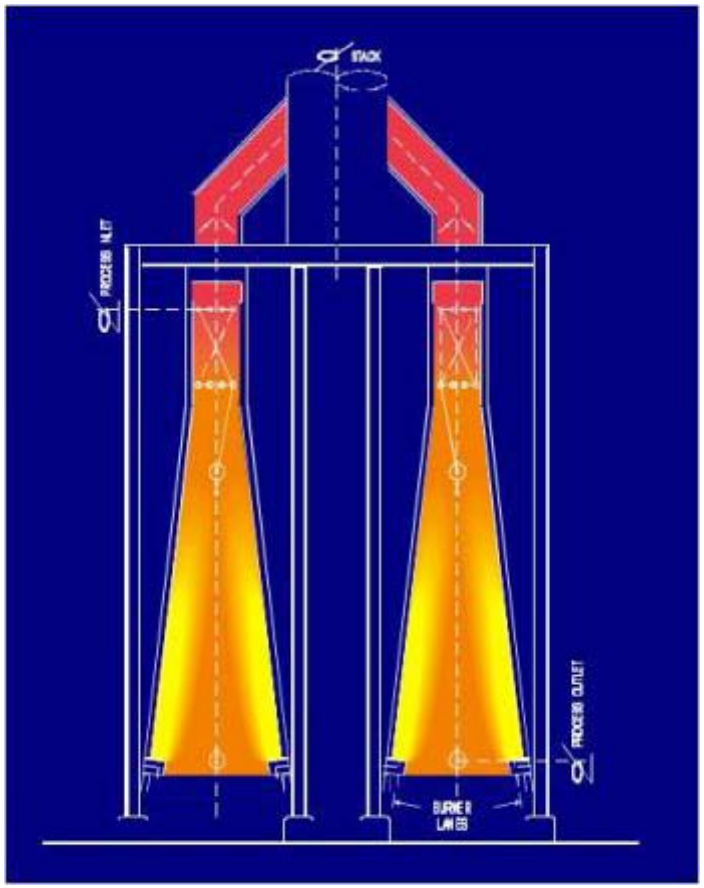
Key Features of SYDEC Delayed Coking

- Proprietary Terrace Wall ™ double-fired furnace
- Maximum liquid product yields
  - Low pressure
  - Ultra low recycle
- Designed in safety
- Large coke drums
- Environmentally friendly
  - Recovery of blowdown vent vapors
  - Coke fines management
- Fractionator design

Coker Heater Design – Elliott's Rules

- Individual pass control and firing ability
- High in-tube velocities (> 6 fps)
- Minimum residence times
- Optimum heat flux and no mal-distribution
- Constantly rising temperature profile
- Symmetrical pass arrangements and piping
- Steam/condensate injection (~1 wt%)

SYDEC[SM] Delayed Coking Heaters



Features

- High average heat flux
- Reduced coil volume
- High in-tube velocities
- Independent pass control
- Sloped wall design for even flux
- On-line spalling & pigging

