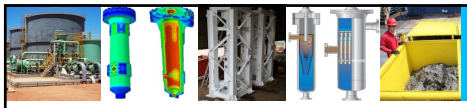
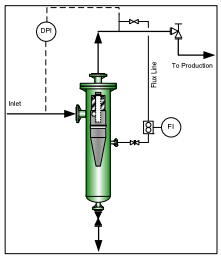


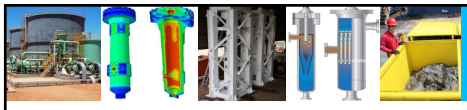


Study on the Interaction of a Flooded Core Hydrocyclone (Desander) and Accumulation Chamber for Separation of Solids from Produced Water

Hank Rawlins - eProcess Technologies
Jesse Costin - Montana Tech

Produced Water Society 2014 Seminar
Houston, TX · January 14-16

eProcess TECHNOLOGIES



Purpose & Outcome

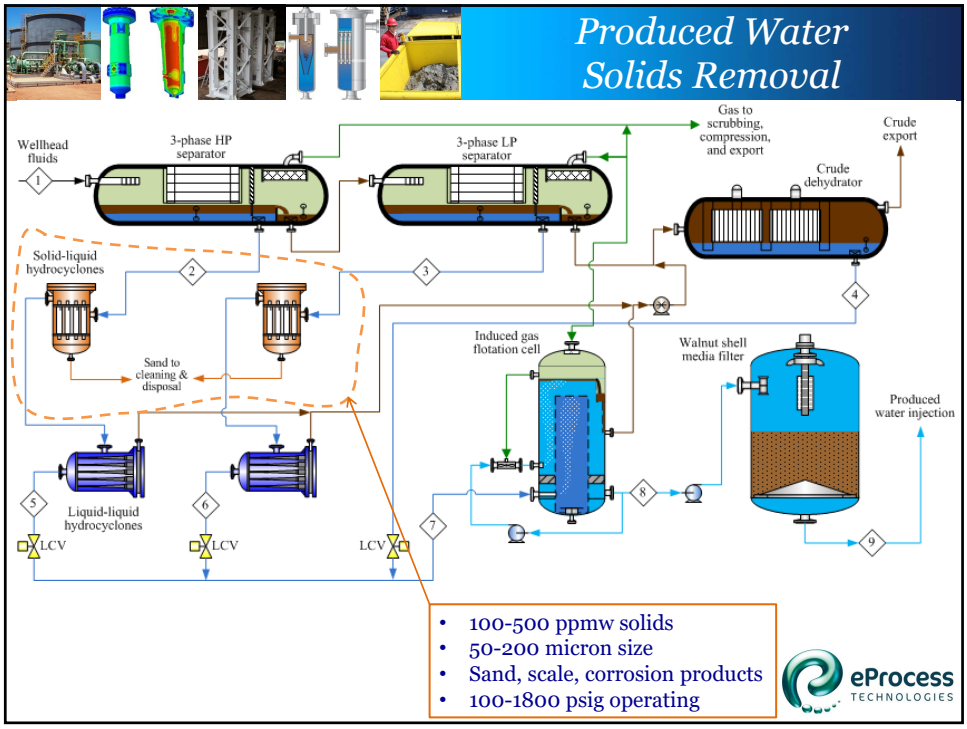
Purpose:

