Pipeline Design for Paste and Thickened Tailings Systems

Robert Cooke
Paterson & Cooke, Denver, Colorado

Overview

- **Paste & thickened tailings drivers**
- **Classification**
- **Pipeline flow behavior**
- **Pumps**
  - Centrifugal
  - Positive displacement

Paste & Thickened Tailings Drivers

- **Shortage of water in arid regions**
- **Underground paste backfill**
  - "No or little bleed water"
- **Potential for reduced environmental impact and increased stability**
- **New technology**

Paste and Thickened Tailings Terminology

“Un-sheared” → “Fully sheared”

Rheomalaxis

Paste and Thickened Tailings Terminology

Increasing Solids Concentration

	"Freely settled" concentration	No bleed water	Soil behavior
Conventional Tailings	**Thickened Tailings**	**Paste**	**Cake**
Fully sheared yield stress: 5 to 20 Pa		100 Pa	800 Pa

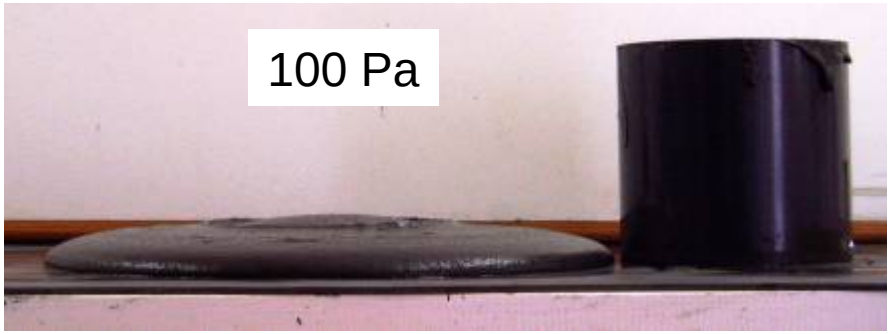
Ketchup 15 Pa

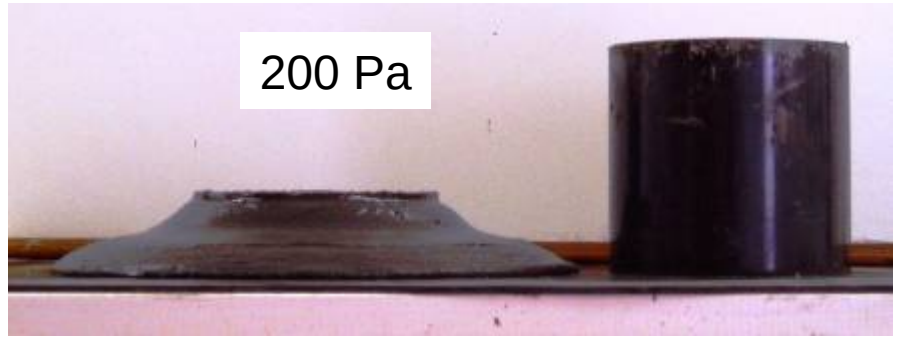
Iron Ore Tailings, 64%m 100 Pa

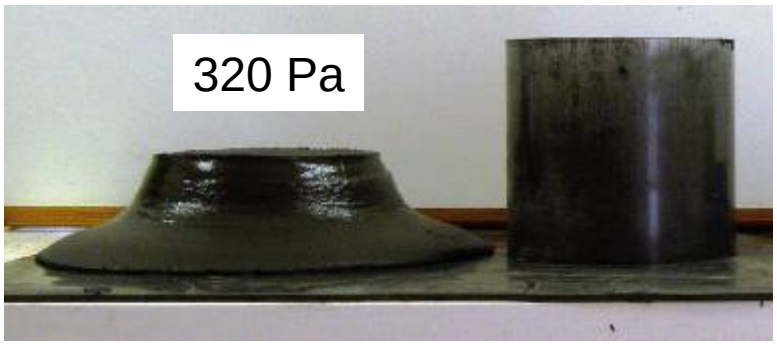
Paste and Thickened Tailings Terminology

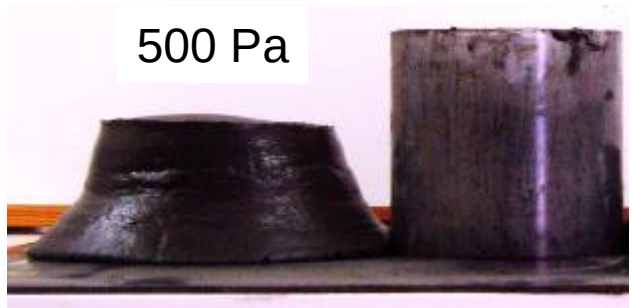
Conventional Tailings	Thickened Tailings	Paste	Cake

