Slurry Transportation
An Overview

Robert Cooke

PhD, Member of the Society of Mining, Metallurgy and Exploration
Fellow of the Southern African Institute of Mining and Metallurgy

Paterson & Cooke, Denver Colorado

RobertC@PatersonCooke.com, Tel 303 867 2264
1580 Lincoln Street, Suite 1000, Denver CO 80203

DOE Slurry Retrieval, Pipeline Transport & Plugging and Mixing Workshop
January 14-18, 2008
Orlando, Florida

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Presentation Outline

- **Slurry properties**
- **System applications**
- **Design considerations for yield stress slurries**
- **Engineering slurry systems**

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Slurry Properties

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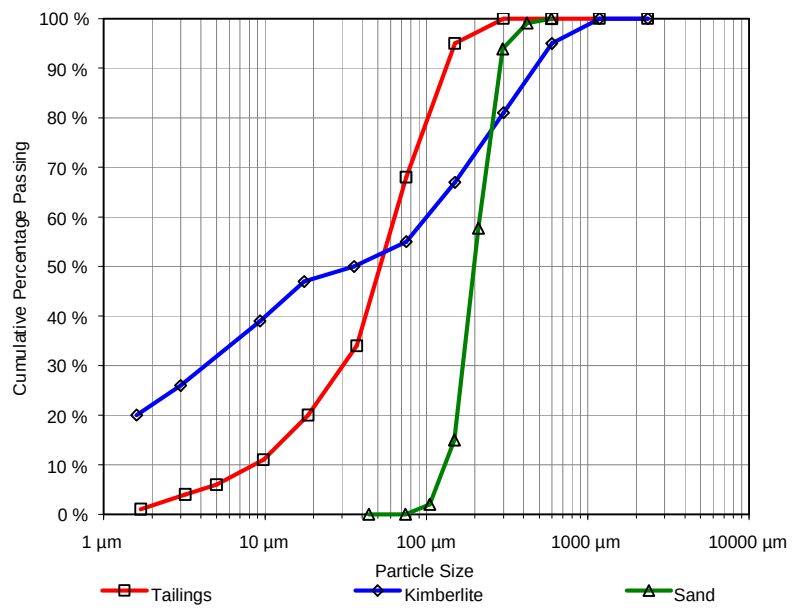

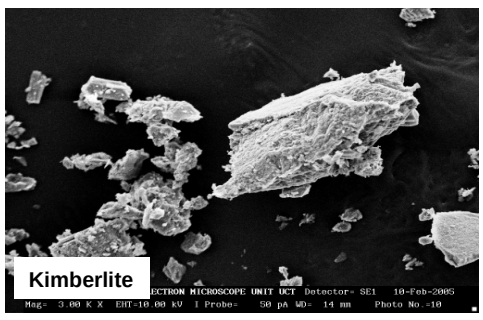

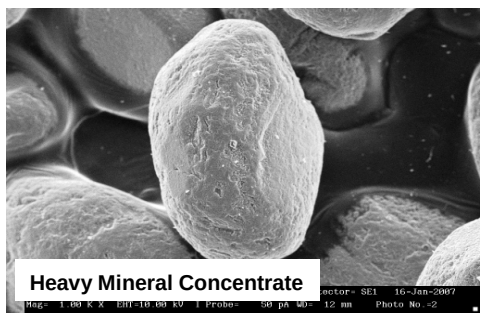

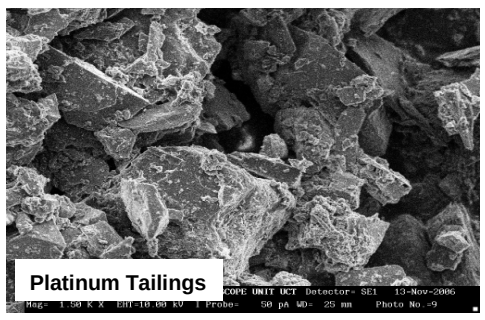

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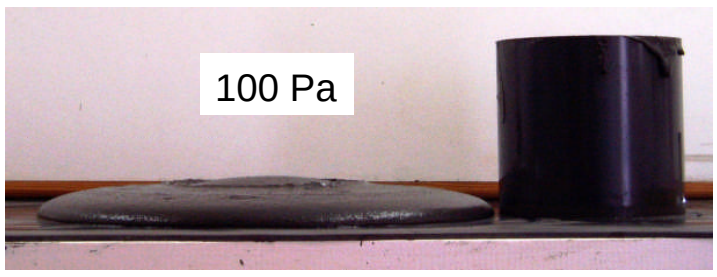

