Specifying Internals in Sour Water Strippers

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Trimeric Background & Questions Policy

- Trimeric Corporation
  - 18 regular staff ChEs & 6 Senior Assoc. ChEs
  - Specialized = Process Chemical Engineers
  - Generalized = Experience Across Industries and Processes
  - Experience in Sour Water Stripper Applications
    - Design and troubleshooting of sour water stripper systems (separation equipment and stripper)
    - Process modeling

- Questions policy

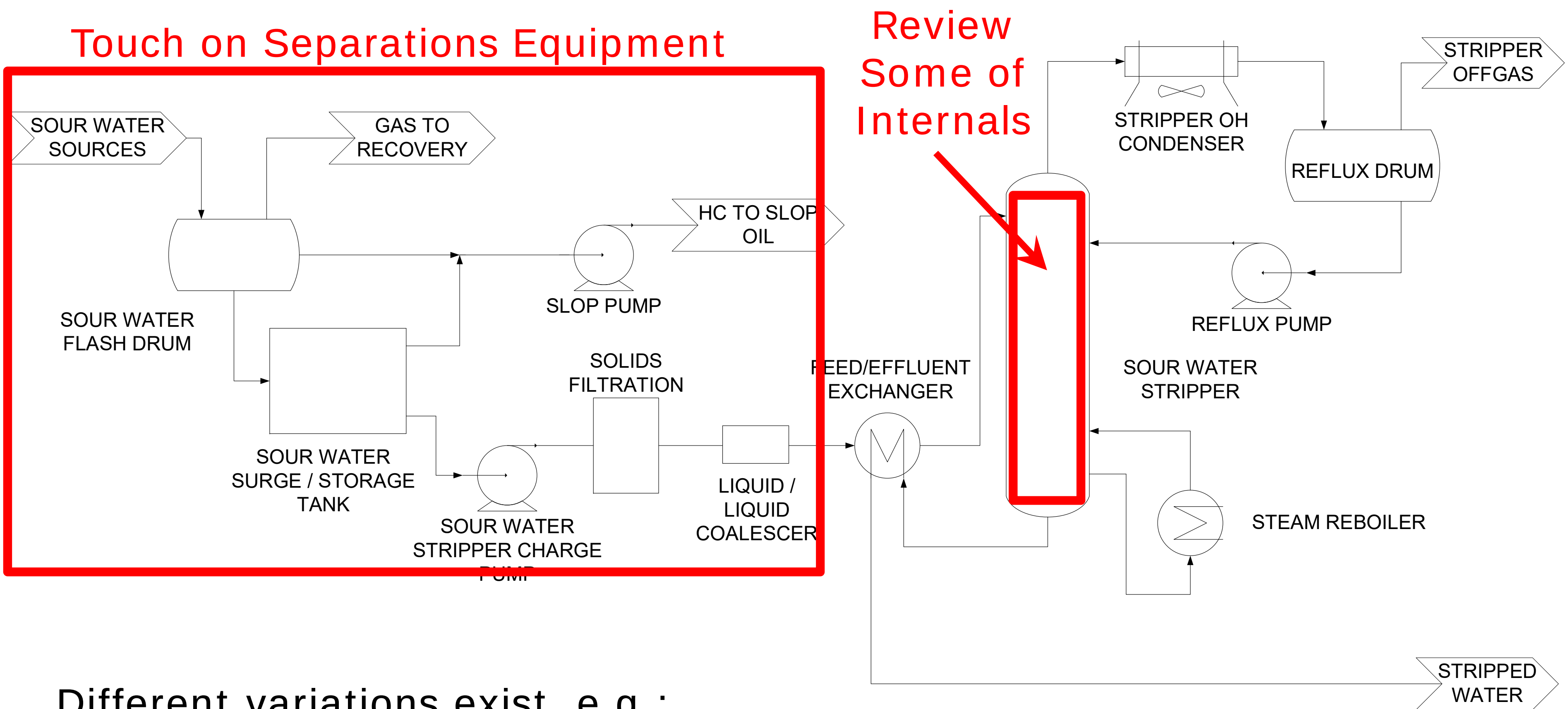
Topics

- Introduction
- Auxiliary Sour Water Separation Equipment
- Sour Water Stripper Design and Internals
- Issues Encountered in Operation
- Conclusions

Introduction

- Sour water stripper (SWS) receives water from many refinery operations
- Variable sour water characteristics
  - H_2S and NH_3 usually primary species for removal
  - Hydrocarbon and solid contaminants
- Highly fouling service
- Critical to refinery operations
- Robust design needed
- **Goal of paper → touch on separation equipment & review some aspects of stripper internals design**

Sour Water Stripper System



Different variations exist, e.g.:

1) Live steam vs. steam reboiler
2) Pumparound vs. conventional reflux
3) Etc.