Fully sheared yield stress: 5 to 20 Pa 100 Pa 800 Pa

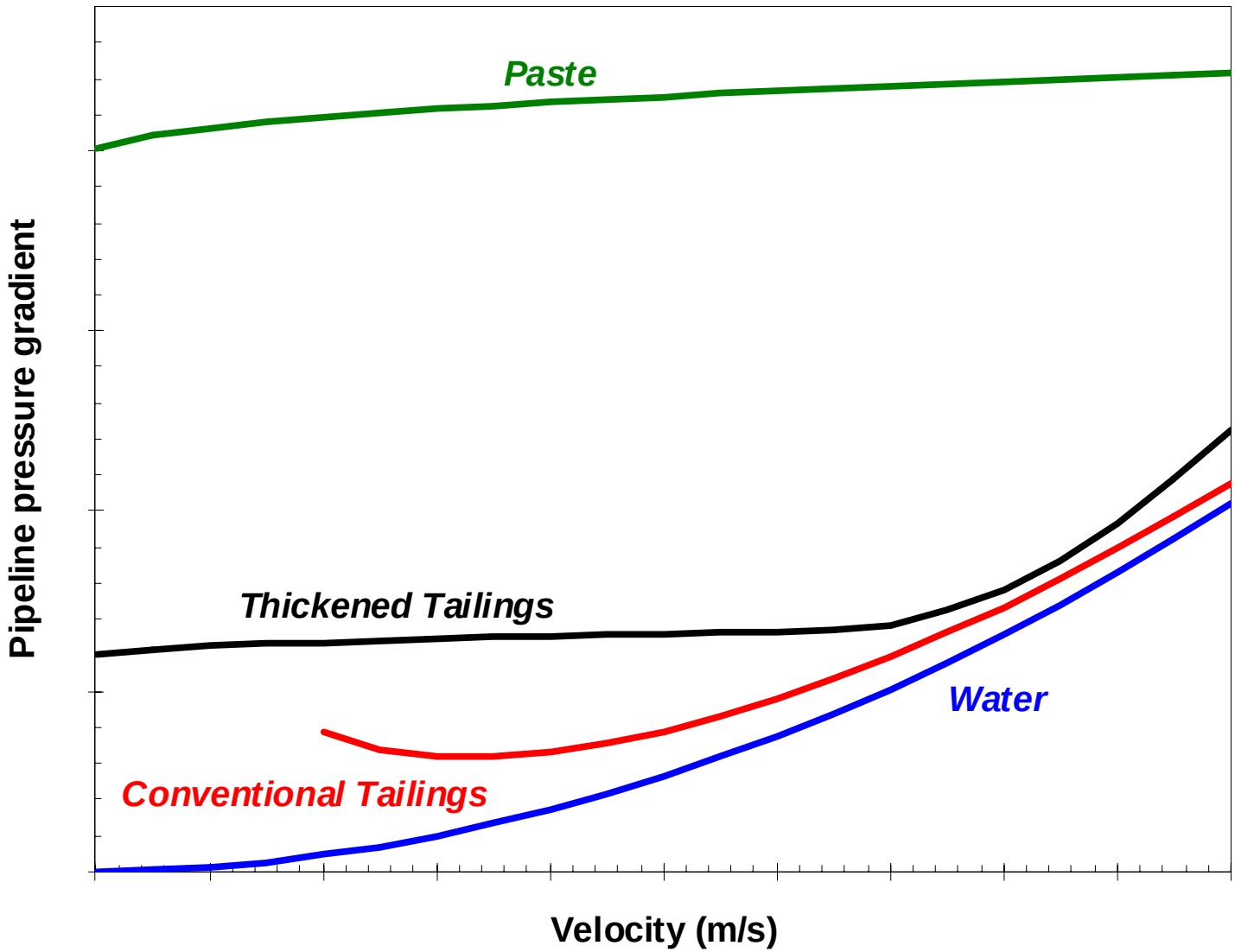




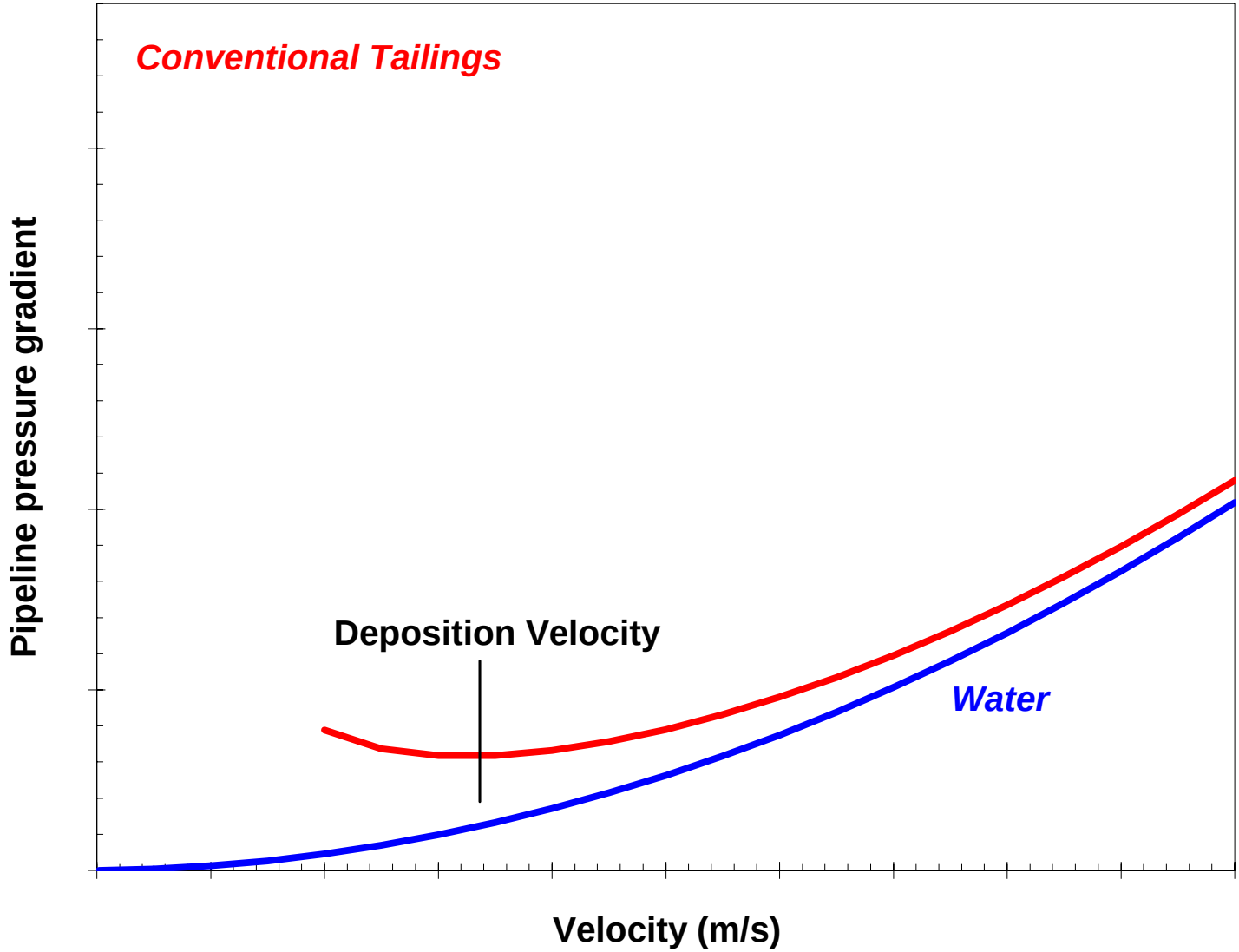




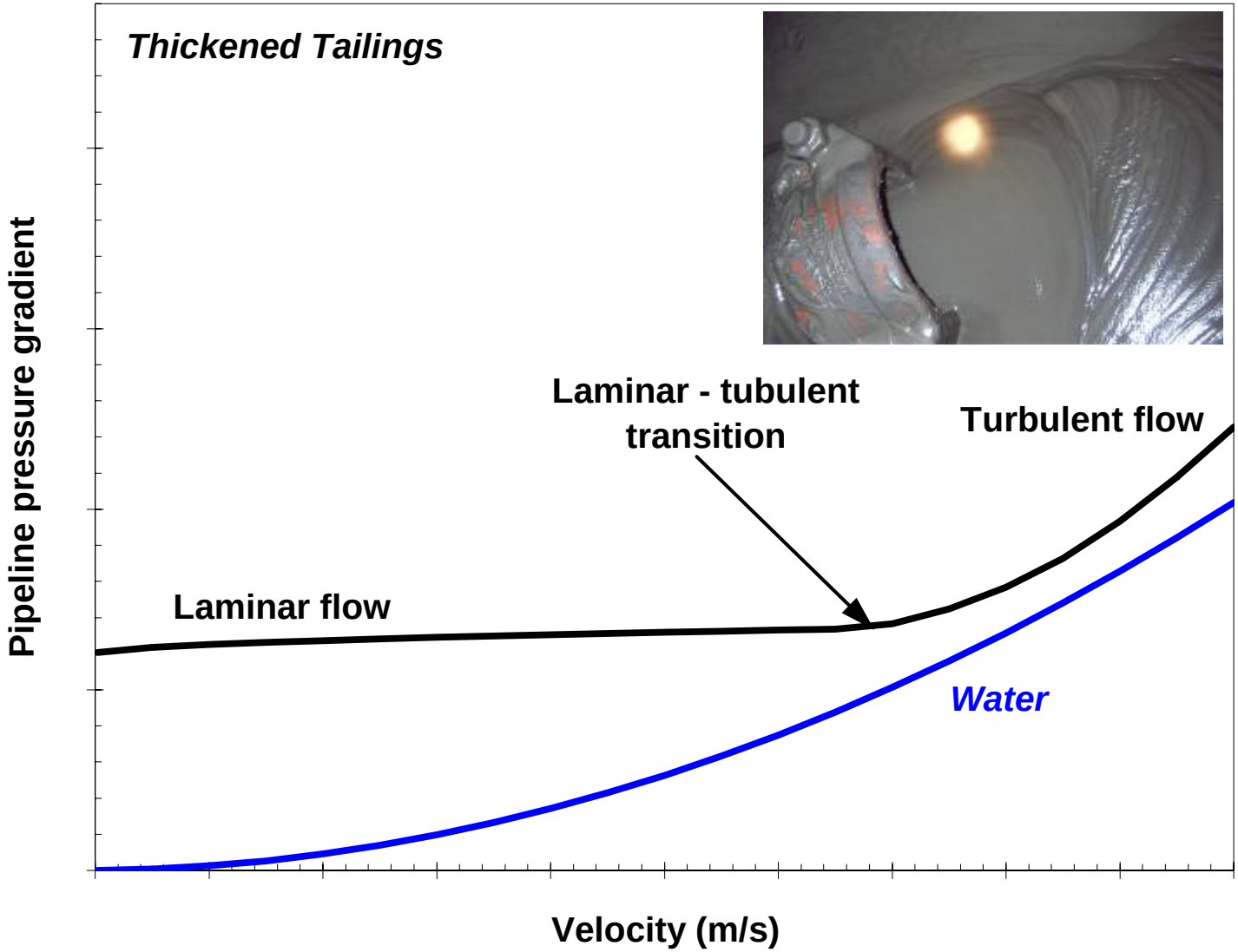
Pipeline Flow Behavior