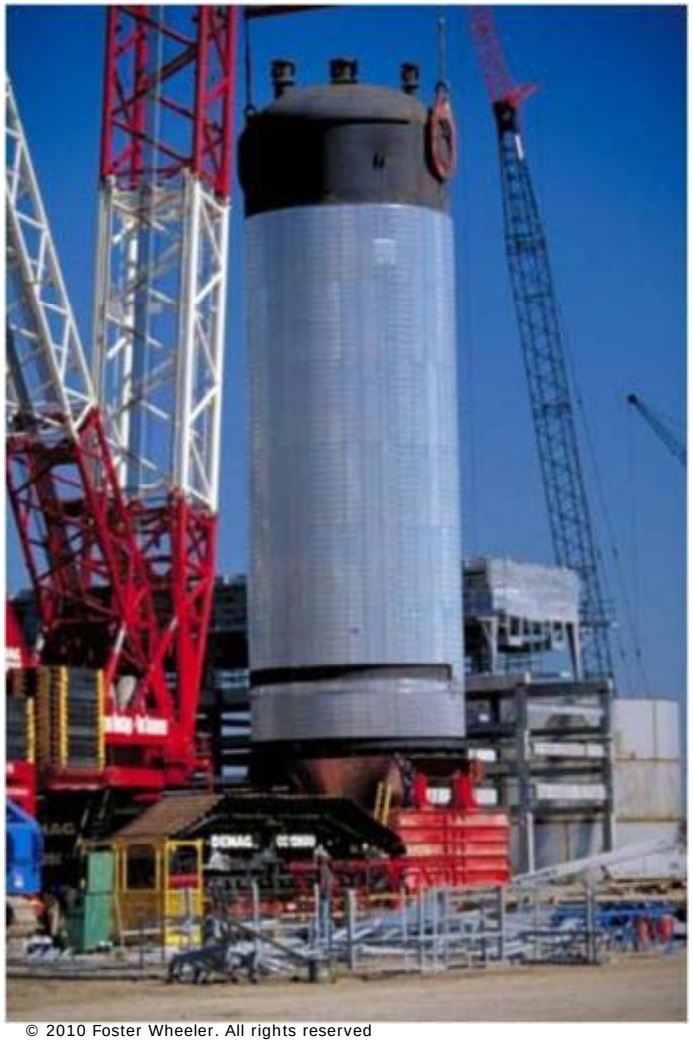
Benefits

- Process difficult feeds
- Provides feedstock flexibility
- Longer run lengths
- More profitable operations

Terrace-Wall Heater

Terrace-Wall Heater

Coke Drum Design



- Single thickness wall
- Skirt-shell connection
- 1¼ Chrome steel with cladding
- Proprietary FW plate chemistry, and welding and finishing specifications
- Long life (>8,000 cycles)

Leader in Large Coke Drum Design

- 33 projects with coke drums over 8.5m diameter
- 144 coke drums
- 9 projects with large, 6 drum design