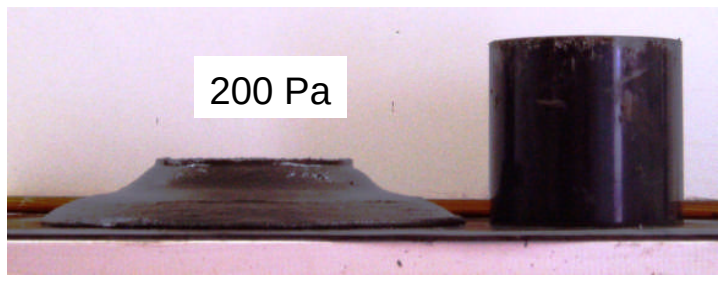

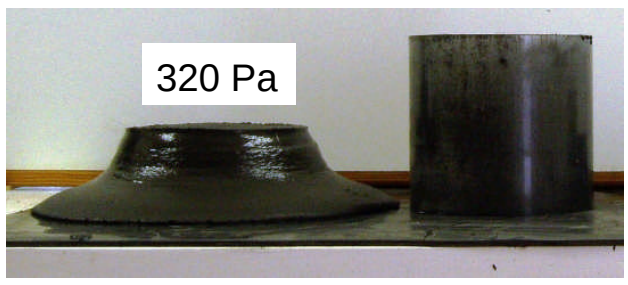

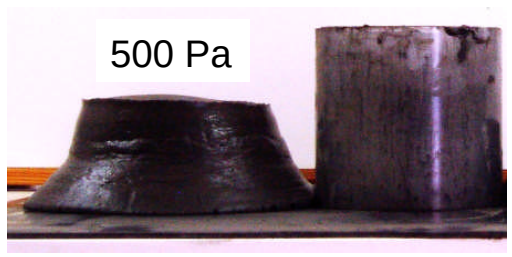

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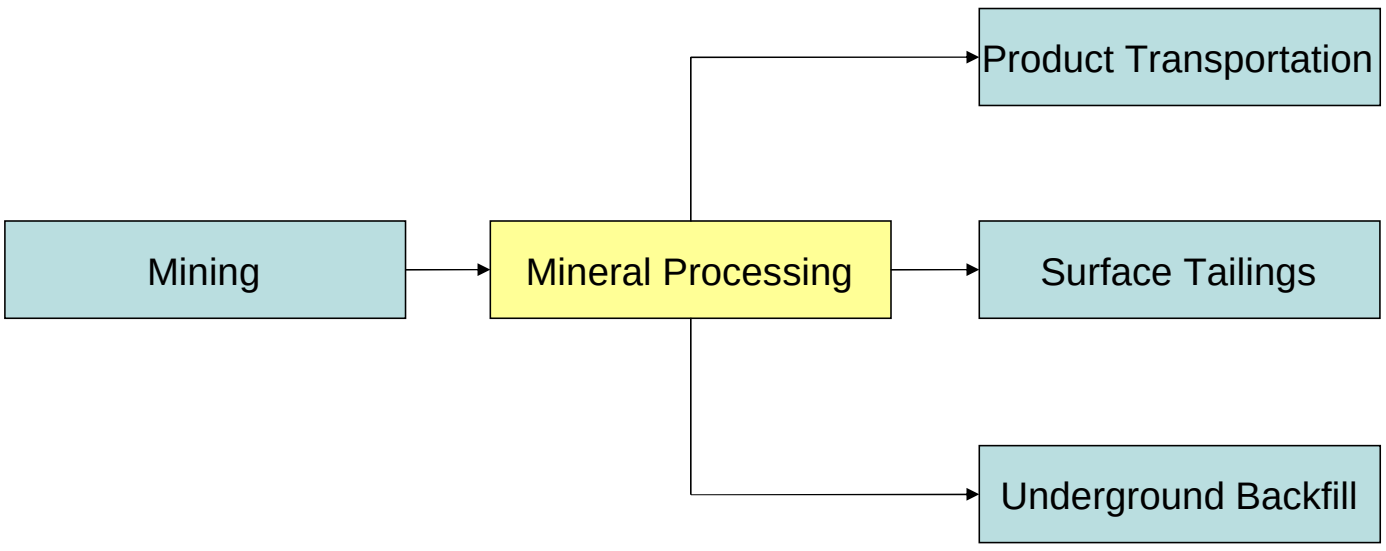
System Applications: Mineral Industry