Pipeline Flow Behavior



Pipeline Flow Behavior



Pipeline Flow Behavior

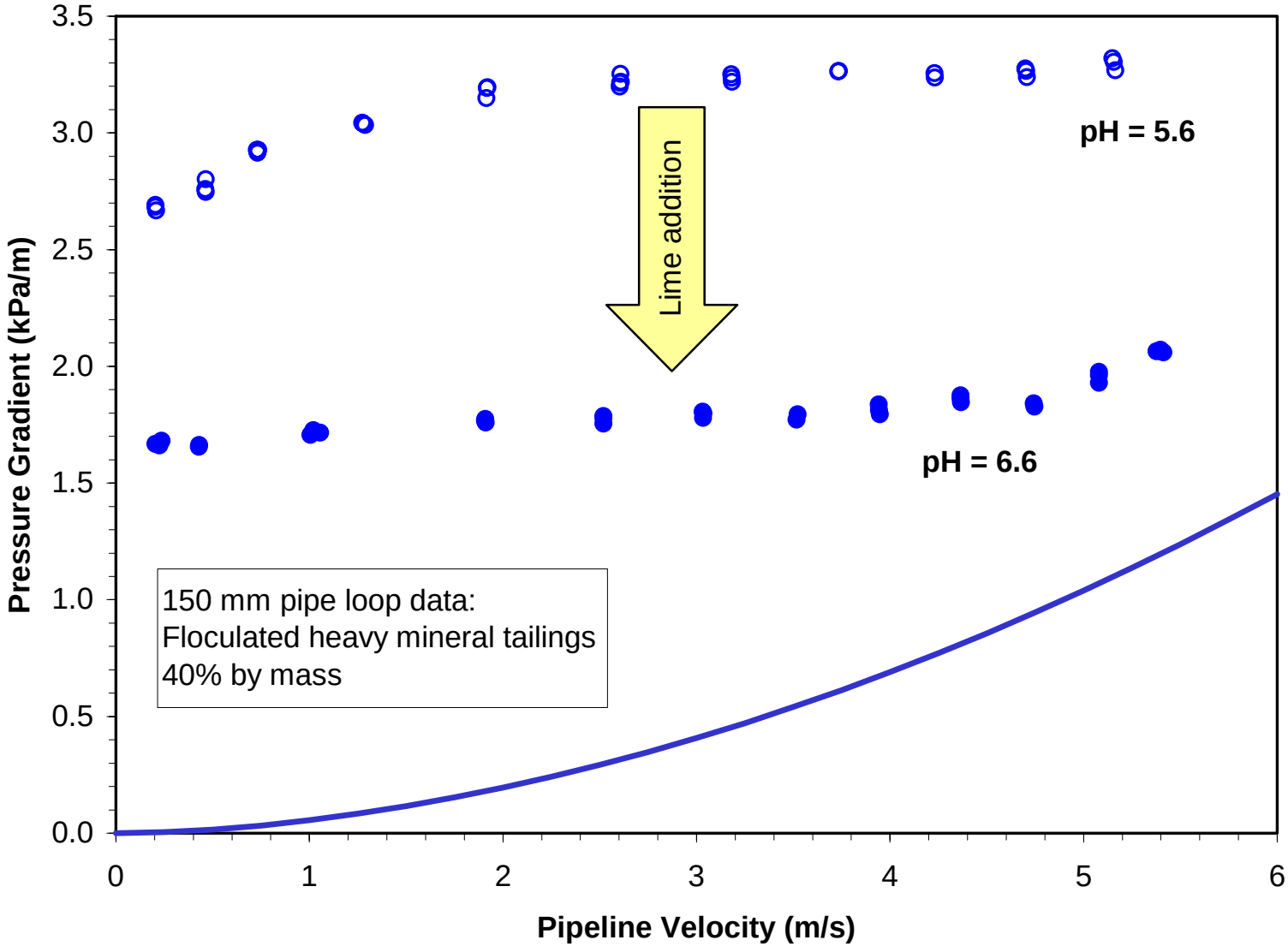
- **Thickened tailings**
  - Transition velocity can be estimated from (Slatter and Wasp):

$$V_{crit} = 26\sqrt{\frac{\tau_y}{\rho_m}}\,.$$

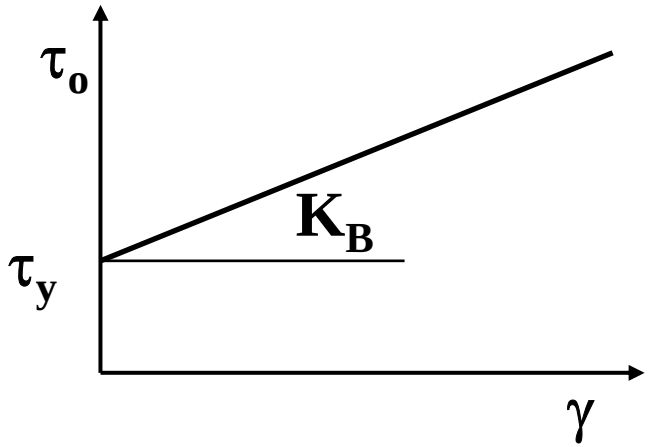
  - Pressure gradient can be estimated using the Buckingham equation provided the flow is homogenous:

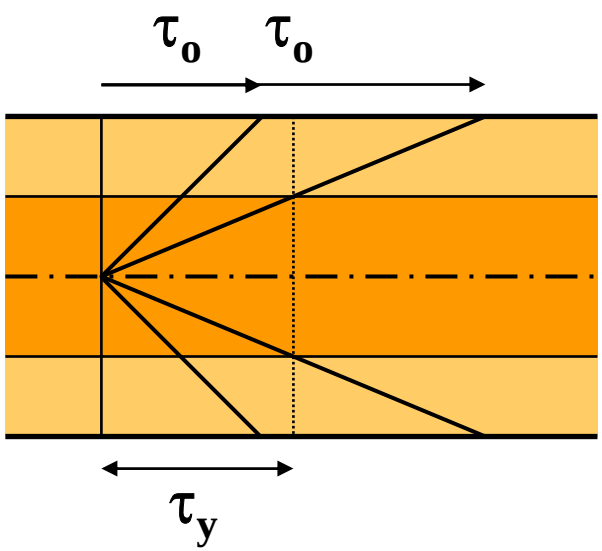
$$\frac{8V}{D} = \frac{\tau_o}{K_{BP}}\left[1 - \frac{4}{3}\left(\frac{\tau_y}{\tau_o}\right) + \frac{1}{3}\left(\frac{\tau_y}{\tau_o}\right)^4\right]$$