Maximum Liquid Yield Operation

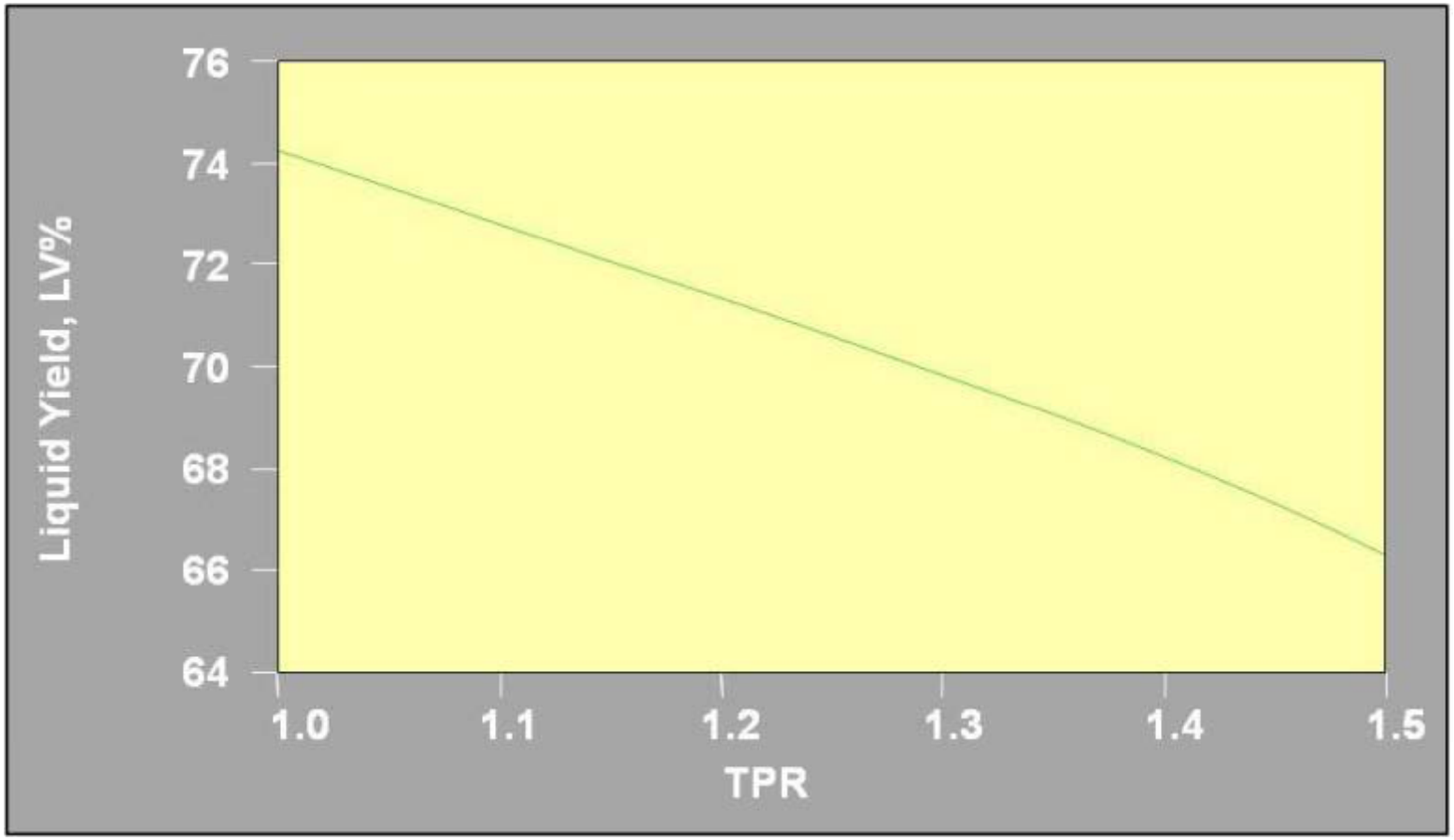
Process Variables

- Temperature — Higher is better
- Pressure — Lower is better
- Cycle time — Depends on operating targets
- Recycle — Lower is better, but….

