Coal Metallurgists & Plant Operators Workshop – Thickening

Can the process be improved upon

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Contents

1. Introduction

- Most Mineral-separation processes involve the use of water
- Final Product requires high water to solids ratios, thus water removal
- Large volumes of water is limited and expensive – we HAVE to recycle
- Recover impure wastewater
- Dewatering = Solid-liquid separation

2. Background to Dewatering

Dewatering can be broadly classified:

- Sedimentation
  - Works well with large density difference between liquid and solids
  - Produces 30-70% solids (by mass)
- Filtration
  - Combined with Sedimentation
  - Hydrometallurgy
  - Produces 80-90% solids (by mass)
- Thermal Drying
  - Expensive
  - > 95% solids (by mass)

History of Thickening

"Those who cannot remember the past are condemned to repeat it" - Philosopher: George Santayana

- 19^{th} Century – Batch settling devices
- 19^{th} Century – Started use of coagulants
- 19^{th} Century – Cones used
- 1905 – First continuous raked thickener
- 1940's – Natural Flocculants introduced
- 1960's – Introduction of Polymeric flocculants
- 1967 – First Hi-rate thickener in USA
- 1980's – High density thickeners introduced

Batch Settling Devices

Why do particles settle?

Stoke's Law for spherical particles

$$V_s = \frac{g\,(p_s - p_\ell)d^2}{18\mu}$$

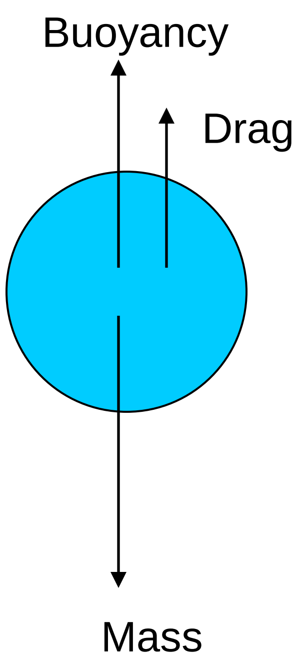
g = acceleration due to gravity, m/s^2

p_s = density of particles, kg/m^3

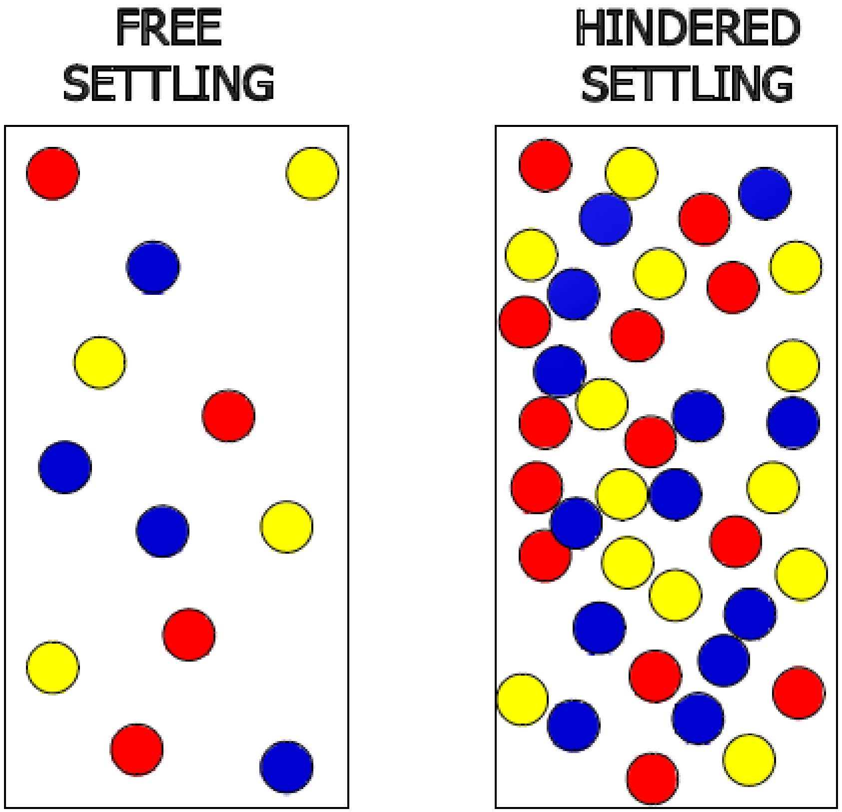
p_ℓ = density of fluid, kg/m^3

d = diameter of sphere

μ = dynamic viscosity of fluid, Pa.s



Settling of Particles



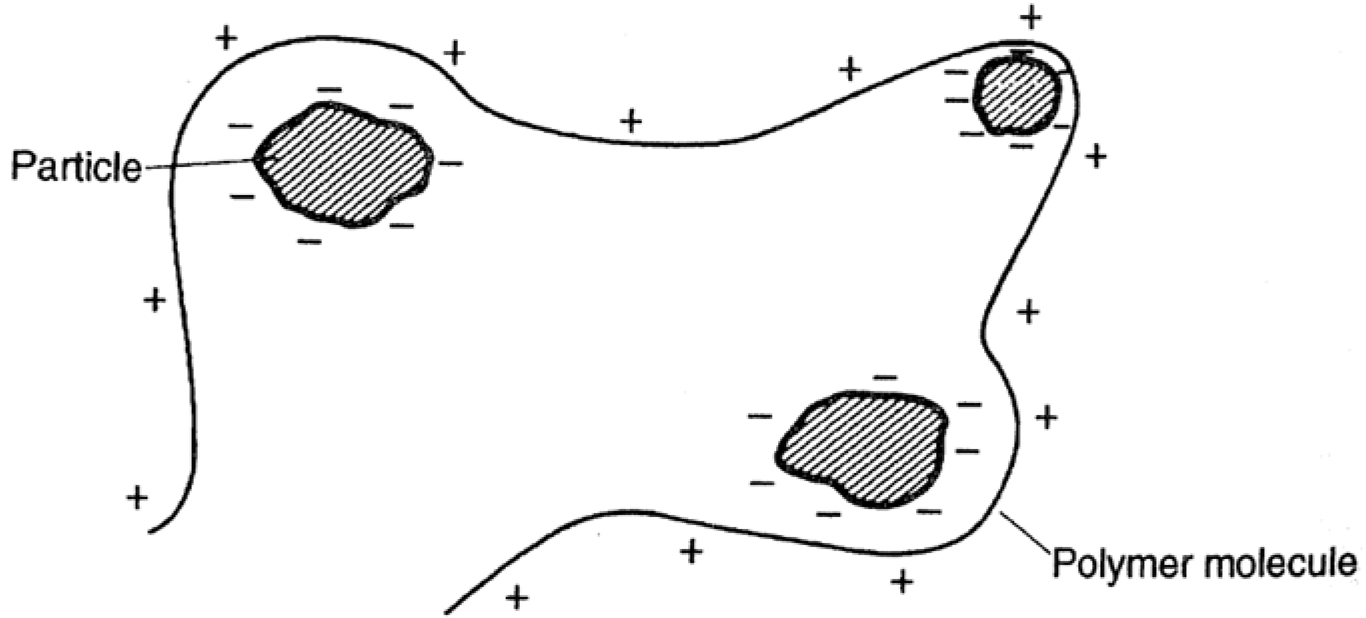
3. Flocculation

Flocculants are polymers that promote flocculation by formation of bridges between themselves and thus getting suspended particles to aggregate. When the suspended particles are flocculated into larger ones, they settle in devices like thickeners and clarifiers and are removed with the underflow.

The flocculants accelerate the settling process which lead to the potential use of smaller thickeners.

Flocculants can also be used to aid filtration.

Action of an anionic polyelectrolyte

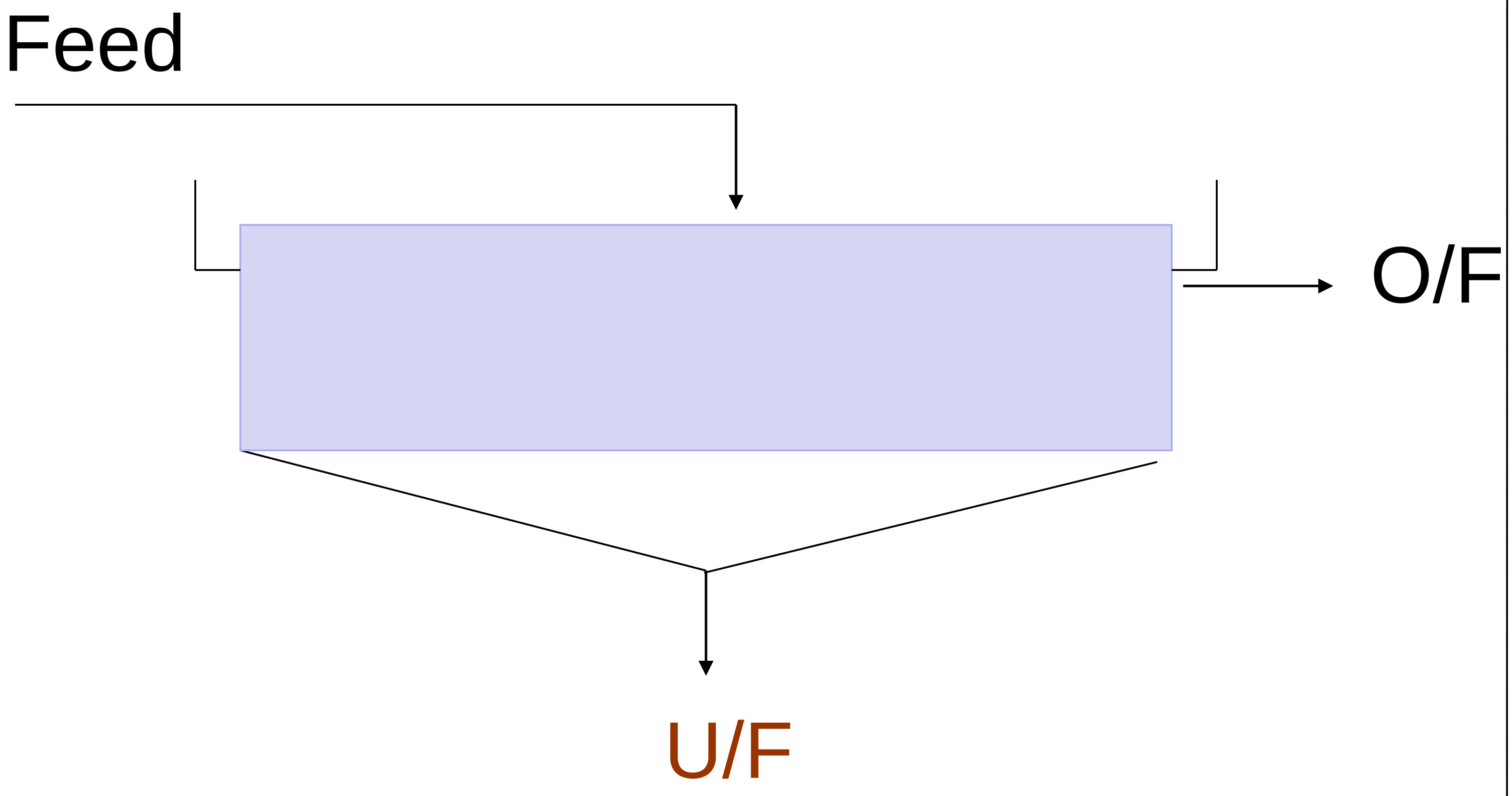


4. The Thickening Process

Thickening involves the removal of water and has the effect of increasing the density and strength of the solids.

The extent to which the tailings are thickened is determined by the costs involved and influenced by the specific needs of the operation (the driver).