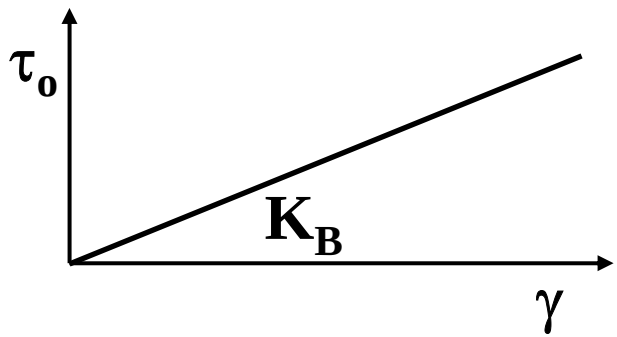
Pipeline Flow Behavior



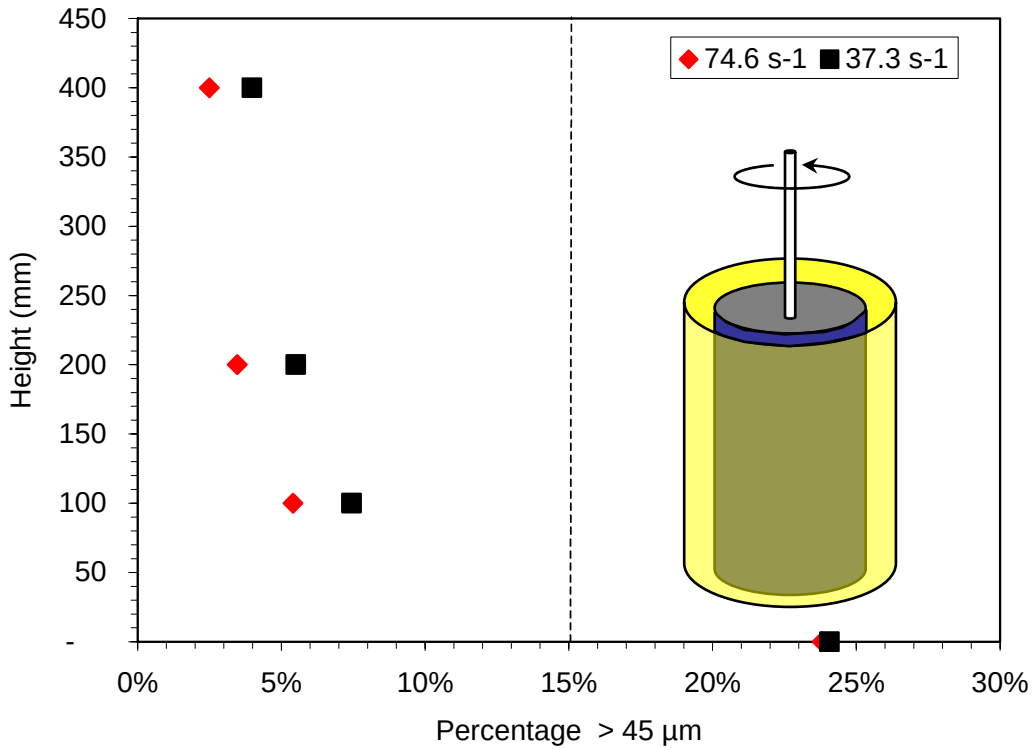
Laminar Flow Segregation





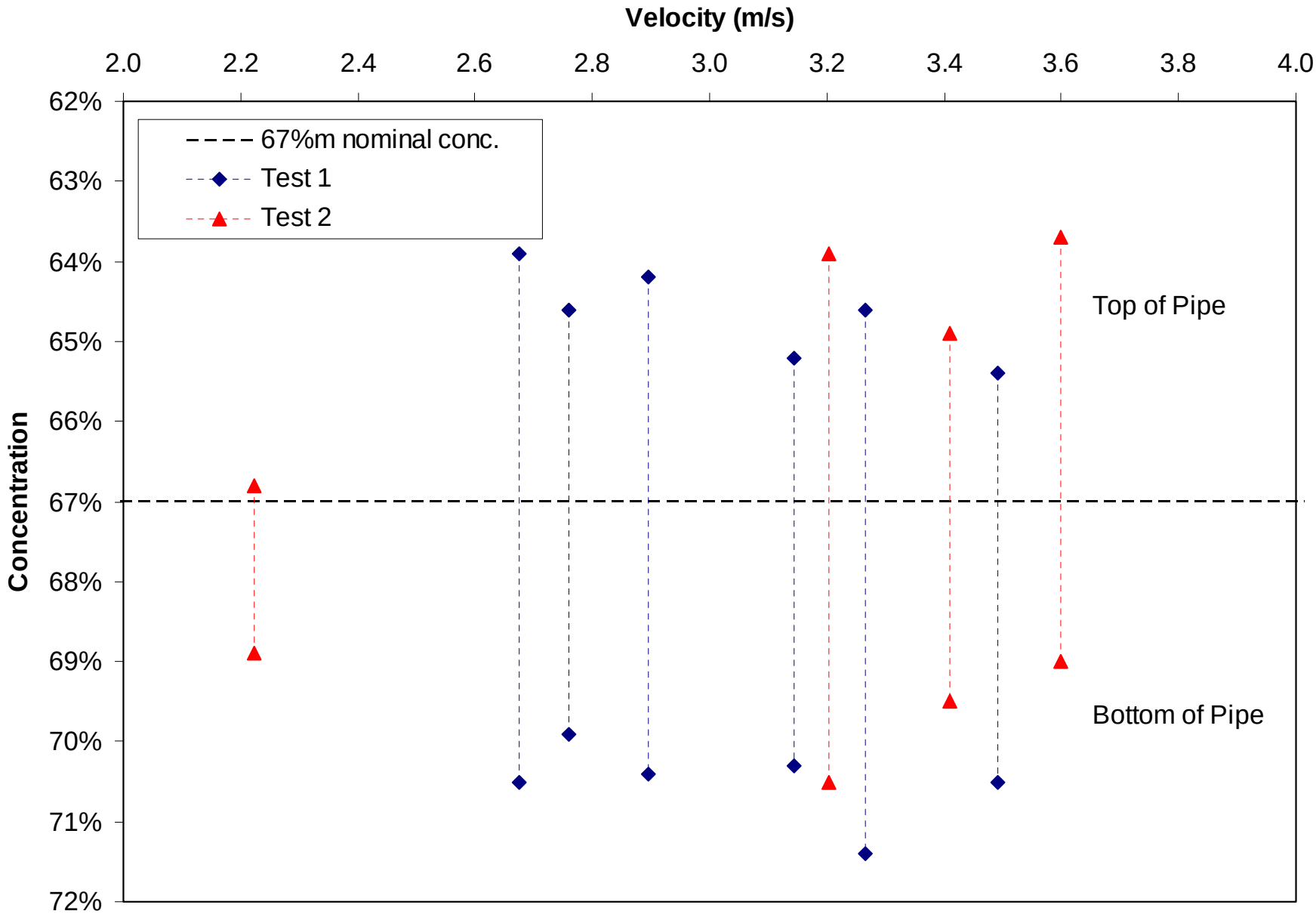


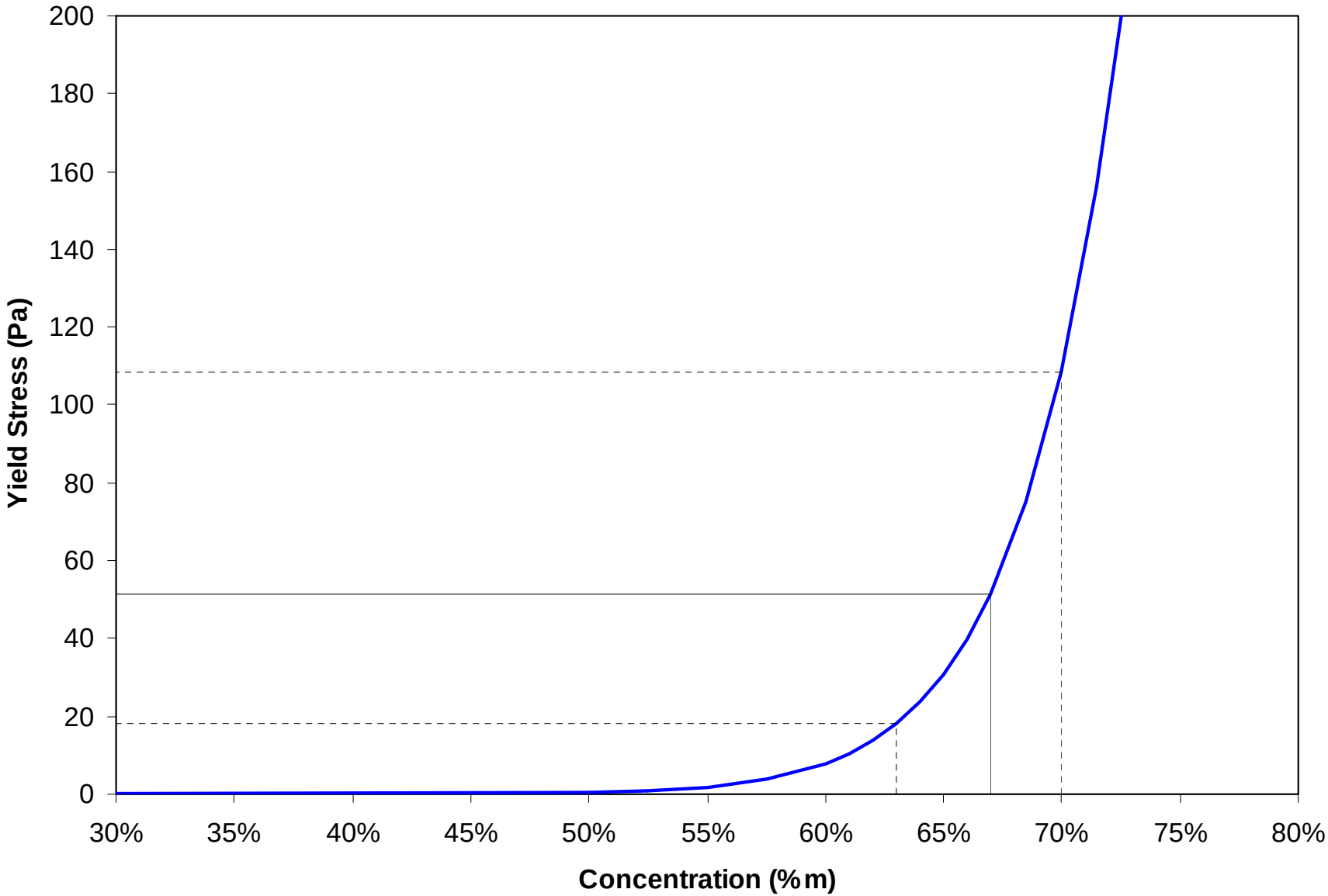
Laminar Flow Segregation



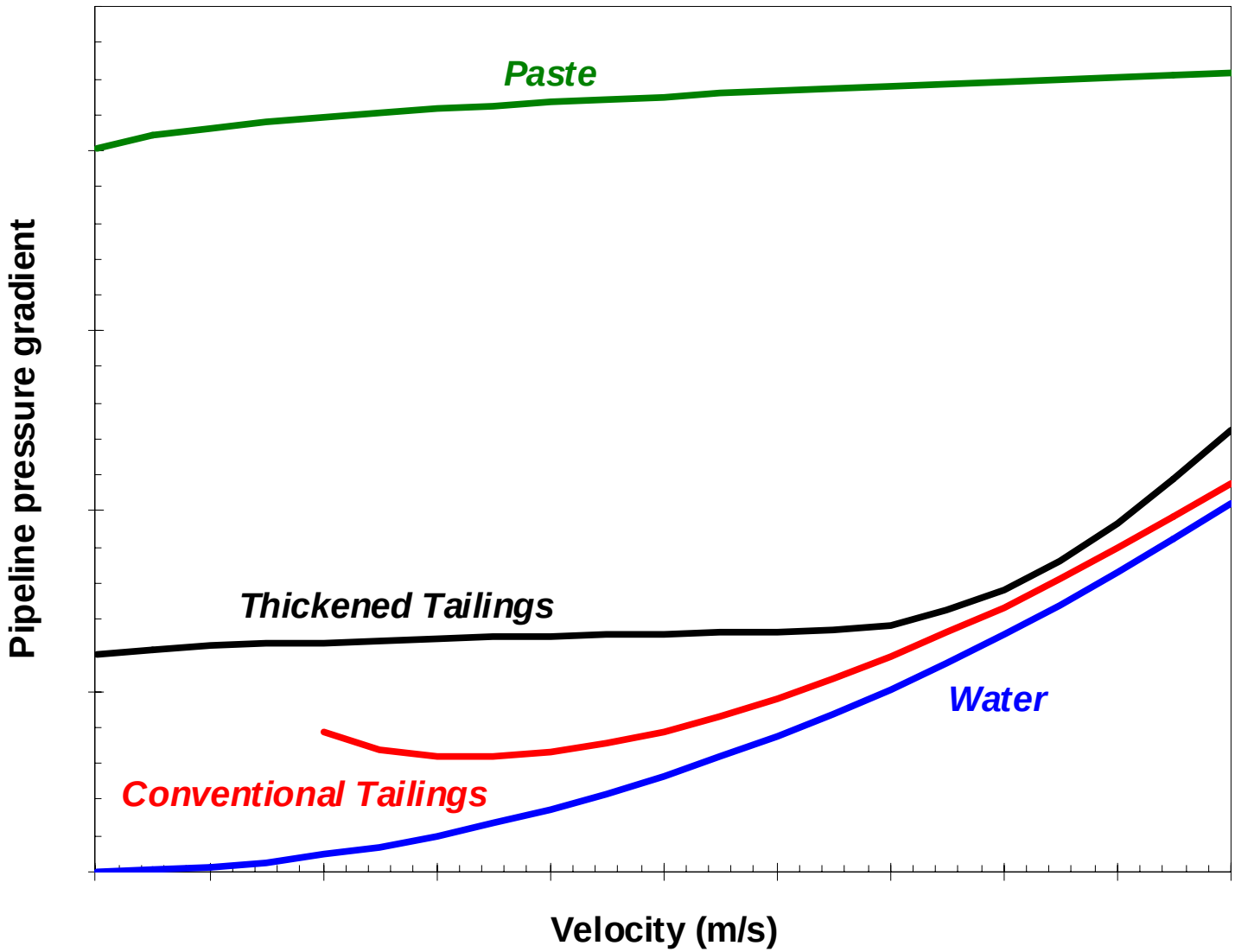
Laminar Flow Settling: Pipe Loop Data

- **4” Pipeline**
- **Laminar flow**
- **67%m, yield stress = 52 Pa**
- **Increasing pressure gradients**

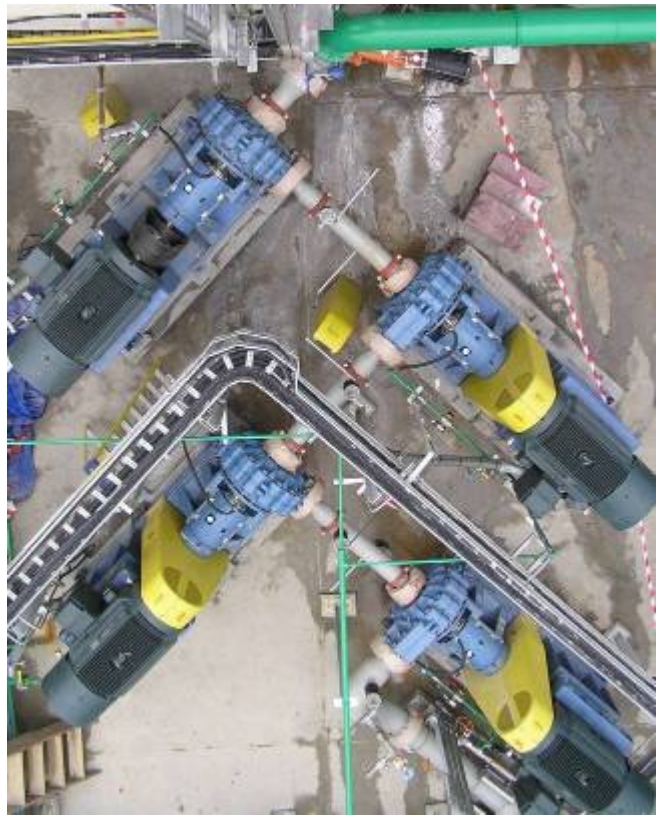

Velocity (m/s)
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
Concentration
62%
63%
64%
65%
66%
67%
68%
69%
70%
71%
72%
67%m nominal conc.
Test 1
Test 2
Top of Pipe
Bottom of Pipe


200
180
160
140
120
100
80
60
40
20
0
Yield Stress (Pa)
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
Concentration (%m)

Pipeline Flow Behavior



Centrifugal Pumps



Centrifugal Pumps

Centrifugal Pumps

- **Operating considerations for P&TT applications:**