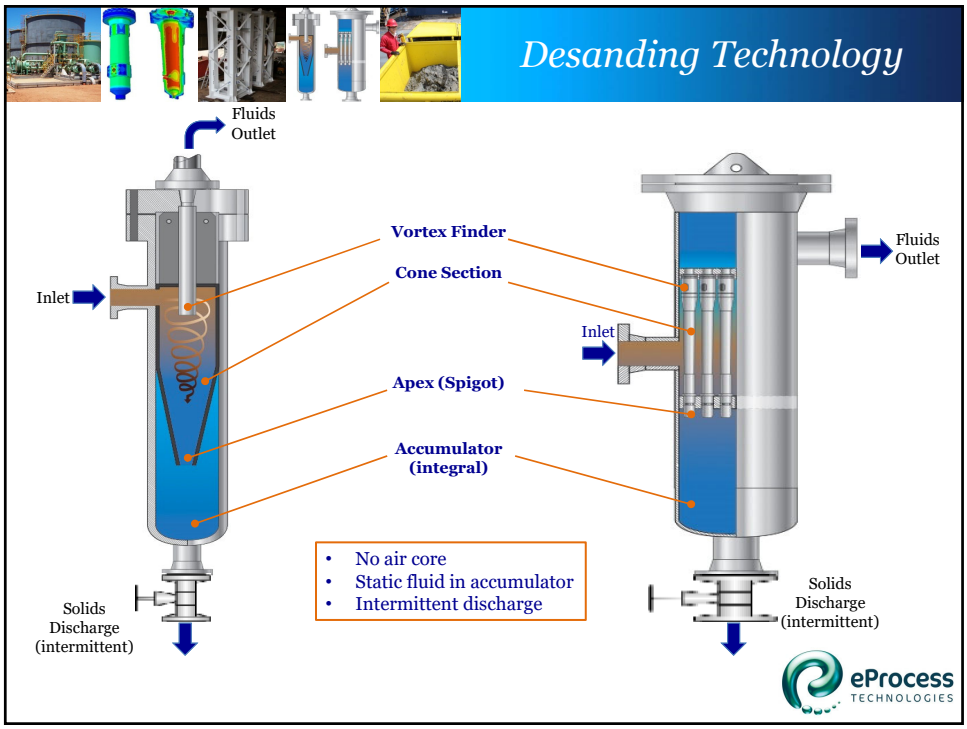
- To test how solids travel from the hydrocyclone body to the accumulator vessel
- Quantify the maximum concentration of solids that a desander can treat without degrading separation performance (rule of thumb is 1%)

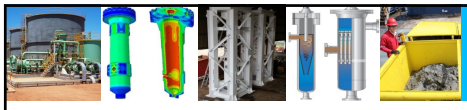
Outcome:

- Provide understanding of how solids transfer from the hydrocyclone through the apex to the accumulator
- Provide quantitative selection guideline for inlet concentration effect on desander performance
- Provide basis for Apex Flux Balancing (AFB)

eProcess TECHNOLOGIES


Produced Water Solids Removal
Wellhead fluids
3-phase HP separator
3-phase LP separator
Gas to scrubbing, compression, and export
Crude export
Crude dehydrator
Solid-liquid hydrocyclones
Sand to cleaning & disposal
Induced gas flotation cell
Walnut shell media filter
Produced water injection
Liquid-liquid hydrocyclones
LCV
LCV
LCV
• 100-500 ppmw solids
• 50-200 micron size
• Sand, scale, corrosion products
• 100-1800 psig operating
eProcess TECHNOLOGIES

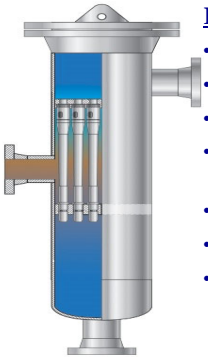

Desanding Technology
Fluids Outlet
Inlet
Vortex Finder
Cone Section
Apex (Spigot)
Accumulator (integral)
Solids Discharge (intermittent)
• No air core
• Static fluid in accumulator
• Intermittent discharge
Fluids Outlet
Inlet
Solids Discharge (intermittent)
eProcess TECHNOLOGIES



Desanding Technology

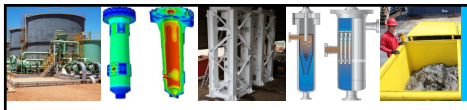
Insert Style (Single Cone)