Thickening & Clarification – The difference



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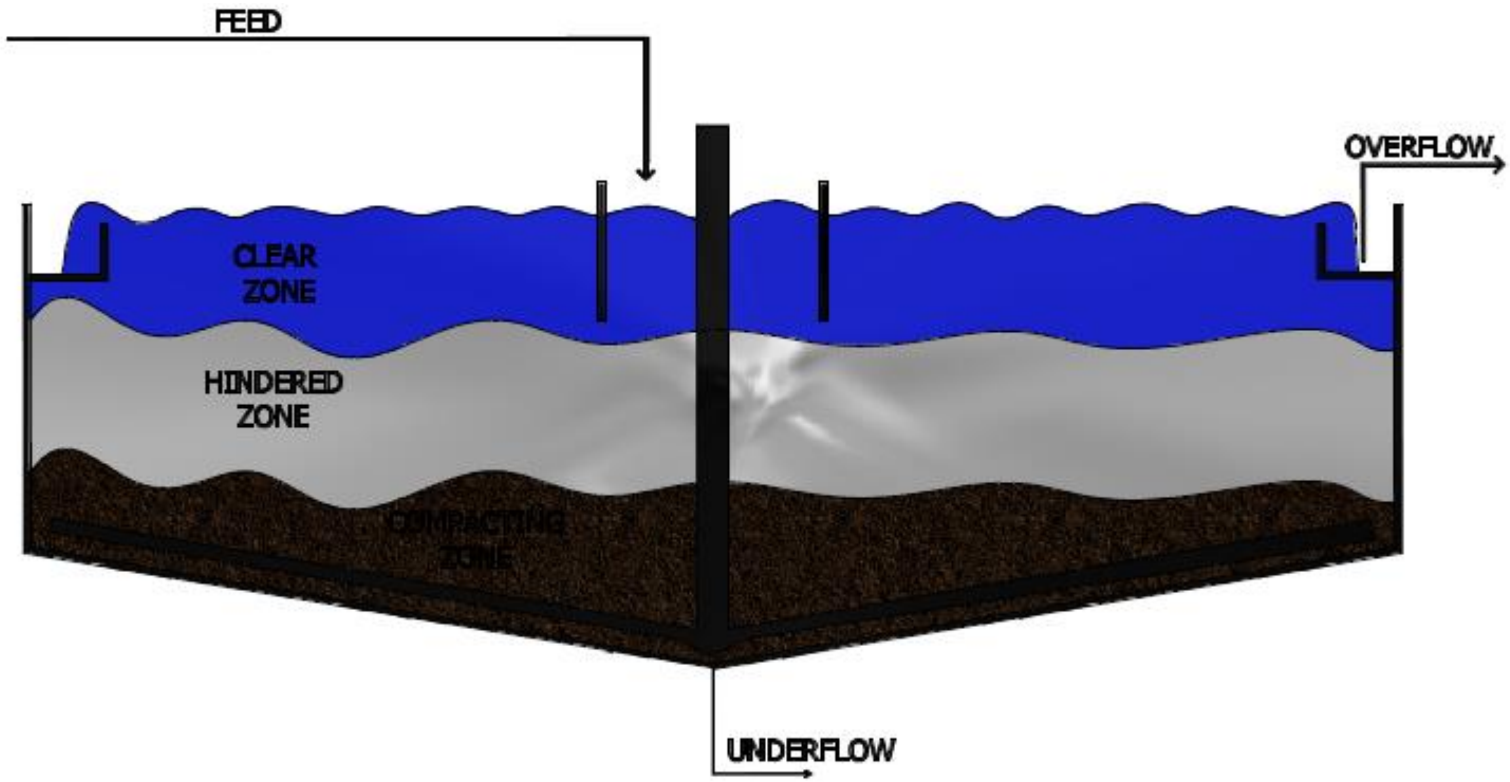
Clarifiers

- Feed well design different
- Generally, no dilution
- Seeding arrangement, i.e. underflow is recycled
- Intermittent underflow discharge

What is a Thickener

- Separates liquid and solids
- Water can be re-used as is (unlike a hydrocyclone)
- Liquid at the top
- Solids settle to the bottom

Settling zones in Thickeners



Basic Thickener Philosophy

- Thickeners are not storage devices!
- Feed solids tonnage in = Underflow tonnage out
- Feed slurry flowrate = Overflow flowrate + Underflow flowrate