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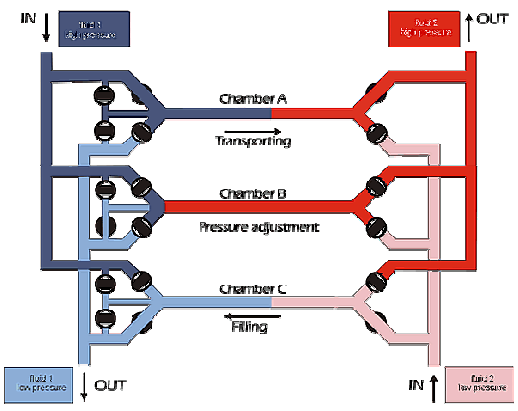
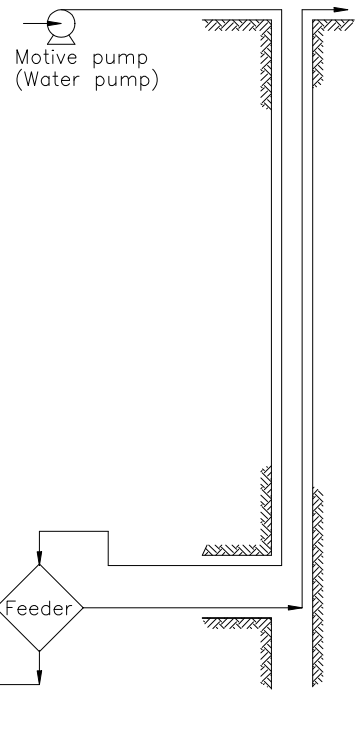
Hydraulic Ore Hoisting





2” rocks
250 t/h
3300 feet vertical
3625 PSI (250 bar)

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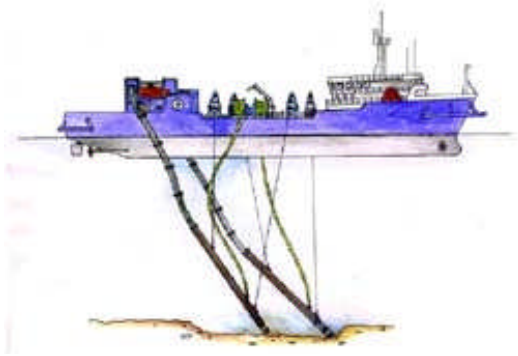
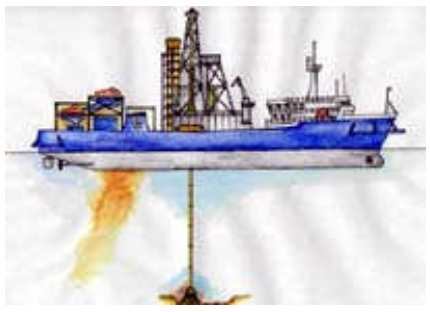
Marine Mining