- Multiphase applications
- One insert per vessel
- Smaller/lighter vessel
- Change insert size for high turndown (>3:1)
- No fluid partitioning
- Particles to 1”-2”
- Concentration to 5 wt.%



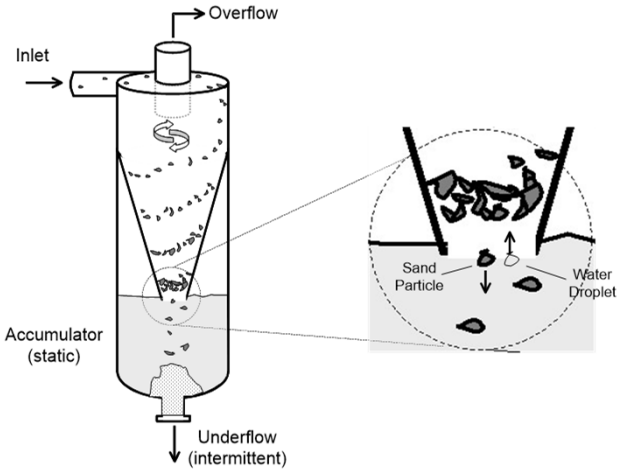
Liner Style (Multi Cone)

- Liquid applications
- Many liners per vessel
- Larger vessel
- Change quantity of liners for high turndown (>3:1)
- Unequal fluid partitioning
- Particles to 0.1”-0.2”
- Concentration to 0.25 wt.%

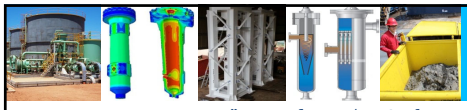


Operation of Flooded Core Hydrocyclone

- Fully enclosed U/F
- Accumulator with static liquid body
- Volume-swapping of solids for liquids through apex
- Reduces terminal velocity
- Maximum flux before choking