Introduction

- Brimstone has a long history of technical papers & presentations on sour water stripping and related topics, including (partial list):

  - 1995, Scott, processes for sour waters
  - 2000, Asquith, balancing needs in SWS
  - 2007, Stevens, Mosher, Ogg, SWS fundamentals
  - 2013, Stavros, case study, improved internals
  - 2012, Hatcher, modelling SWS w salts present
  - 2015, Keller, SWS fundamentals, Q&A style
  - And others

  - (2011, Carioscia, Johnson, Wissbaum, Matls of construction)

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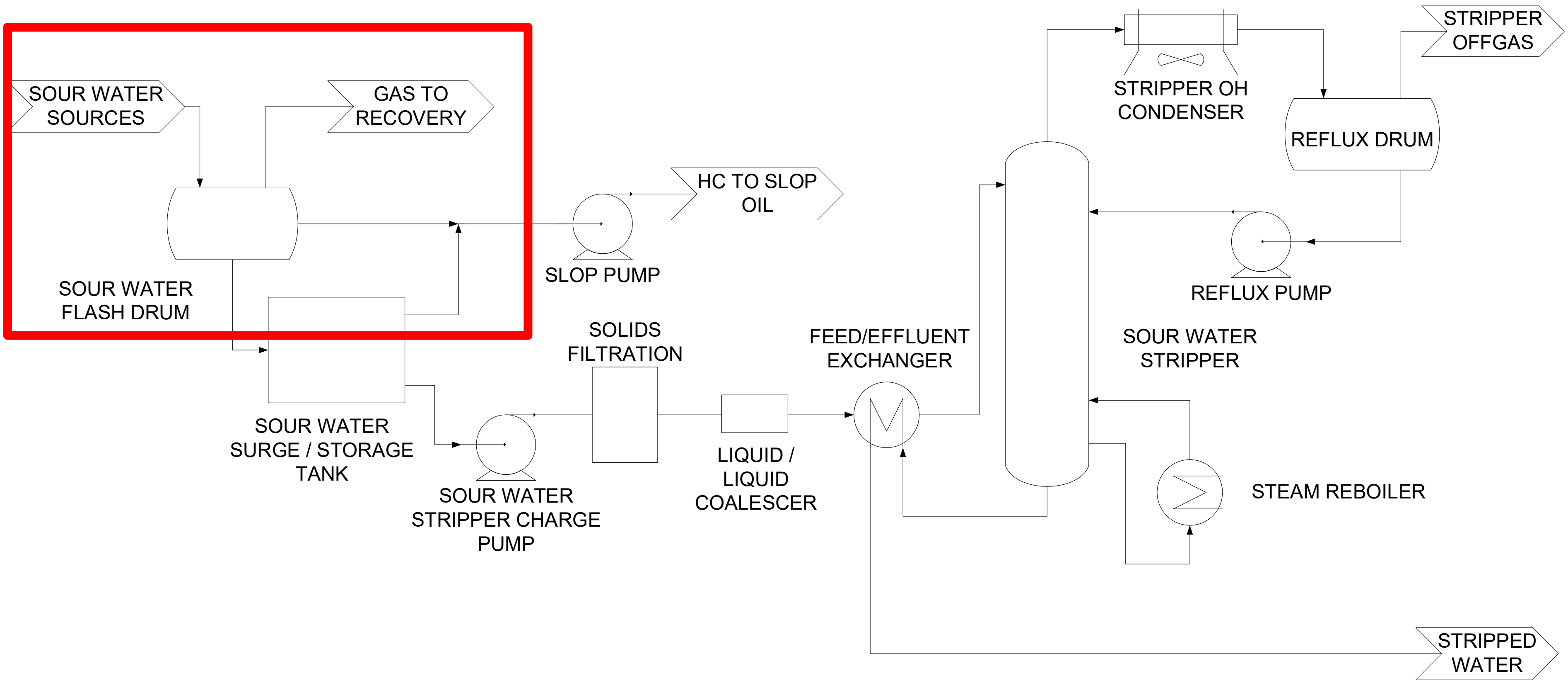
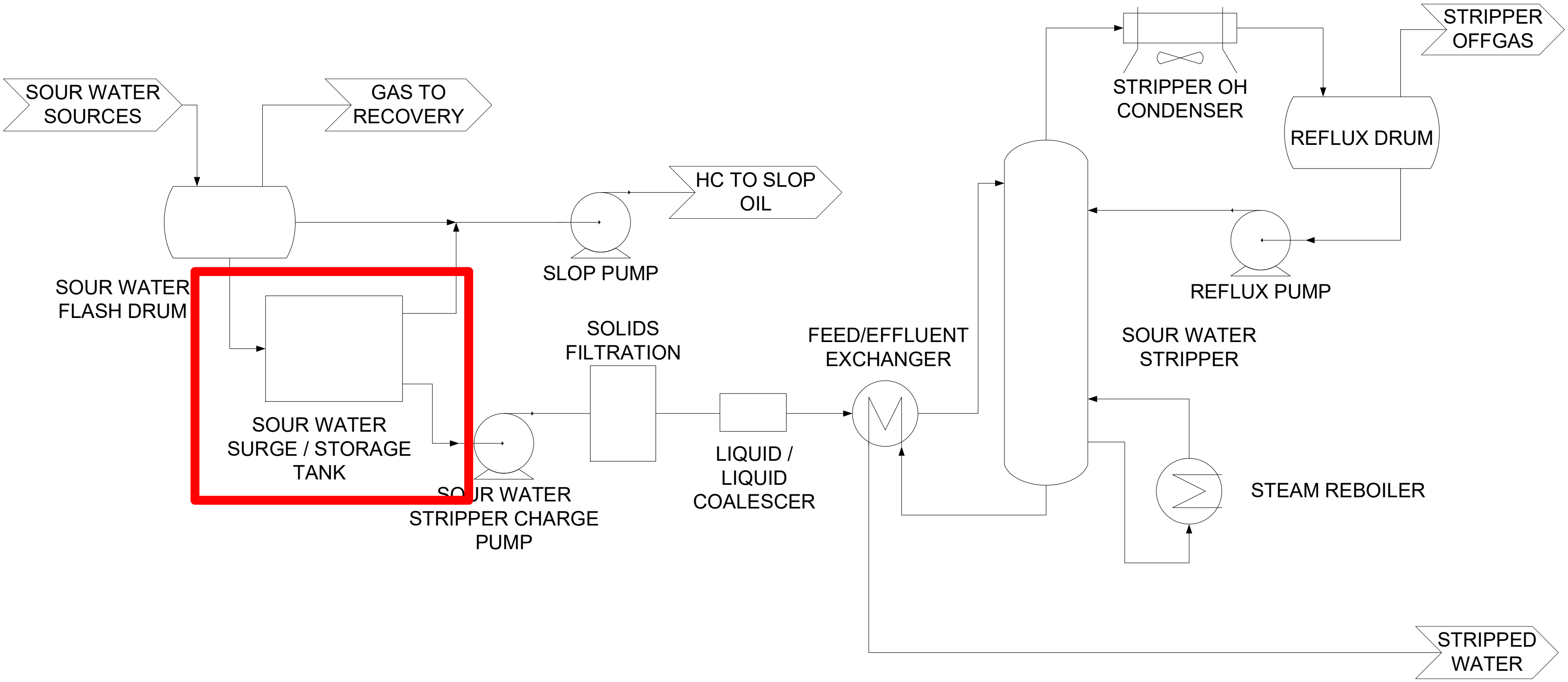
Sour Water Flash Drum