Thickener Types

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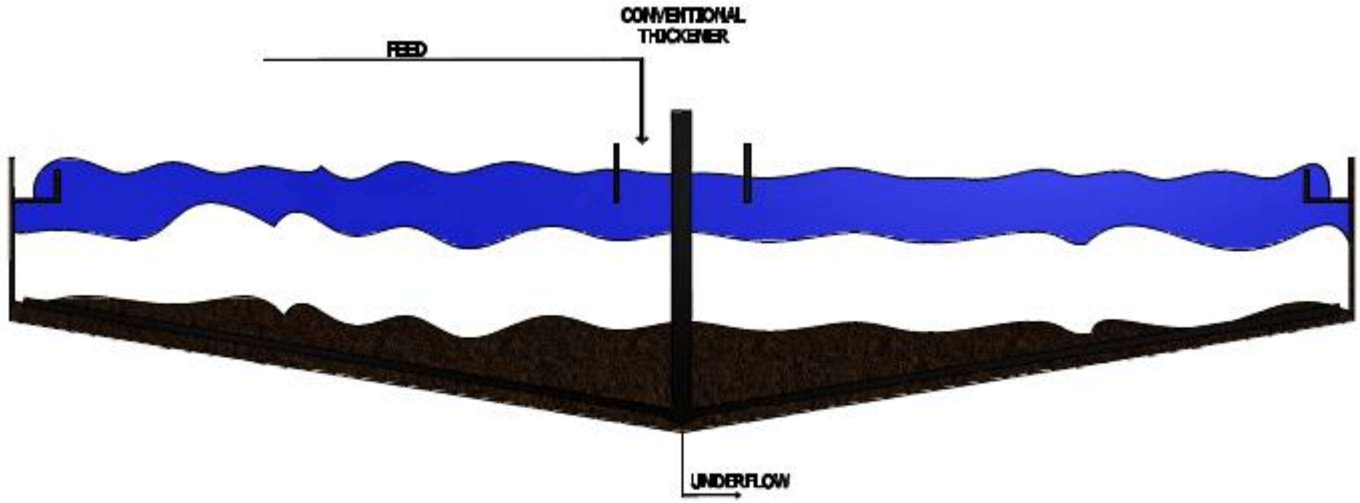
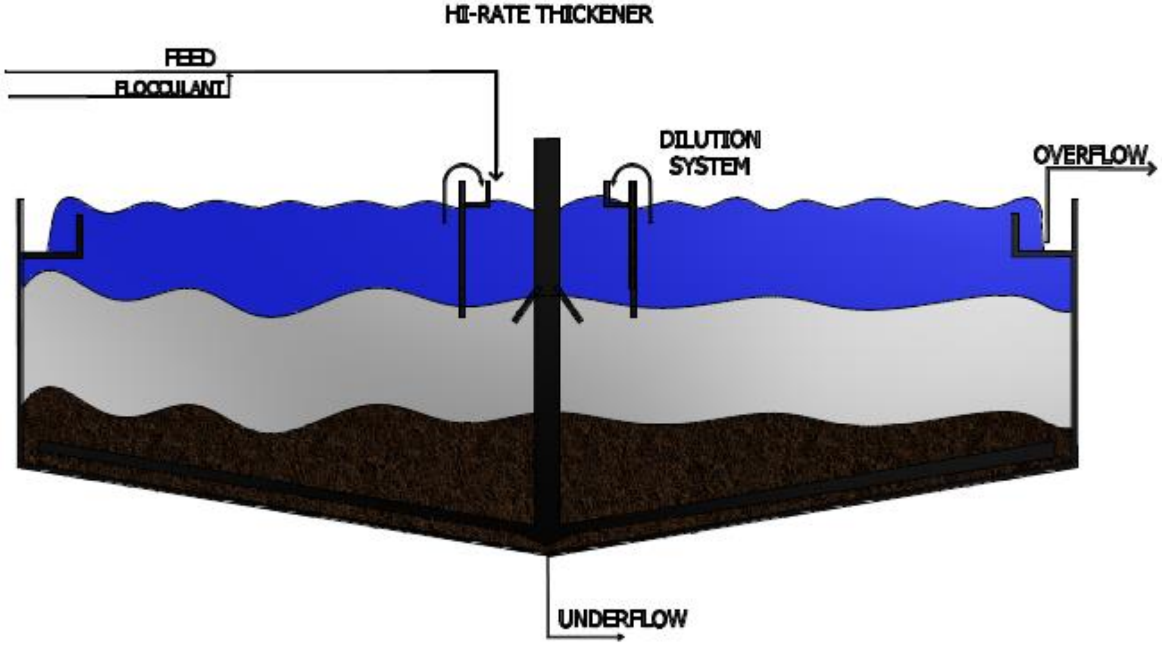
a. Conventional Thickener



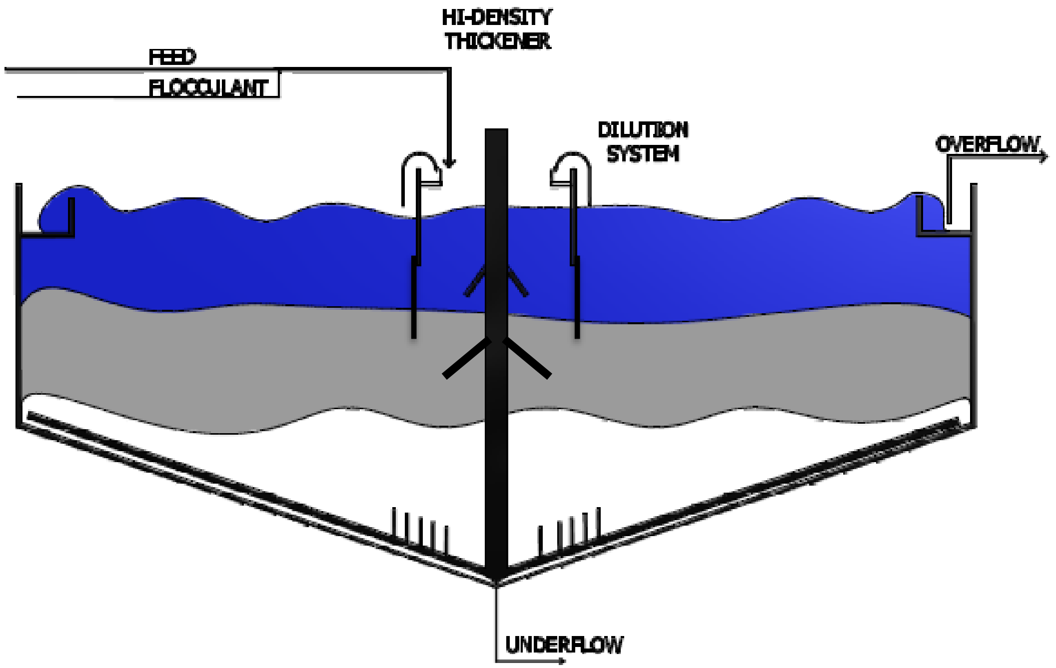
- Large thickening area
- Safe design with shallow feedwell
- Low torque
- Slow reaction time
- Provide longest residence time
- Sidewall, typically 1.8 to 3m
- Uses very little flocculant (<5g/t)

b. Hi-rate Thickener



- Better settling with deeper feedwell
- Dilution of feed
- Smaller area/footprint
- Lower capital cost for same feed
- Shorter reaction time
- Sidewall, typically 2.0 to 3.5m
- 5 to 300g/t of flocculant
- Low Yield stress

c. High Density Thickener



- Higher sidewall (>4m), thus higher compression zone
- Steeper floor cone angle (15 to 30 degrees)
- Pickets to release interstitial liquid
- Higher yield stress
- High torque drive