16” rocks
1000 t/h
600 feet vertical
53 000 GPM

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Mineral Processing

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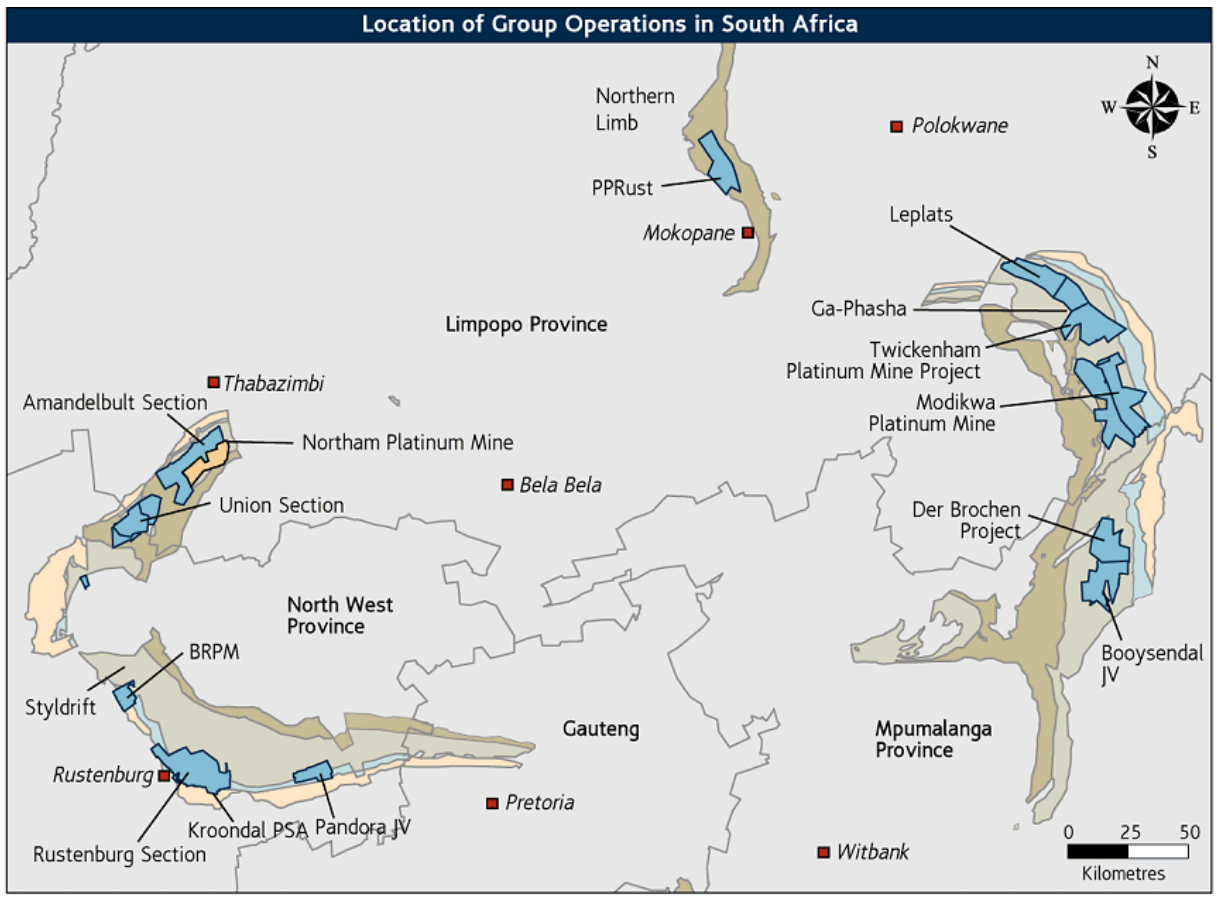