Sour Water Flash Drum

- 3-phase, horizontal vessel
- Vapor and liquid hydrocarbon removal
- Vapors to flare gas recovery , fuel gas, other
- Hydrocarbons to slop, other
- Design:
  - Overflow weir or draw-off box
  - Minimum residence time = 20 minutes
  - Liquid level = 50-60%
  - Water and hydrocarbon level control
  - No demisting equipment (too likely to plug up)
  - Designed for highly fouling service

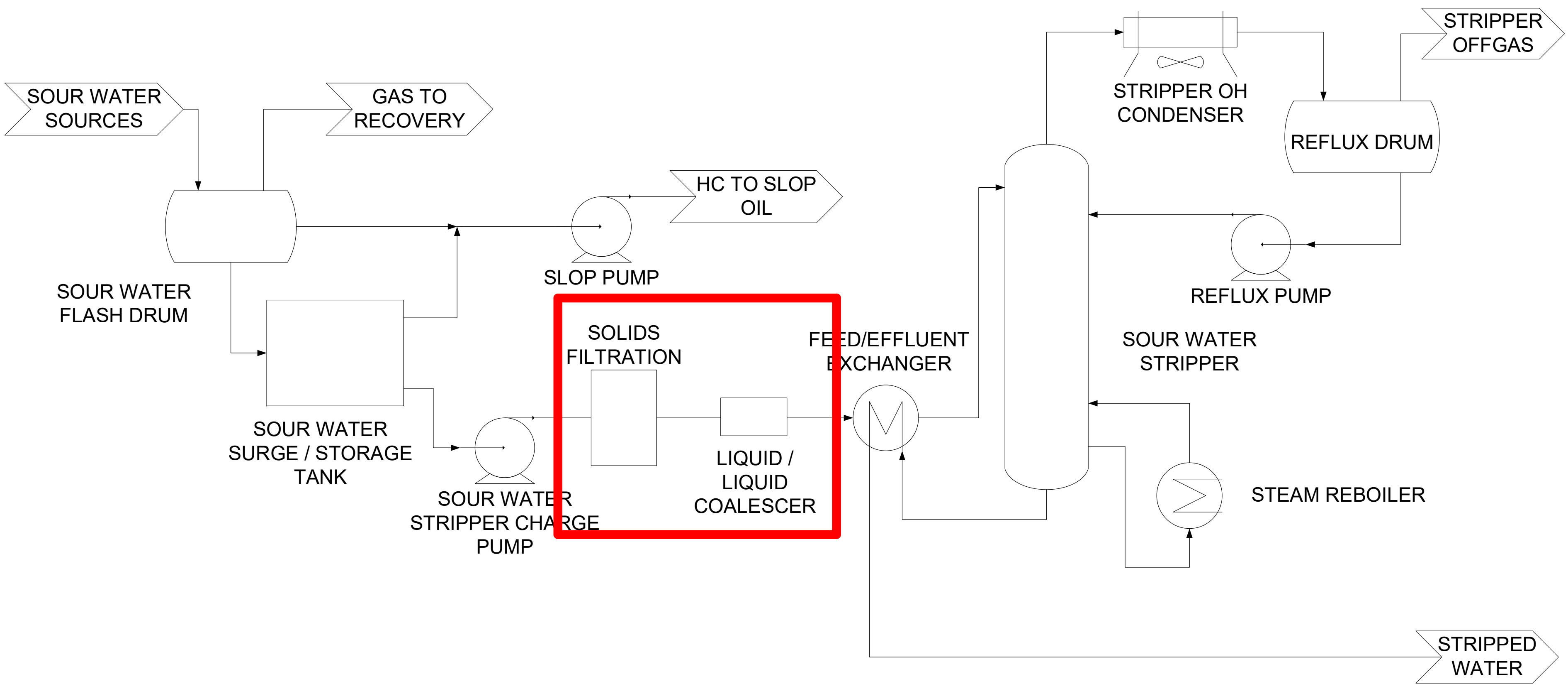
Sour Water Surge / Storage Tank



Sour Water Surge / Storage Tank

- Several days of sour water storage
- Remaining hydrocarbon & emulsions separate
- Uniform sour water composition
- Design:
  - Minimum retention time = ~3 days
  - Liquid level = 50-60%
  - Floating diesel / rag layer or blanket common
  - Oil skim nozzles
  - Level and interface controls
  - Sloped tank bottom
  - Possible angled ports specifically meant for periodic solids removal (e.g., stir up and filter)
  - N2 blanket and pyrophoric iron sulfide concern (AFPM Process Safety Bulletin #14-01)

Sour Water – Additional Filtration



Additional Filtration

- Locate after sour water charge pump and upstream of feed/effluent exchanger
- Solids filtration
  - Improves coalescer efficiency
  - Minimizes fouling
  - Strainers sometimes used instead of filter
- Liquid / liquid coalescer
  - Controls hydrocarbon fouling
  - Reduces risk of oil carryover to sulfur plant
  - Minimizes oil in stripped water

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Stripper Sizing and Feed Location

- Stripper sizing
  - Derate column sizing for foaming
  - System factor of 0.6 to 0.7
- Feed location
  - Dependent on many factors
  - Model to determine optimal location
  - Typically within top several trays
- Corrosion resistant lining or stainless steel above feed location

Tray Selection

- Most sour water strippers may use trays
- Fixed valve trays are probably best practice
  - Vapor flows horizontal out of tray deck
  - Minimizes bridging of deposits on fixed valves
- Trays made of 300 series stainless steel
- Cartridge trays for small towers
- Pumparound trays not active mass transfer trays

Sieve Tray Fouling

- Sieve trays can sometimes be fouling resistant
- But, severe fouling observed in sour water strippers
- Efficiency decrease up to 90% (Bela, 2003)

- Bela, F.; Comprimo, “SWS Fixed Valve Trays, 2003
- R. Hauser and R. T. Kirkey, Refinery Tests Demonstrate Fixed Valve Trays Improve Performance in Sour Water Stripper, New Orleans, LA: AIChE, 2003.