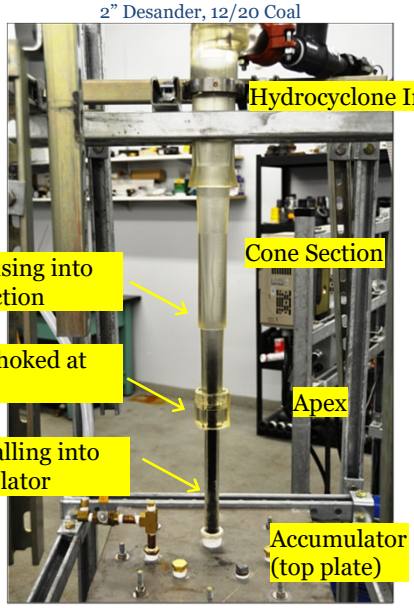


Video

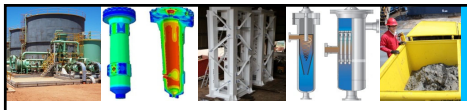


Operation of Flooded Core Hydrocyclone

2" Desander, 12/20 Coal

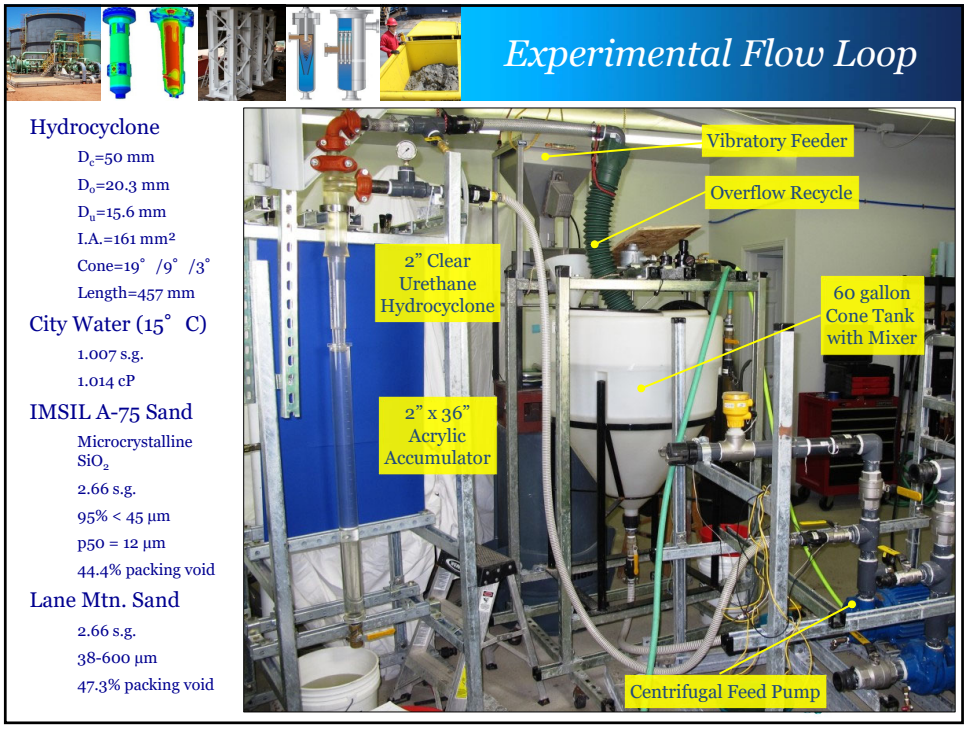


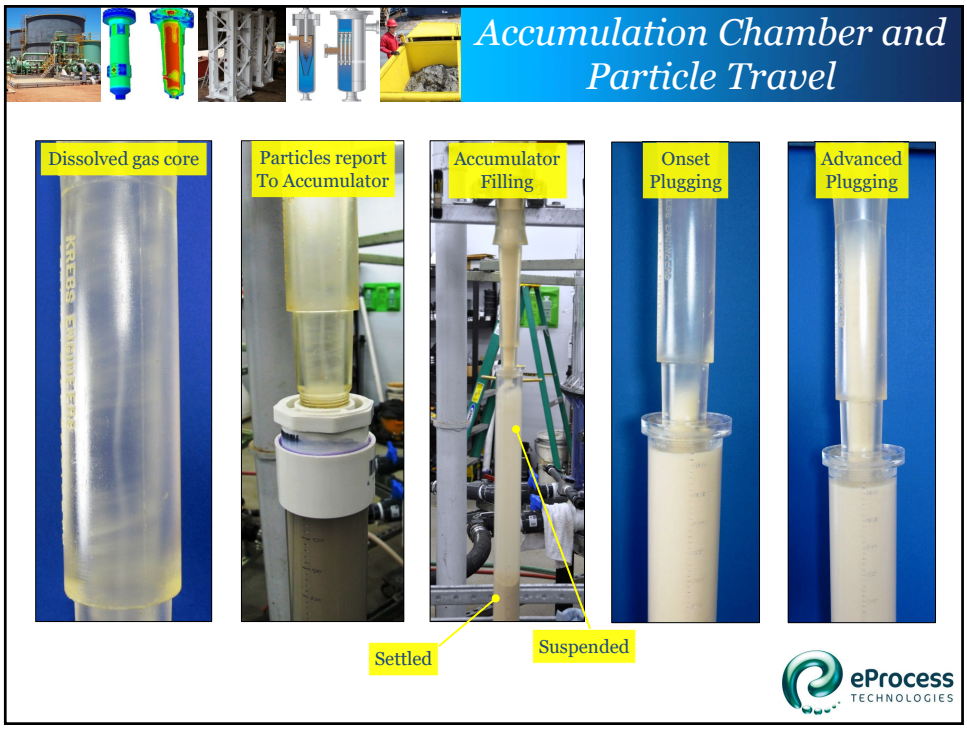
Premature failure due to choked apex

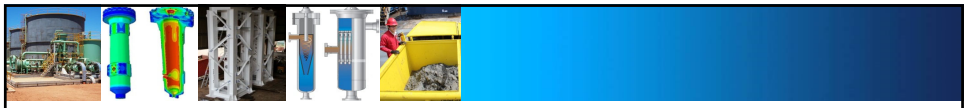


Previous Studies

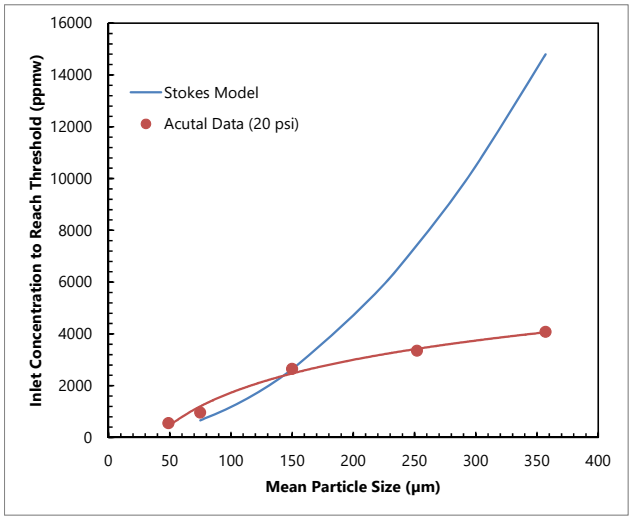
- 1973, Knowles, Woods, & Feuerstein, McMaster University
  - 3" glass hydrocyclone with Rietema design
  - U/F to pipeline network (continuous discharge): U/F = O/F
  - Measured velocity distributions only
- 1984, Witbeck and Woods, McMaster University
  - 3" glass hydrocyclone with Rietema design
  - U/F to pipeline network (continuous discharge): variable U/F:O/F split
  - Flatter classification (Yoshioka & Hotta curve: low α) than hydrocyclone
  - 4-7 times higher ΔP than with air core
  - Rietema D_{50} correlation gives best approximation