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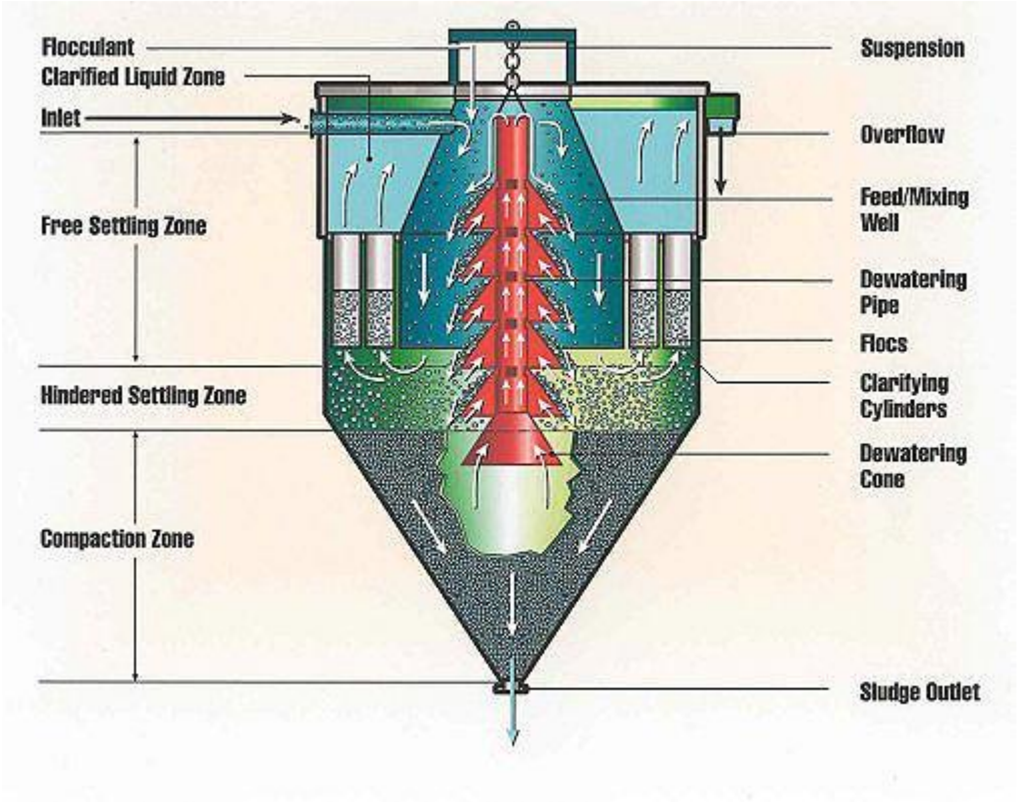
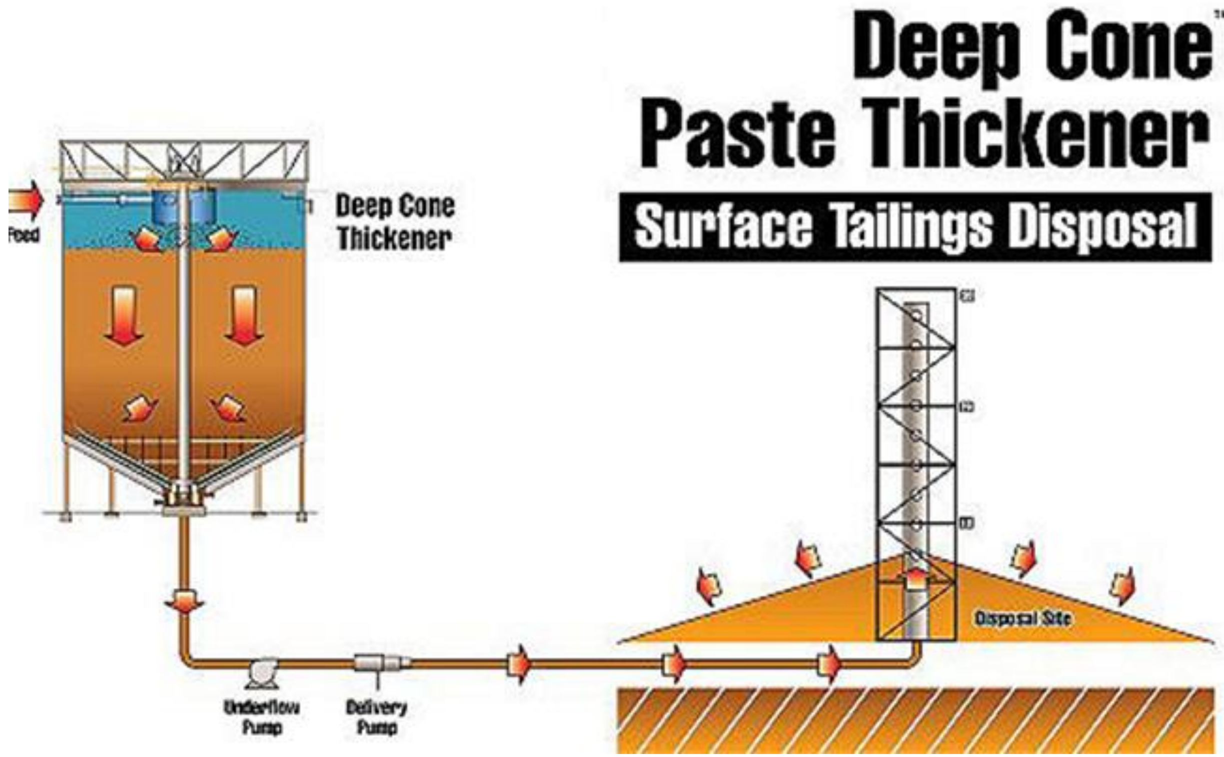
d. Ultra Hi-rate Thickener



- Higher Sidewall (>8m)
- 60 degree cone angle
- No Moving Parts
- Shorter reaction time
- >10g/t of flocculant
- Can have inconsistent discharge