Fixed Valve Tray Fouling

- Applications in fouling service
- Horizontal vapor flow out of valve stirs up liquid and helps prevent solids settling
- Efficiency decrease reduced to 10-15% (Bela, 2003)

- Bela, F.; Comprimo, “SWS Fixed Valve Trays, 2003
- R. Hauser and R. T. Kirkey, Refinery Tests Demonstrate Fixed Valve Trays Improve Performance in Sour Water Stripper, New Orleans, LA: AIChE, 2003.

Tray Efficiency

- Tray efficiency range: 15-50%
- Typical # of trays: 30 to 60
- Tray efficiency applied to equilibrium design
- Efficiencies vary by:
  - Component
  - Across column
- Use conservatively low efficiency
- Consider mass-transfer-based stripper models

Additional Precautions

- NH_3 harder to remove than H_2S
  - NH_3 can be 'fixed' in stripper water
  - Caustic displaces NH_3
  - Caustic sometimes added to tower bottom (no H_2S impact)
- Efficiency reduction in trays
  - Hydrocarbons and solids in stripper
  - Potential for salts formation
  - 10-15% reduction observed in fixed valve tray
  - Account for efficiency loss in design

Packed Strippers

- Random packing less common than trays
  - 1969 API DRW
    - 11 trayed, 5 packed in Chap 10, table 10.1, op performance
    - 12 trayed, 3 packed in Chap 15, Examples 1-15 (actual unit summaries)
  - Shown in a minority of sketches in Brimstone papers
    - E.g., 2007, 2008 fundamentals presentations
  - At least one article suggests packing becoming more common for cleaner sour water (Weiland, 2012)
- But, there are still quite a few out there
  - 2013, Stavros paper
  - Trimeric conversations with oil company SMEs
  - Trimeric clients

Packed Strippers

- Why might one use packing instead of trays?
  - Familiarity - the facility has packed SWSs already
  - Pressure Drop – the possibility of lower dP
  - Cost – packed columns may be perceived to be less expensive than trayed columns
    - Column itself
    - Internals
  - Desire to re-use existing equipment
- Fouling is a key issue with random packing
  - Pre-treatment critical (clean sour water)
  - Fouling-resistant distributors and packing critical