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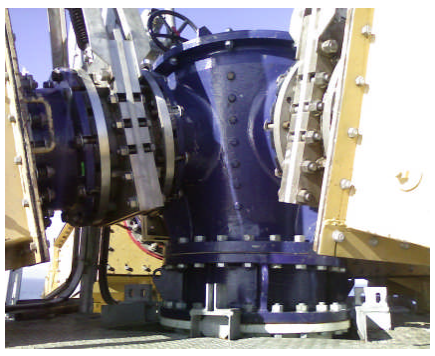
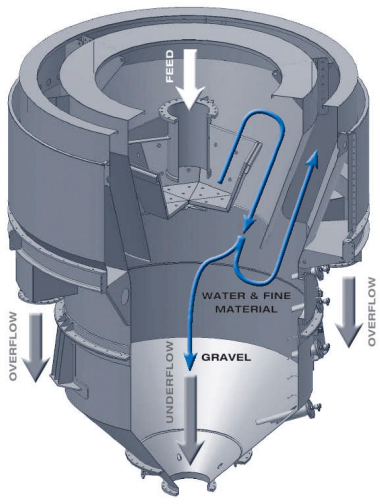
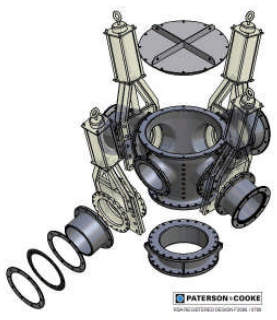
Mineral Processing







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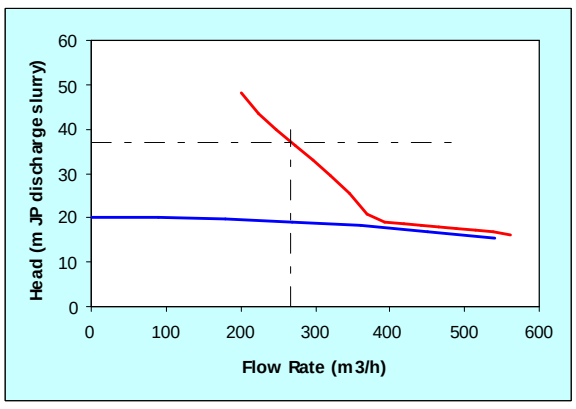
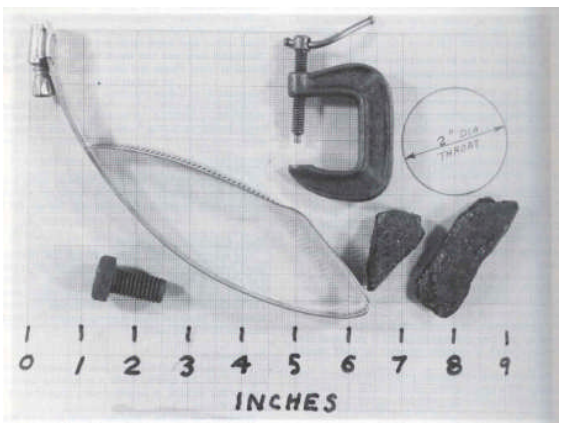
Mineral Processing





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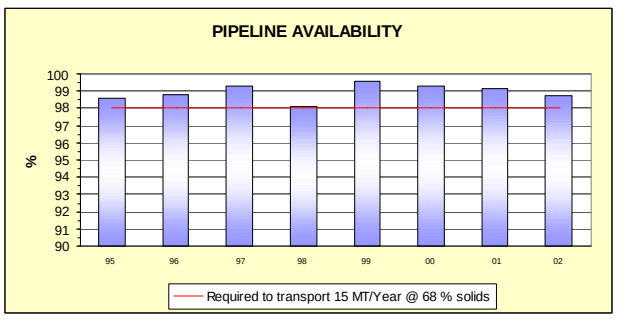
Concentrate Transport