Source: www.flsmidth.com

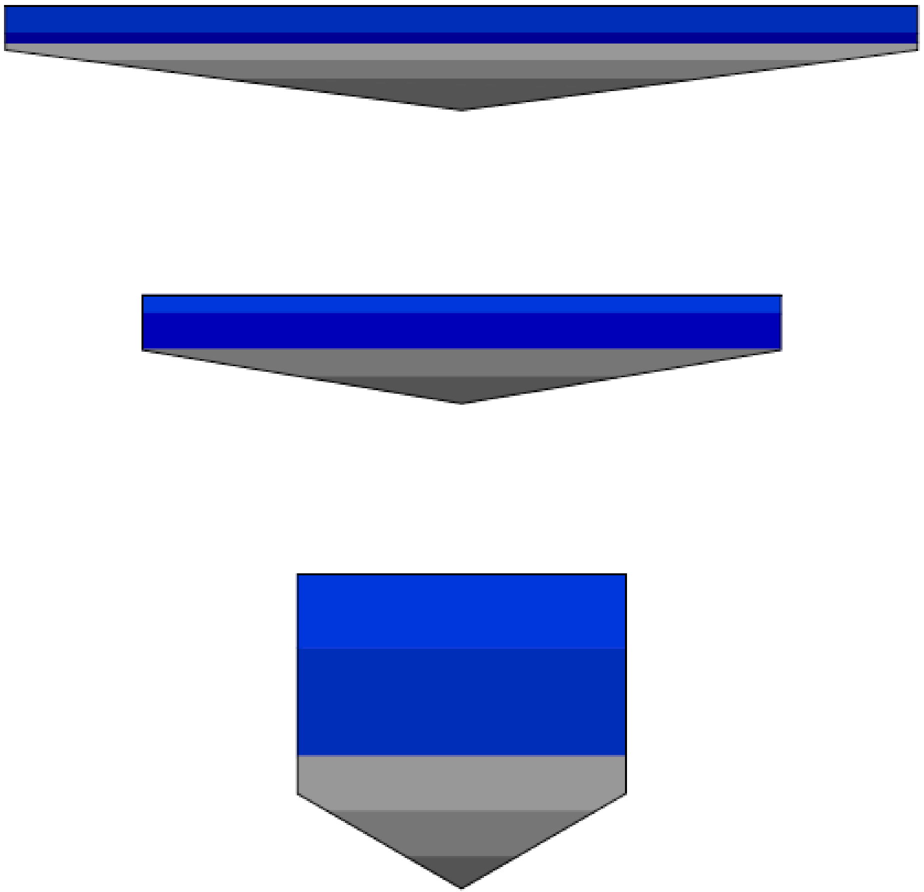
e. Paste Thickener



Source: www.flsmidth.com

- Higher Sidewall (>10m)
- Extended compression zone
- Pickets to release interstitial liquid
- Maximum underflow densities
- Yield stress > 150Pa
- Extremely expensive

Size does count



- Conventional
  - Large area
  - Low torque
  - Slow settling
- High Rate
  - Better settling
  - Low yield stress
  - Smaller area
- Deep Bed Thickener (Paste and/or High Density)
  - Max underflow solids
  - Higher yield stress
  - Steep cone angle
  - Highest Torque
  - Decreased area

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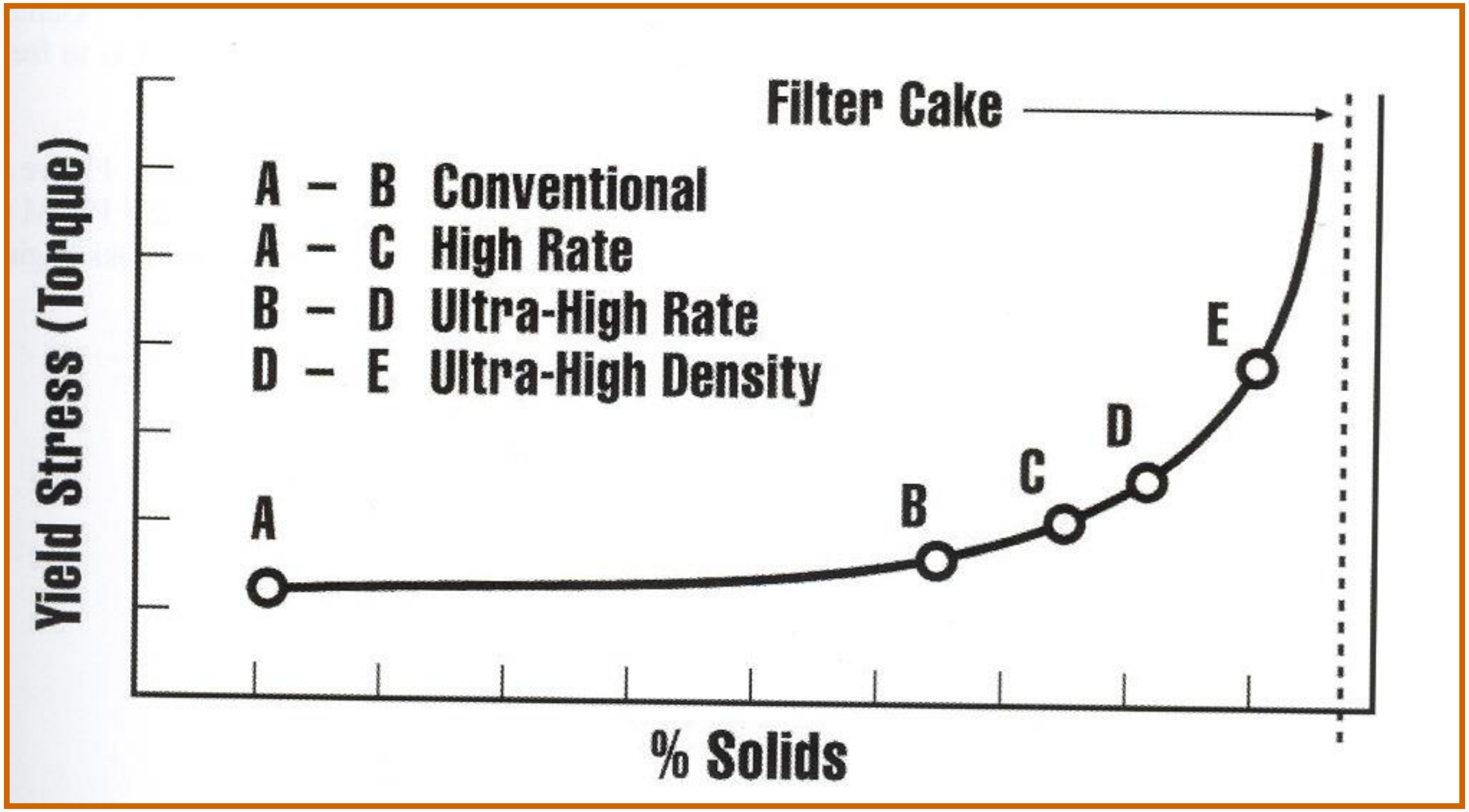
Dewatering Underflow Density Variations



