Shale Oils – Designing for Improved Crude Preheat Train Reliability and Performance

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Introduction / Overview

- Shale plays – locations and current production
- Tight oil and condensate – composition
- Design approach for crude preheat train design
  - Exchanger fouling and design
  - Desalter design and operation
  - Flash drum placement and design
  - Crude charge heater fouling and design
- Conclusions
Shale Plays Location & Current Production

- **Shale plays - lower U.S. 48 map:**
  - Niobrara
  - Bakken
  - Monterrey
  - Haynesville-Bossier
  - Utica
  - Wolf Camp & Bone Springs
  - Eagle Ford

- **Largest liquid “Tight Oil” producers:**
  - Bakken in Montana / North Dakota
  - Eagle Ford in South Central Texas

- **Production:**
  - Bakken 2014E: 0.94 MMBPD
  - Eagle Ford 2014E: 1.21 MMBPD
Tight Oil & Condensate Composition

- Tight oil and condensate are:
  - Light and sweet
  - Sulfur: < 0.25 wt%
  - High naphtha content
  - Paraffinic
  - Heavy metals are low
  - High filterable solids
- Tight Oil: ~ 40 – 55 API gravity
- Condensate: ~ 55 – 65 API gravity
- Processing Challenges from:
  - Paraffinic nature – wax deposition, asphaltene precipitation when blend crudes, exchanger and charge heater fouling
  - Filterable solids – exchanger and fired heater fouling
  - Refiners lack of ability to clean equipment on-line

Source: AFPM AM-14-17, 2014
Crude Preheat Train - Design Approach for Reliability & Performance

- Exchanger Fouling and Design
- Desalter Design and Operation
- Flash Drum Placement and Design
- Charge Heater Fouling and Design
Crude Preheat Train Overview

**Design Considerations:**

* Exchanger Fouling and Design

Diagram showing the process flow of a crude preheat train:

- "Tight Oil" "Crude Oil"
- Cold Preheat
- Desalter
- Intermediate Preheat
- Flash Drum
- Hot Preheat
- Crude Heater

Outputs:
- Light Ends
- LN
- HN
- Kero
- Dist.
- AGO
- AR

*Crude Preheat Train Overview*
Exchanger Fouling & Design

- **Tight oil and condensate considerations:**
  - High paraffin content - wax deposition
  - High filterable solids – solids deposition
  - Asphaltene precipitation potential - crude blending
  - Desalter design and operation – upsets and carryover

- **Exchanger Types:**
  - Shell and tube
  - Helical baffle
  - Refer to figures on next two slides
Exchanger Types – Shell and Tube (S&T)

- **Tube side** – high velocity
- **Shell side:**
  - Lower velocity vs helical baffle exchanger (HBE)
  - Higher pressure drop (same velocity) vs HBE
  - Segmental baffles - potential for deposition
Exchanger Types – Helical Baffle (HBE)

- **Tube side** – high velocity
- **Shell side:**
  - Can achieve higher velocity vs S&T
  - Can achieve lower pressure drop with high velocity (without vibration)
  - Reduced dead zones – extended run times
Exchanger Selection Methodology

- **Exchanger Selection – to start:**
  - Optimization / process simulation is complete
  - Configuration / number of heat exchangers defined
  - Hot and cold streams, flowrates, and exchanger duties defined

- **Methodology**
  - Assess causes of fouling in the cold, intermediate and hot train
  - Based on causes, assess: can hot and cold fluids be placed on the shell and/or the tube side for S&T and Helical baffle exchangers (HBE)?
  - Use exchanger modeling tool (i.e. HTRI, B-JAC) with prescribed design requirements and conduct comparison
Exchanger Selection Methodology

- **Methodology (continued)**
  - Apply design margins, fouling factors, exchanger cleaning requirements
  - Tabulate results for S&T and HBE’s while placing the hot and cold fluids on each of the applicable sides of the exchanger
  - Compare area, pressure drop, on-line cleaning considerations and installed capital and/or lifecycle costs
  - Based upon results - select exchanger type and fluid placement

- **Other considerations – bigger picture**
  - Exchanger pressure drop
  - Pumping horsepower
  - Equipment design pressure
  - Metallurgy
  - Seek existing exchanger fouling data
Exchanger Fouling & Design – Cold PHT

- **Causes of Fouling:**
  - Fouling is more likely to occur on cold crude side
  - Cause: Wax build-up, high filterable solids deposition

- **Design Considerations:**
  - Maintain high fluid velocity (>5 fps)
  - Minimize dead spots on crude side (i.e. NOT place on shell side for S&T option)
  - Recognize potential to reduce ΔP for crude if placed on the shell side.
  - Other (include design margins, fouling factors, exchanger cleaning requirements)

- **Exchanger Selections:**
  - Tabulate and compare results
  - Continue through all cold PHT exchanger services and make selections
  - Apply “Other considerations” for final selections

*EXAMPLE*
Exchanger Fouling & Design – PHT Exchangers

- **Causes of Fouling:**
  - **Cold Train:**
    * Fouling is more likely to occur on cold crude side
    * Cause: Wax build-up, high filterable solids deposition
  - **Intermediate Train:**
    * Fouling potential for the cold crude and hot stream sides
    * Cold (crude) side - desalter operation/upsets with carryover of emulsions or solids, possible asphaltene precipitation
    * Hot side – potentially higher fouling streams (AGO, AR, VR, etc.)
  - **Hot Train:**
    * Highest temp in train - fouling potential for the cold crude and hot stream sides
    * Cold (crude) side - desalter operation/upsets with carryover of emulsions or solids, higher temps result in higher fouling with asphaltene precipitation potential
    * Hot side – higher fouling streams at high temps, in particular AGO, VGO, Atm and Vac resid
To achieve the most cost-effective, safe, and reliable PHT design - Evaluate and determine a balance between:

- Exchanger fouling
- Fluid velocity criteria
- Exchanger pressure drop
- Placement the cold and hot fluids
- Exchanger metallurgy
- On-line cleaning
- Pumping head
- Equipment design pressures
Crude Preheat Train Overview

Design Considerations:
- Exchanger Fouling and Design
- Desalter Design and Operation

Diagram:
- “Tight Oil” or “Crude Oil”
- Cold Preheat
- Desalter
- Intermediate Preheat
- Flash Drum
- Hot Preheat
- Crude Heater
- CDU
  - Light Ends
  - LN
  - HN
  - Kero
  - Dist.
  - AGO
  - AR
Desalter Design & Operation

* **Purpose & Function of Desalter:**
  - Reduce salt content and remove solids
  - Wash Water mixed with Oil. Separates by differential gravity enhanced by electric field
  - Resulting Oil is clean and dry. Brine contains salts, sediment

* **Design Considerations:**
  - Feed characteristic including paraffinic-asphaltene compatibility
  - Temperature to reduce viscosity, limited by water solubility in oil & mechanical equipment
  - Corresponding Pressure needed to maintain liquid phase and prevent vaporization
  - Tendency to form emulsions and need for addition of chemical dispersants and demulsifiers
  - Solids handling capacity internal and external oily brine processing

* **Tight Oil Desalter Features**
  - Two-Stage has higher removal efficiency than Single Stage. Reduces chance of carryover, Can be serviced w/o total shutdown
  - Robust Mudwash system for high solids and stabilized emulsions.
  - Wash Water pH control to assist in removal of amine added during transportation (to lower H2S content in tight oil)
Desalter Design & Operation

Source: Piping Engineering
Crude Preheat Train Overview

Design Considerations:
- Exchanger Fouling and Design
- Desalter Design and Operation
- Flash Drum Placement and Design

“Tight Oil”
“Crude Oil”
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Flash Drum Placement & Design

* **Location of vapor feed to column**
  
  * **Option 1:** Flash zone where fired heater transfer line connects to the crude tower
    * Results in a larger crude tower bottom section diameter.
    * Vapor stream in flash zone acts as a quench requiring a higher heater outlet temp. to maintain the desired flash zone temp.
  
  * **Option 2:** Taken to an appropriately higher section in the tower where temp. and composition of the flash drum vapor is similar.
    * For light oil flashed at 400°F, vapor return location would be above the distillate section and below the naphtha section.
    * Required heater duty and crude tower diameter could be reduced in this scenario.
**Option 3: Flash tower with trays and overhead system**

- Does NOT return any flashed vapor to the crude tower.
- More complex and costly than a flash drum.
- Typical for a revamp due to:
  - Limitations on existing crude tower.
  - Requirement of additional throughput and improved separation.

*Source: Process Consulting Services*
Crude Preheat Train Overview

Design Considerations:
* Exchanger Fouling and Design
* Desalter Design and Operation
* Flash Drum Placement and Design
* Charge Heater Fouling and Design

Diagram:
- "Tight Oil"/"Crude Oil"
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**Charge Heater Fouling & Design**

- **Causes of fouling:**
  - Asphaltene deposition from blending crudes
  - Desalter carryover of emulsions and solids can also contribute
  - High tube metal temperatures (TMT)
  - High residence times
  - High percent vaporization (tube running dry)
  - Cracking reactions with coke laydown

- **Design Considerations:**
  - Even radiant heat flux – avoid localized hot spots
    - See figures to right
  - High mass velocity – lower residence time
    - Consider velocity steam injection at multiple locations
Charge Heater Fouling & Design

- **Design Considerations (cont’d):**
  - Max percent vaporization (50 – 60%)
    - Lights content of tight oil exacerbates
    - Can recirculate atm resid
  - Include on-line decoking or pigging of tubes
- **Charge Heater type:**
  - Double fired – even heat flux
    - All floor or wall and floor burners
    - Floor burners alone can accomplish even heat flux and is lower cost
  - Multiple cells – for on-line cleaning
Charge Heater Fouling & Design

- **Charge Heater Type:**
  - Figure to right features:
    - Two-cell, box cabin with floor burners
    - Ability to isolate each cell for on-line decoking and/or pigging (smart pigs)
  - Design may or may not include:
    - ID, FD fans, with SCR and common stack
Charge Heater Fouling & Design

- **Other Design Considerations:**
  - Carefully consider charge heater design margin
    - Allows operation at higher capacity when cleaning one cell
  - Fouling in fired heater tubes is less desirable than fouling in heat exchanger
    - Strive for max heater inlet temperatures
  - Vaporization at heater outlet affected by
    - Flash zone temperature and pressure
    - Consider recirculation of atm resid
Conclusion

- Tight oils and condensates are presenting unique challenges for design of new CPHT’s and in operating existing CPHT’s.

- Existing crude units are experiencing high fouling in heat exchangers and charge heater tubes leading to unplanned outages and loss of production.

- Crude unit reliability can be increased in new unit design, in crude unit retrofits and/or in adjusting operating parameters in existing units.
Conclusion

- This paper has provided specific design approaches for the CPHT to address the unique challenges when processing tight oil and condensates, including:
  - Exchanger fouling and design
  - Desalter design and operation
  - Flash drum placement and design
  - Fired heater fouling and design
Questions and Answers

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