  - Minimize the possibility of air entrainment into the mixture through careful sump design.
  - Minimize the suction piping friction losses.
  - Consider shear effect (rheomalaxis).
  - Avoid operating with negative gauge pressures, it is suggested that a positive head of at least 2 m at the pump inlet is provided.
  - Avoid using pumps smaller than 4”/3” for mixtures with yield stresses exceeding 200 Pa. Peristaltic pumps may be a better option for these duties.
  - Pressurized flush water may be required for pipeline flushing.
  - The Walker & Goulas (Warman) pump Reynolds number method may be used to estimate the pump performance derating.

Positive Displacement Pumps

Positive Displacement Pumps

- **Operating considerations for P&TT applications:**
  - Provide excellent flow control.
  - High efficiency pumps not affected by the paste properties provided the chambers are filled on each stroke.
  - Reciprocating pumps require a positive suction pressure:
    - Hydraulic pumps - provided by an elevated feed sump
    - Others – need a positive charge pressure, this is either provided by gravity (thickener underflow pump) or through a charge pump.
  - Residual pressure due to yield stress slurries.

Conclusions

- **Conventional tailings**
  - Low risk, turbulent flow operation
  - Design methodology well established and proven.
- **Paste**
  - Generally not economic for surface disposal due to high pump costs
  - Underground backfill
  - Laminar flow operation
  - Design more complex, but methods reasonably well developed.
- **Thickened tailings**
  - Most high concentration surface tailings will fall into this classification
  - Risk of non-homogeneous laminar flow
  - Understanding of flow behavior being developed
  - Current designs are based on engineering for the uncertainty.