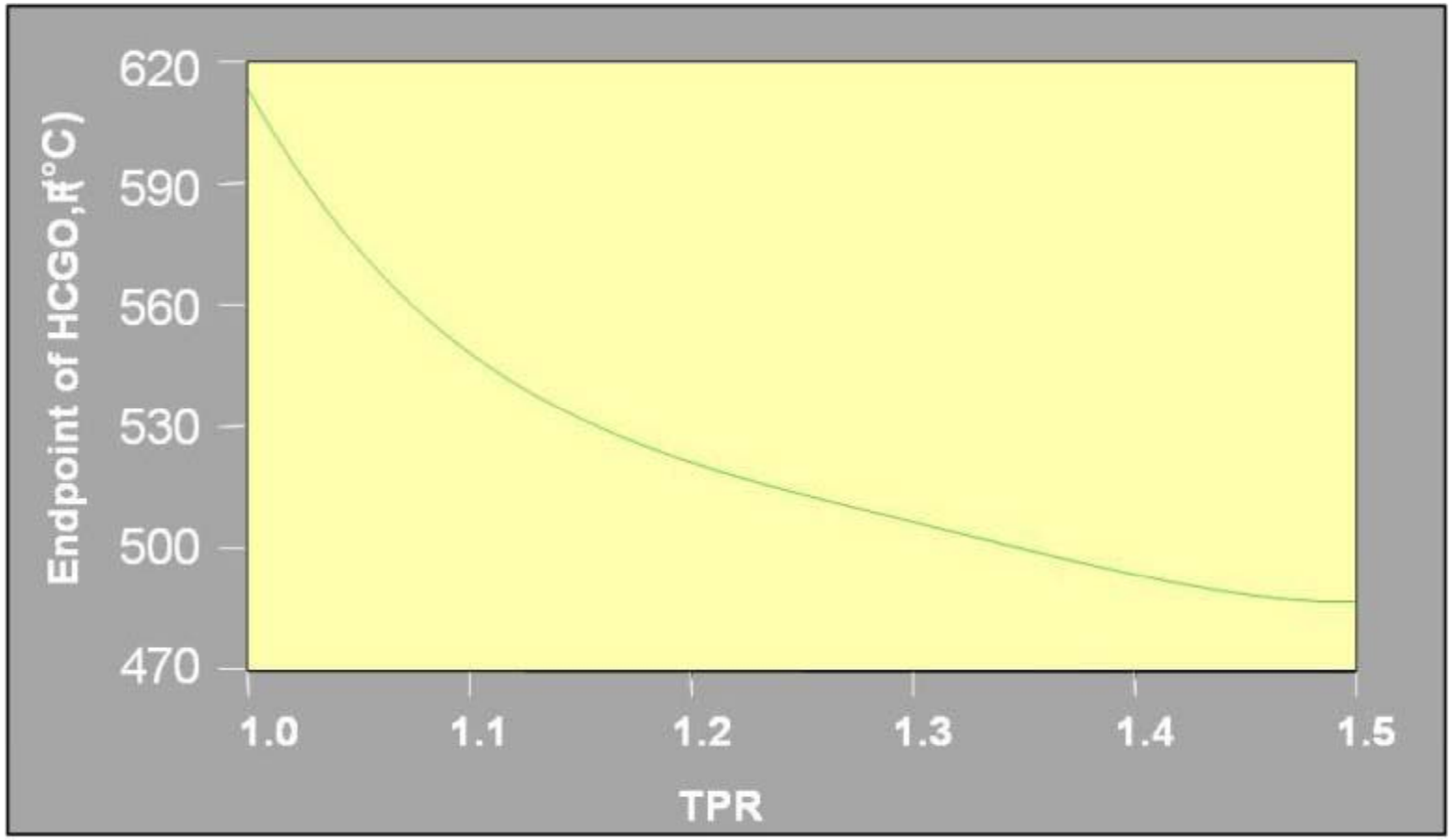
Lower recycle increases HCGO

- Endpoint
- CCR
- Metals
- C_7 insolubles

Impact Of Recycle On Liquid Yield



Impact Of Recycle On HCGO End-Point



Impact of Recycle on HCGO

	Ultra Low Recycle	True Zero Recycle
Gravity, °API	12.78	11.55
Sulfur, wt%	2.58	2.55
Nitrogen, wppm	5,303	5,087
CCR, wt%	0.53	2.43
C_7 Insol., wppm	432	2,000
Ni + V, wppm	1.0	3.8
Distillation		
10%	729	734
50% LV	864	893
EP	1,072	1,141
Watson K	11.13	11.12