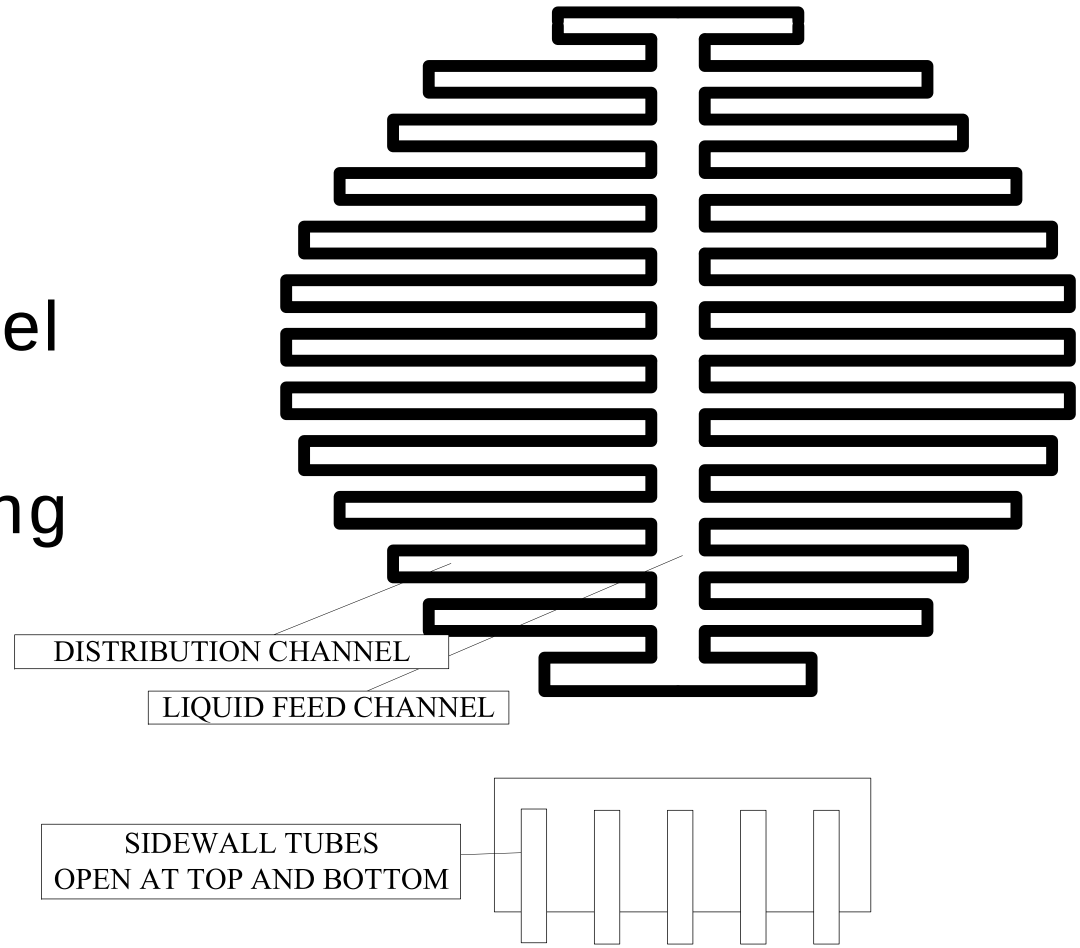
This is where we'll spend the most time

Liquid Distributors

- Trade-offs
  - Tendency to plug and foul vs. adequate distribution
- General conclusions
  - Larger orifices minimize fouling and plugging
  - Reduced number of drip points
  - Orifices in sides of distributor walls, not bottom
  - Distributor levelness critical for distributors using gravity driving force

Channel-Type Distributor

- Tubes at side of channels to distribute flow
- No holes in channel bottoms
- Somewhat plugging resistant with pretty good distribution