- 1989, Quian et al, Northeast University of Tech., Shenyang
  - 2" and 3" hydrocyclones in water-sealing chamber with continuous U/F
  - Higher classification efficiency (?), greater solids recovery
  - 10X apex (less blockage potential), and 1.6 times higher ΔP


Experimental Flow Loop
Hydrocyclone
D_c=50 mm
D_o=20.3 mm
D_u=15.6 mm
I.A.=161 mm²
Cone=19° /9° /3°
Length=457 mm
City Water (15° C)
1.007 s.g.
1.014 cP
IMSIL A-75 Sand
Microcrystalline SiO_2
2.66 s.g.
95% < 45 µm
p50 = 12 µm
44.4% packing void
Lane Mtn. Sand
2.66 s.g.
38-600 µm
47.3% packing void
Vibratory Feeder
Overflow Recycle
2" Clear Urethane Hydrocyclone
60 gallon Cone Tank with Mixer
2" x 36" Acrylic Accumulator
Centrifugal Feed Pump

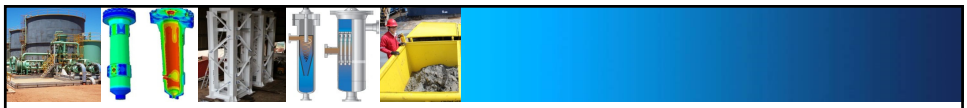

Accumulation Chamber and Particle Travel
Dissolved gas core
Particles report To Accumulator
Accumulator Filling
Onset Plugging
Advanced Plugging
Settled
Suspended
eProcess TECHNOLOGIES