Source:Paste & Thickened Tailings – A Guide, Editors R.J.Jewell,et.al

5. Design of Thickeners

- How to size thickeners
- Thickener Testwork
- Instrumentation
- Common design mistakes

Thickener Nomenclature

$$\text{Flux} = \frac{\text{Feed Tonnage}}{\text{Thickener Area}} \qquad \left[\frac{\text{tpd}}{m^2}\right] \quad \text{or} \quad (\text{tph}/m^2)$$

$$\text{Settlement Rate} = \frac{\text{Pulp Feed Flowrate}}{\text{Thickener Area}} \qquad (m^3/h/m^2)$$

$$\text{Rise Rate} = \frac{\text{Overflow Flowrate}}{\text{Thickener Area}} \qquad (m^3/h/m^2)$$

What is the controlling factor?

On Coal – Settlement Rate

How to size thickeners

Data required:

- Application
- Feed tonnage
- Particle density
- % Feed solids
- % Solids in underflow
- Overflow requirement
- Flux/Settlement rate

Sizing thickeners

- Database of previous installations
  - Controlling factor – flux or settlement rate

- Testwork

Thickener Testwork

Objective:

- Flocculant Type and Dosage Rate
- Flux or Settlement Rate
- Optimum Feed Solids
- Overflow clarity

Equipment:

- Static Cylinder Test
- Cylinder test with rakes
  (better underflow comparison)
- Dynamic test unit

Thickener Testwork

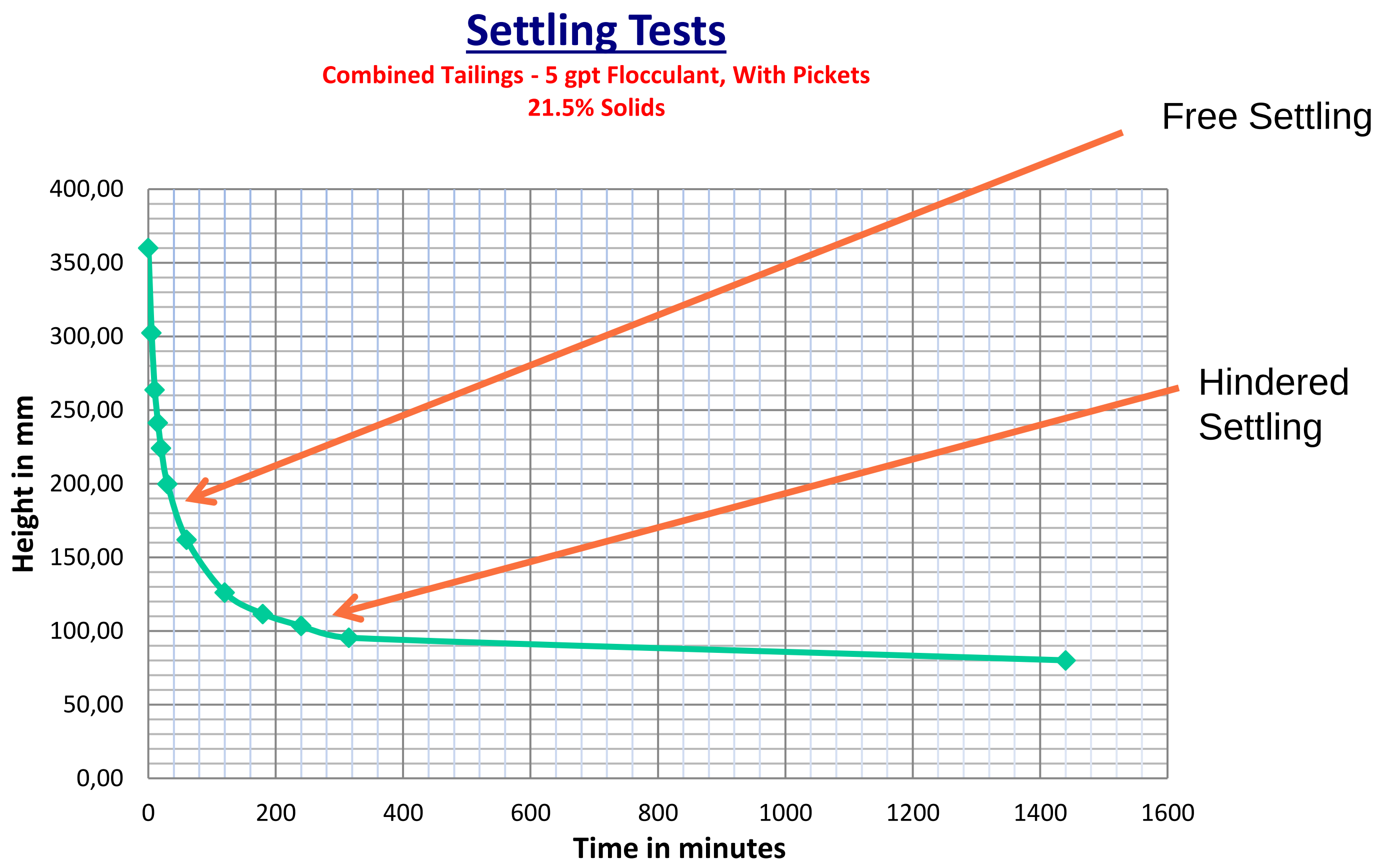
Test work is indicative but accurate enough for scale-up

Provides thickener diameter:

- Settlement rate (m/h) with Pulp flowrate (m^3/h)

- Flux (tpd/m^2) with Feed tonnage (t/h)