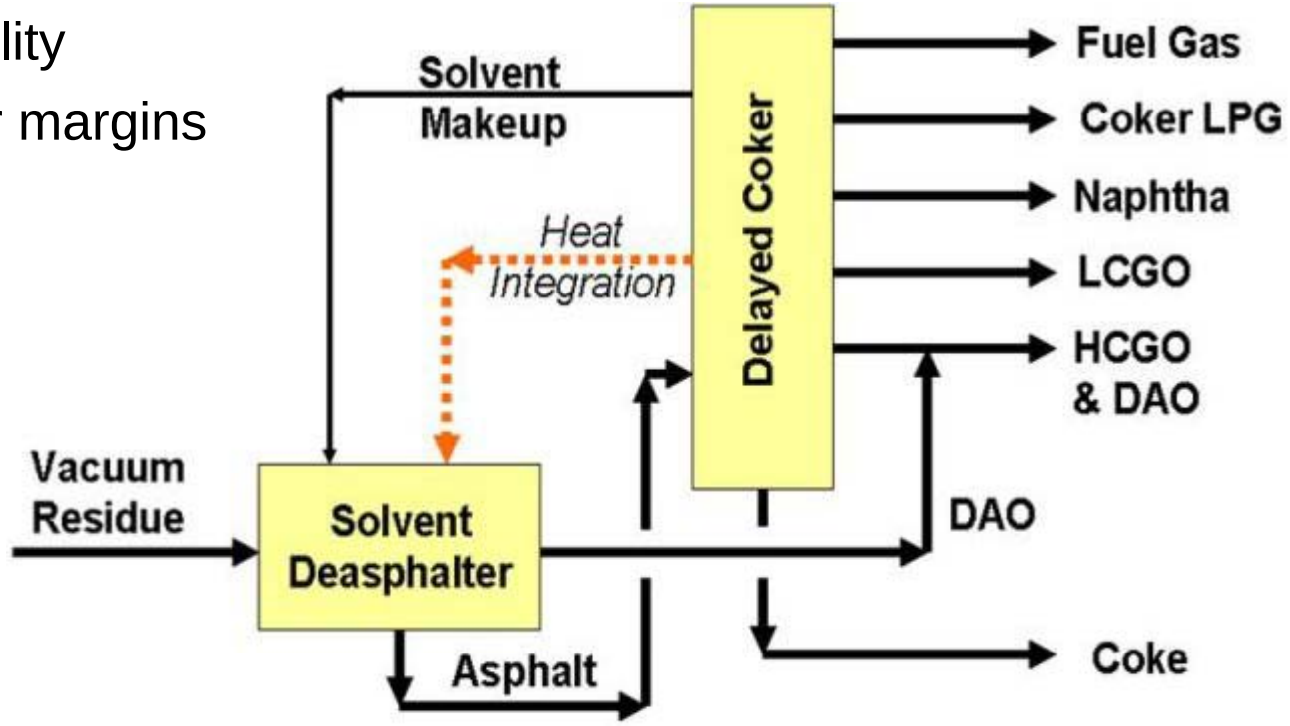
SYDEC Advantages

- Experience
  - Most installed units (> 60%)
  - Over 30 designs in the last 3 years
  - Multiple repeat clients
  - Large units
- Innovative designs
  - Proprietary heaters
  - Safety systems
  - Large coke drums
  - Total automation

Integrated SDA and Coking

Increased liquid yields

- Reduced coke make
- Flexibility
- Higher margins



Summary

- Variety of residue upgrading options exist
- Choice depends upon particular circumstances
  - Fuel oil market
  - Asphalt market
  - Downstream processing
- Coking provides complete conversion
- Coking can be integrated with other processes