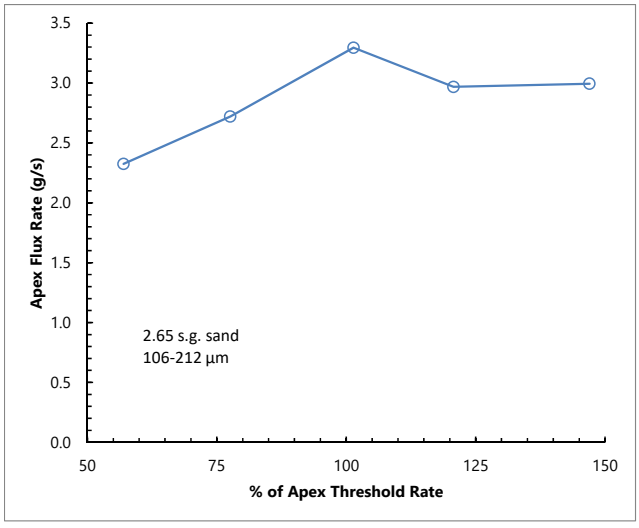
- 1st Order Stokes Model
- Specific Sand Size Range
  - 53-106 µm
  - 106-212 µm
  - 212-300 µm
  - 300-425 µm
  - Same type & s.g. all sizes
- Visual Indication of Threshold
  - Below = Continuous Separation
  - Above = Cyclone Filling
- 2nd Order Model Development