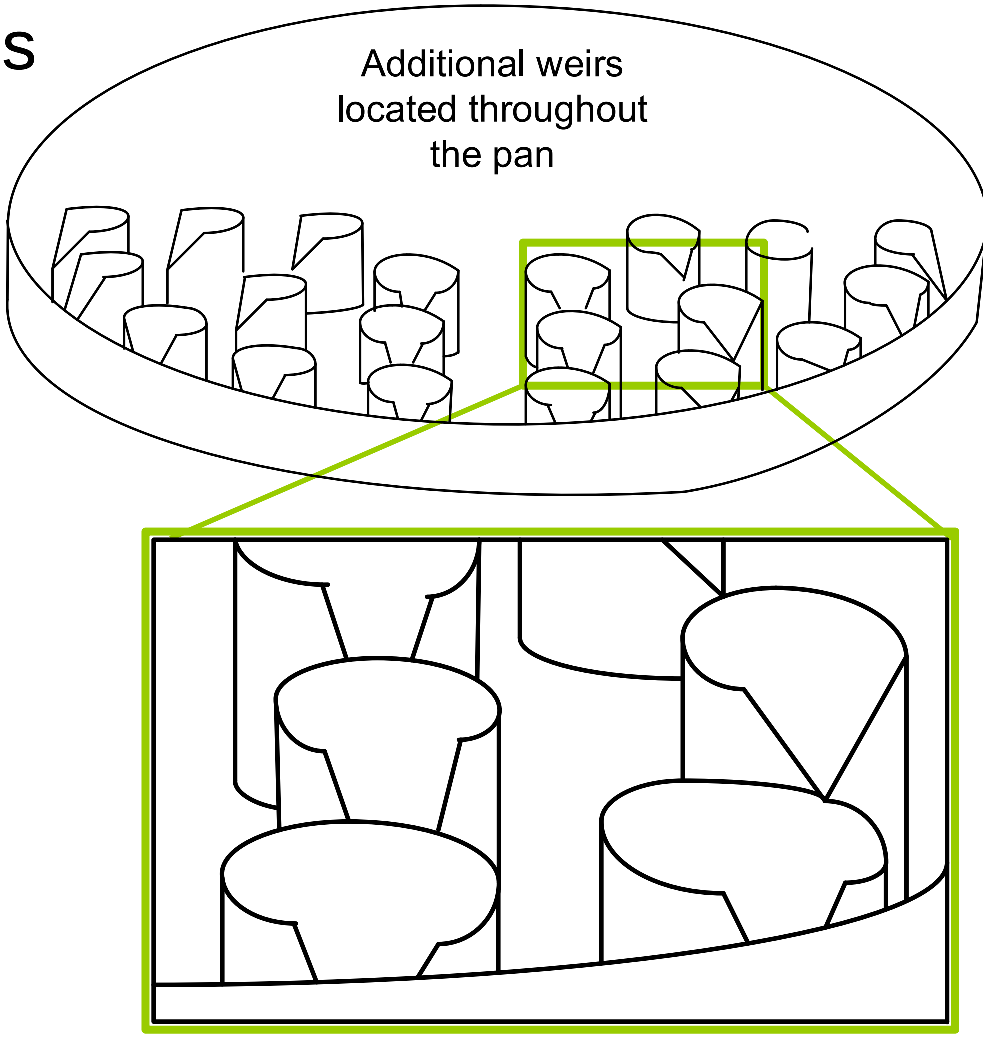
DISTRIBUTION CHANNEL DETAIL

Channel-Type Distributor

- Possibly exclude the guide tubes
- Holes as large as possible...
- While still providing as many drip points as required by the packing that was chosen

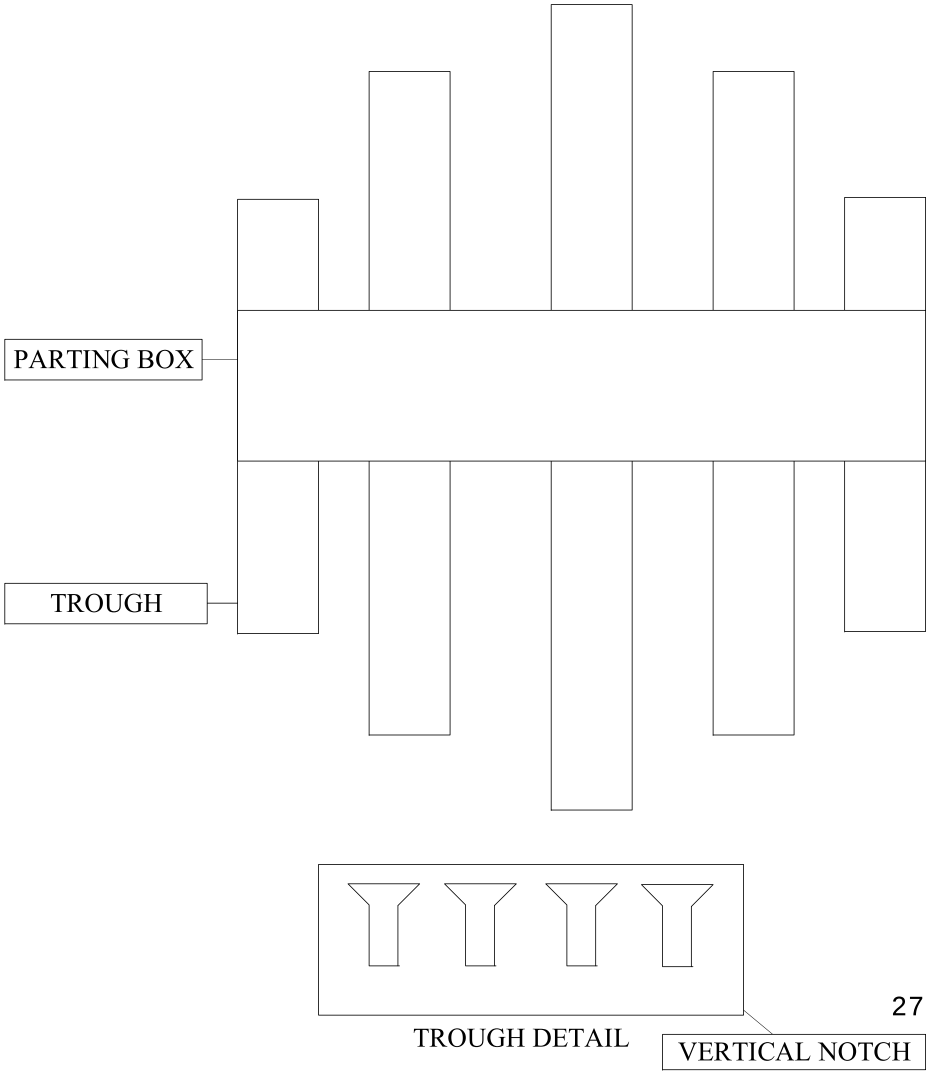
Weir Riser Pan Distributor

- For smaller diam towers
- ‘Weirs’ have v-notches
- Used in highly fouling services
- Probably not as good distribution as some