Options For Coke

Petcoke Types

- Fuel grade
  - Shot coke
  - Sponge coke

- Anode grade
  - Sponge coke
  - Electrodes for aluminum smelters

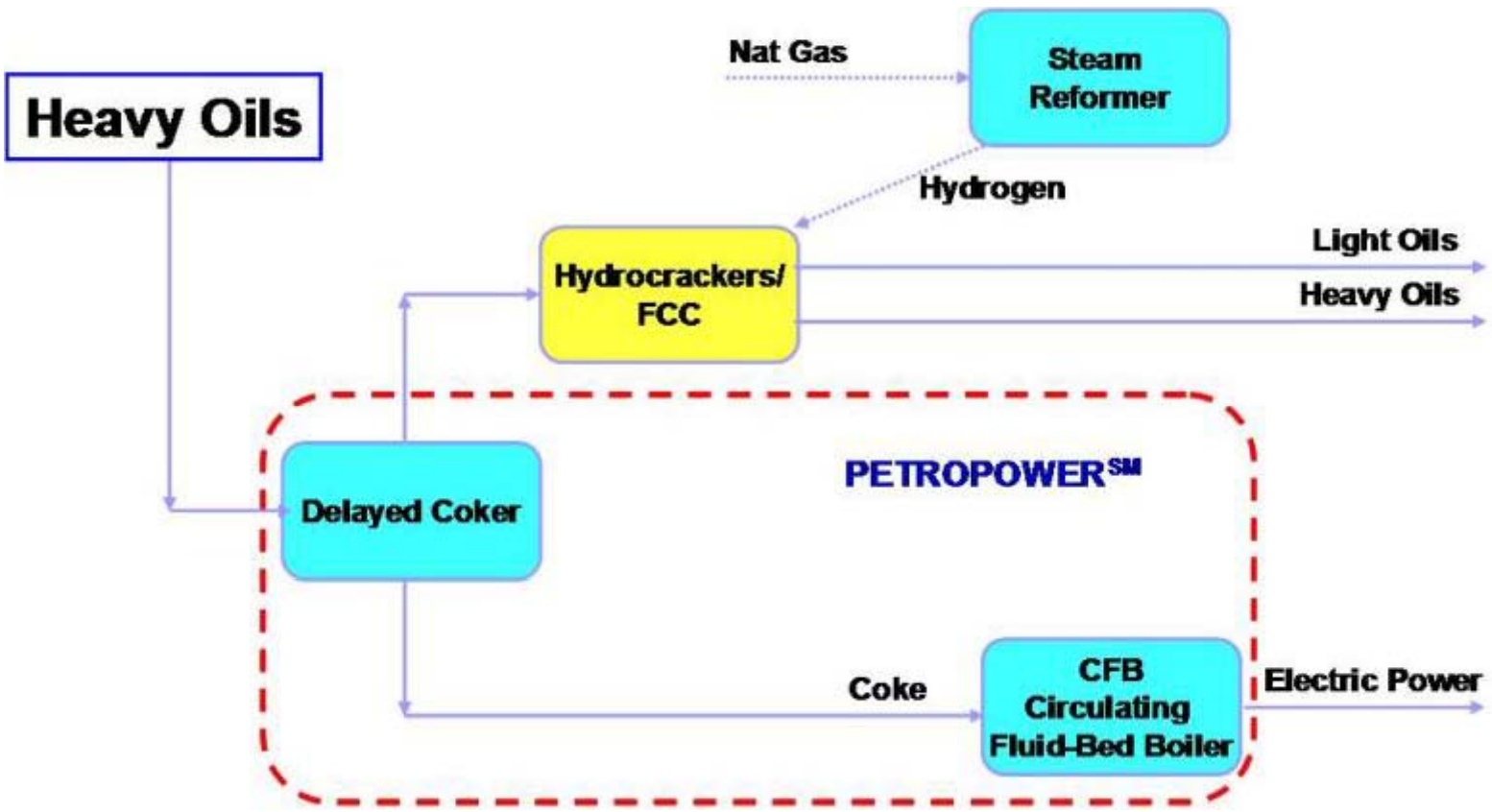
- Needle coke
  - Crystalline
  - Graphite electrodes for electric arc steel mills

Fuel Grade Coke Markets

Source: Oxbow Carbon

- Utility companies
- Cement
- Calcining
- Numerous pet coke marketing companies
- High calorific value and low ash
- Production over 80MM MTPA worldwide
- Value of coking is in liquid products produced not coke

Integrated Refining and Power Production



Petropower – ENAP, Chile

Other projects under consideration

Anode Coke

- Feedstocks
  - Low Sulfur and metals residues
  - Coal tar
  - Distillate tars
- High demand
- World market approx. 17 to 20 MM MTPA
- Purchasers distinguish between anode grades
  - Premium (S < 1.5%, V < 150 ppm)
  - Regular
  - Blend coke (S ~ 4% max, V ~ 400 ppm max)

Needle Coke

- **Feedstocks**
  - Low Sulfur and metals aromatic tars
  - Decant oils
  - Thermal tars
- **Small specialty market**
- **Approx. 1.2 MM MTPA**
- **Grades dependent on properties**
  - Regular
  - Premium
  - Super Premium
- **Approx. half dozen manufacturers**
  - Supply constrained (one with more than 50% share)
- **Approx dozen purchasers**
  - Some manufacturers left market to increase refinery margin making fuel coke with low price heavy crude.

Summary

- Coke produced depends on feedstock
- Fuel coke easily disposed of
- Specialty cokes have smaller markets
  - Needle coke is a niche market
- Not always necessary to make the highest value coke
  - Increased liquid products