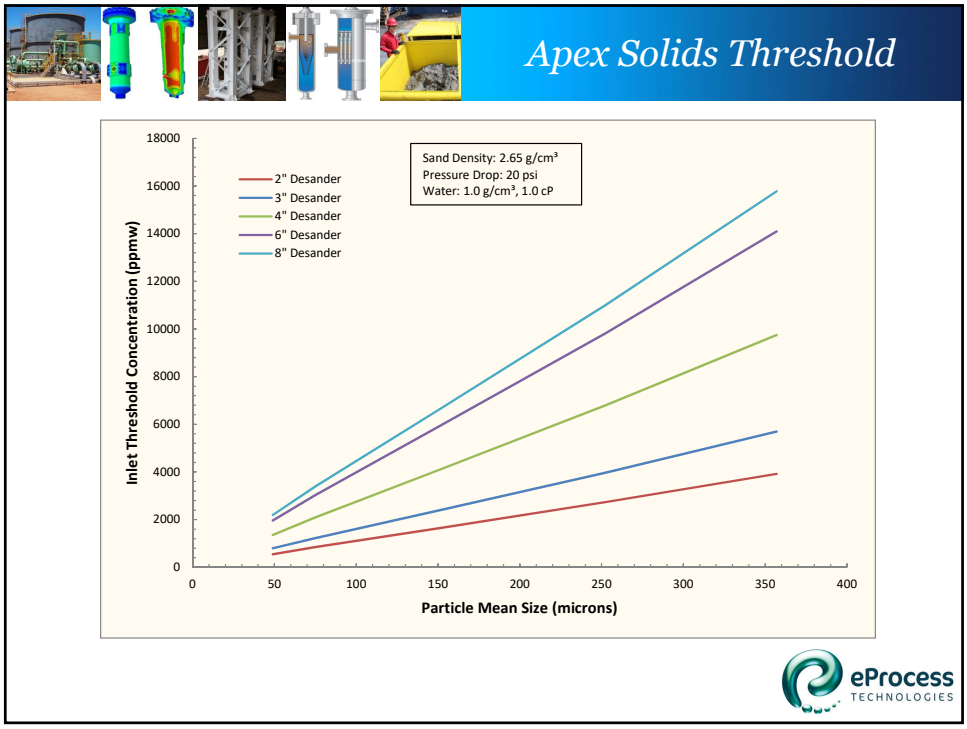
eProcess TECHNOLOGIES

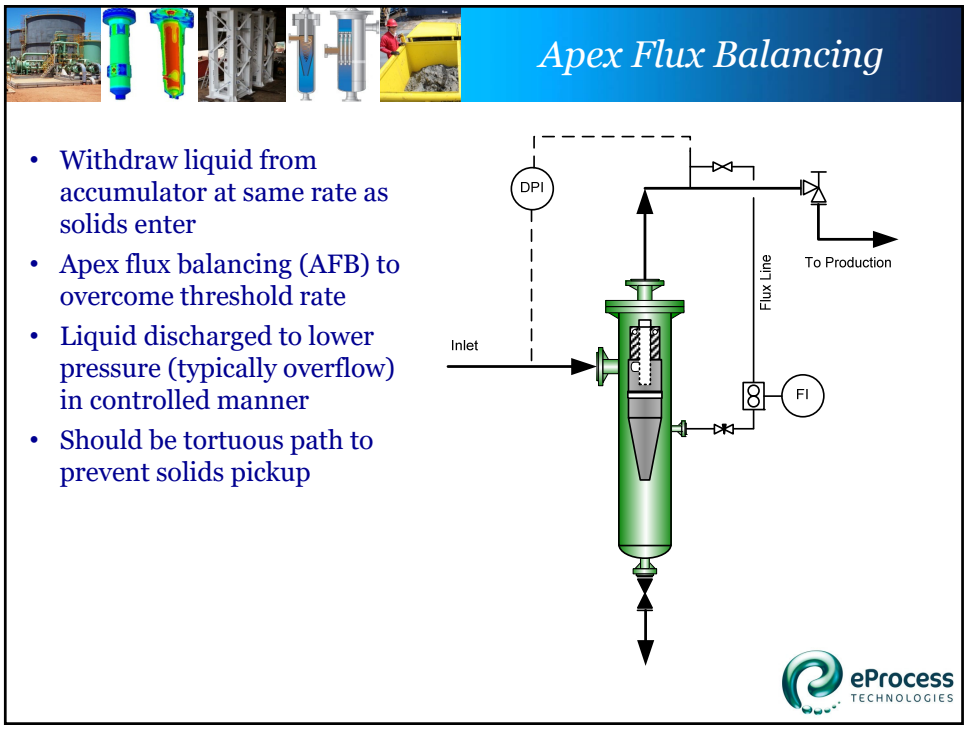


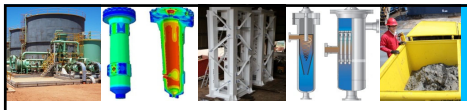
- Measured collection rate in accumulator
- Flux rate (g/s) increases with increasing inlet concentration to reach maximum at threshold
- After threshold the flux rate becomes constant



eProcess TECHNOLOGIES


Apex Solids Threshold
Sand Density: 2.65 g/cm³
Pressure Drop: 20 psi
Water: 1.0 g/cm³, 1.0 cP
2" Desander
3" Desander
4" Desander
6" Desander
8" Desander
Inlet Threshold Concentration (ppmw)
Particle Mean Size (microns)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
50
100
150
200
250
300
350
400
eProcess TECHNOLOGIES


Apex Flux Balancing
• Withdraw liquid from accumulator at same rate as solids enter
• Apex flux balancing (AFB) to overcome threshold rate
• Liquid discharged to lower pressure (typically overflow) in controlled manner
• Should be tortuous path to prevent solids pickup
DPI
To Production
Flux Line
Inlet
FI
eProcess TECHNOLOGIES



Conclusions

- Desander is a simple separating device with complex flow pattern
- Accumulator settling not simple Stokes Law relationship
- Laboratory analysis yields apex threshold
- For common PW desanders, inlet concentration limited to ~2000 ppmw
- Apex flux balancing extends operating range
- Further research: viscosity effect, larger desander, and 2nd order model with mixed particles

eProcess TECHNOLOGIES

Questions?

COMPREHENSIVE SAND MANAGEMENT SOLUTIONS

eProcess TECHNOLOGIES