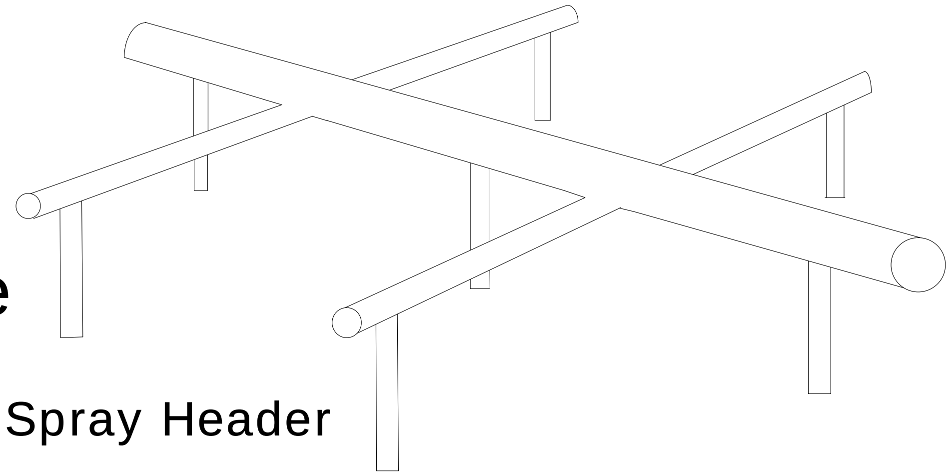
Trough Distributor

- Trough wall v-notch
- Used in severe fouling conditions
- High liquid flow rates
- Not as good distribution as some
- Proven in sour water service

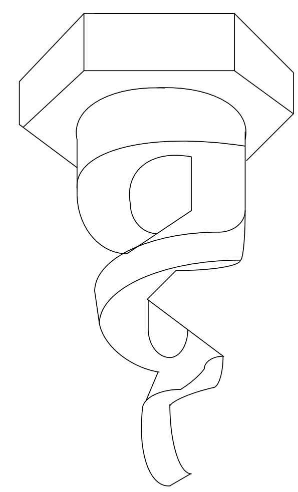


Spray Nozzle Distributor

- Proven in various severe fouling conditions
- Higher liquid pressure needed
- Use nozzles w max free passage
- Probably poorer distribution than the others mentioned here



Spray Header



Large, free-passage full cone spiral nozzle

Packing HETP

- "Efficiency" represented as Height of an Equivalent Theoretical Plate
- Vendor HETP values for random packing
  - Published
  - Favorable hydrocarbon distillations
  - Not specific to sour water service
- Need to account for severity of process and tendency to foul over time
- Consider mass transfer based column simulation

HETP Comparison – Actual Operation

Parameter	Source 1	Source 2 (API DRW, Ch 15, 3)	Source 3 (Stavros, 2013)
Packing type	Small diam ring	1” Pallring	1.5” Specialty
Actual HETP, inches	2+X	13	21
Vendor/literature published HETP, inches	X = ~17	15, 17, 19	20, 16
Ratio of Actual HETP/ Published HETP	2+	0.9, 0.8, 0.7	1.1, 1.3
Ratio of SME Design HETP / Vendor HETP	~1.8 to 2.4		

Packing HETP

- Why is Source 1 experiencing 2+ times the vendor HETP and Source 3 only 1.1 to 1.3 time vendor HETP?
  - Discussion with author indicates good liquid distributor for Source 3
  - Source 1 known to have poorer distributor type (not one of those mentioned previously)
  - Source 1 may have other issues, such as bed plugging
  - Feed conditioning may be different between the two sources

Packing Recommendations

- Open design packing, to reduce plugging
  - Koch-Glitsch: ULTRA®
  - Sulzer: NeXRing™
  - And similar products from other vendors

Parameter	Open Type Packing	Open Type Packing
Packing type	Specialty, Size #2	Specialty, Size #3
Published HETP, inches	23-29	32-38
Service-Specific Vendor Recommended HETP, inches	48-50	58-62
Ratio of Actual vendor-recommended HETP / published HETP	1.7-2.1	1.6-1.8

- Sour water feed conditioning critical

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Issues Encountered in Operations

- Fouling of tower internals: corrosion byproducts and heavy hydrocarbons
- Salts precipitation
  - Ammonium bisulfide, carbamate and bicarbonate
  - Soft metal salts on lower packing beds
  - Hydrocarbon fouling on lower packing beds
- Maintenance and monitoring
  - Equipment cleaning, overhead cold spots, level control
  - Monitor operating data
  - Sample solids and liquids from filters
  - Sample sour and stripped water

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Conclusions

- Demanding service
- Many contaminants, plus NH_3 and H_2S
- Reliable operation difficult
- System design:
  - Proper separator sizing and level control
  - Additional solids and liquid filtration
  - Fouling resistant trays/packing and distributors
  - Stripper design safety margin
- Routine maintenance and proper operating conditions