Typical Settling Test and Output



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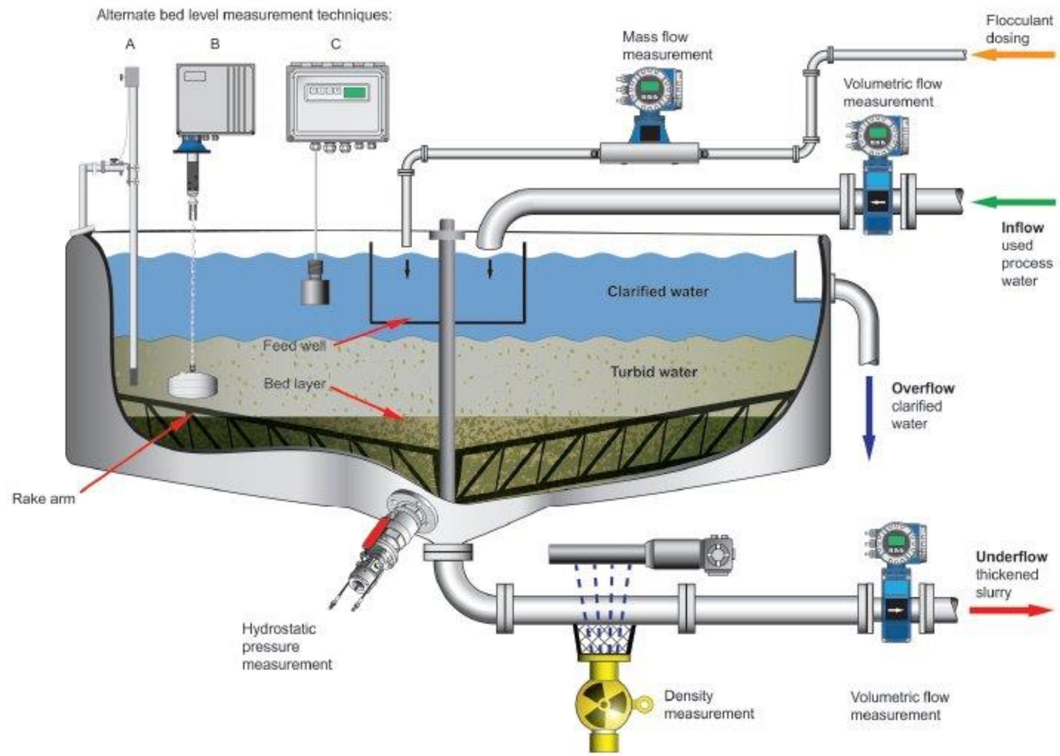
Instrumentation



- Bed Level Device
- Bed Mass
- Inflow measurement
- Measurement of flocculant
- Output density and flow

Source: www.Endress.com

Common Design Mistakes

- Feedwell sized too small
- Overflow launder and overflow pipe undersized

Huge cost and production implications

6. Comparison of Thickener types

The extent of water recovery achieved by increasing the underflow density diminishes as the density increases, but the cost of thickening the tailings increases significantly

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Torque factors

Thickener Type	Feedwell Flocculation	Yield Stress of Underflow	Average Tank Slope	Torque Factor
Conventional	No dilution	< 10 Pa	4-10º	K <30
High Rate	Dilution	< 20 Pa	4-14º	K <50
High Density	Dilution	50-120 Pa	8-30º	K <125
Paste	Dilution	>150 Pa	30-45º	K >200

Equipment Capital Cost Comparison

Thickener Technology Type	Thickener Diameter	Side Wall Depth (m)	Cost
Conventional	80	2.4	1.0
High Rate	55	2.4 to 3.0	0.85
High Density	40	6.8 to 8.0	1.6
Paste	30	12.0	2.5

7. The Future

- Thickeners will remain with us, although its form may adapt.
- At the risk of going out on a limb, here are a few ideas for future development:

  - Feed characterisation

  - Flocculant Control

  - Feedwell design

  - Underflow density management

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Feed characterization

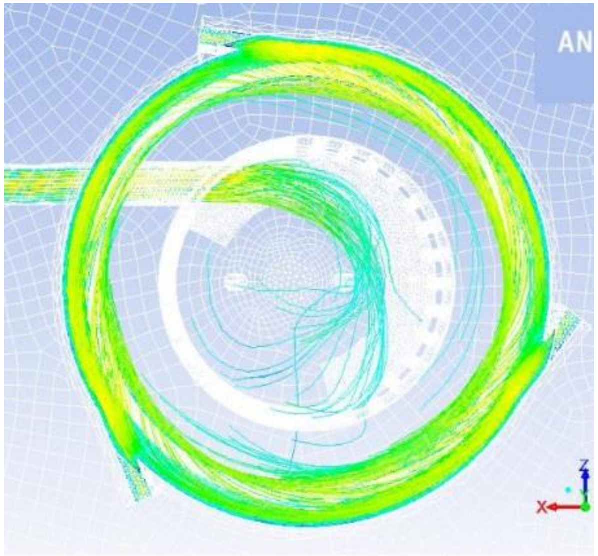
- Feed solids characterisation – specifically the particle size distribution and mineralogy, and their effects on flocculation requirement and underflow rheology, are areas where the tools for improvement are being developed but have not yet been applied in mainstream operations.

Flocculant Control

- The importance of slurry dilution and flocculant dispersion within the diluted pulp is recognised and is generally considered in design and operation.

Feedwell design

- Improvements in computing capacity have opened the practical opportunity to use upgraded CFD modelling for feedwell design. Besides regulating the degree of shear and the zones for quiescent settling in the feedwell, these improvements can help avoid short-circuiting and unbalanced discharge from the feedwell.



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Underflow density

- With the improvement of the Feedwell and Flocculation. The underflow density will increase.
- Underflow pump and pump suction line systems will need to accommodate the increased rheological problems associated with higher slurry densities.
- Shear-thinning systems – where slurry properties permit – and future thickeners should be designed with provision for retrofitting a shear thinning system if deemed necessary.
- Underflow nozzles to be oversized to account for line entry head losses and to permit large bore pump suction lines to be installed.

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8. Operator Challenges & Maintenance

- Input minus output equals Accumulation
- Excessive accumulation = Operating Problems

  - Dirty overflow

  - Underflow too thick

  - “Doughnut” formation in thickener

  - Rakes overloaded – not designed to remove solids
- Leads to clean out = start digging!!!

8. Operator Challenges & Maintenance

- If a thickener is designed correctly, minimum maintenance is required.
- Grease the slew bearing.
- Check oil in gearbox.
- Minimal spares – designed for 30 year lifespan.

Q & A