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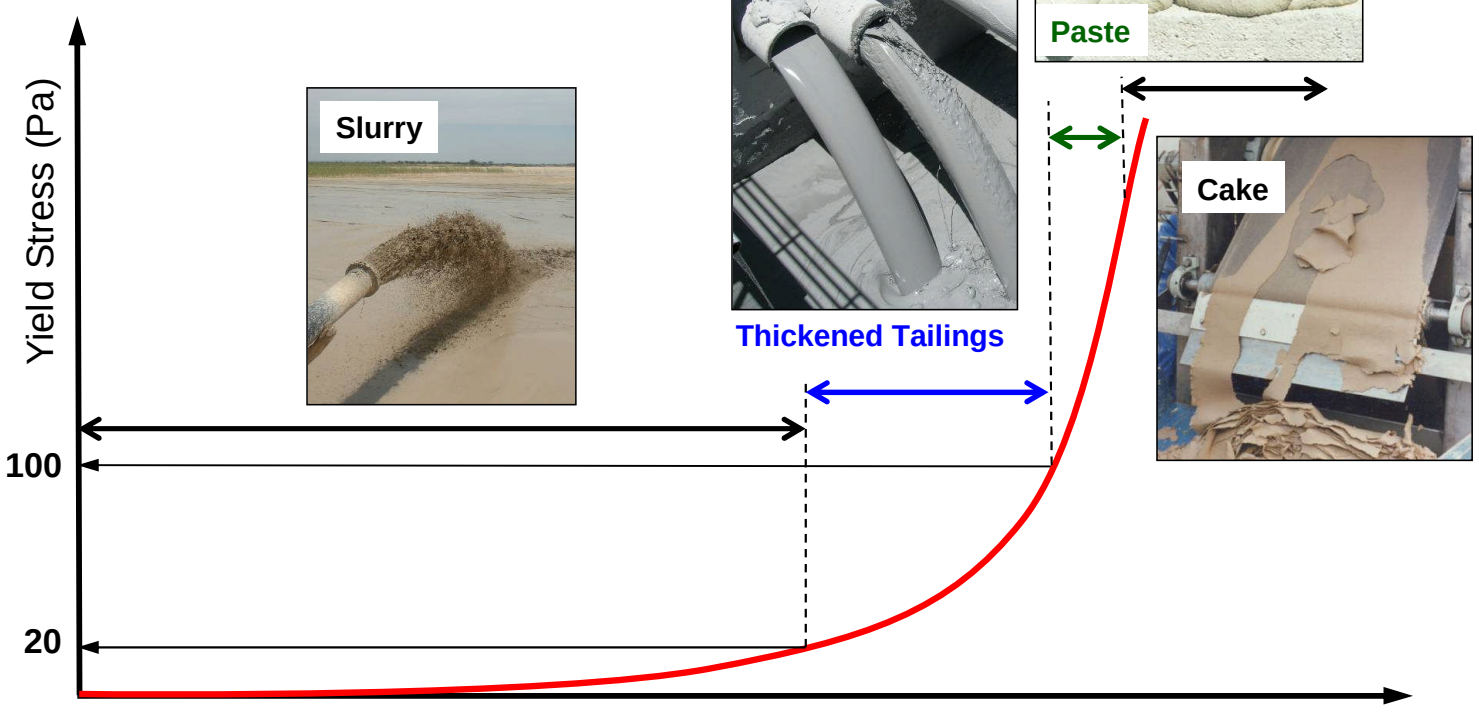
Paste and Thickened Tailings



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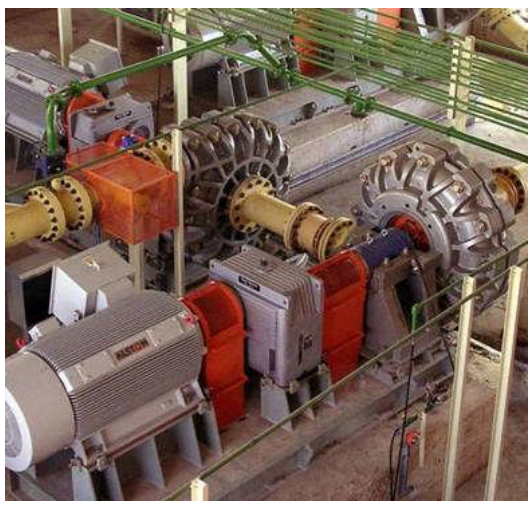
Surface Tailings



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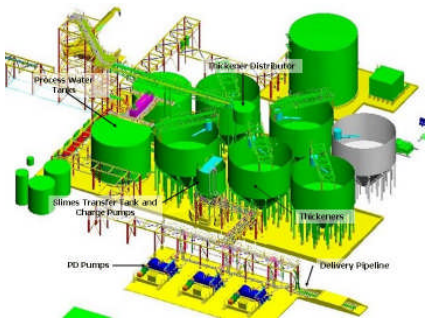

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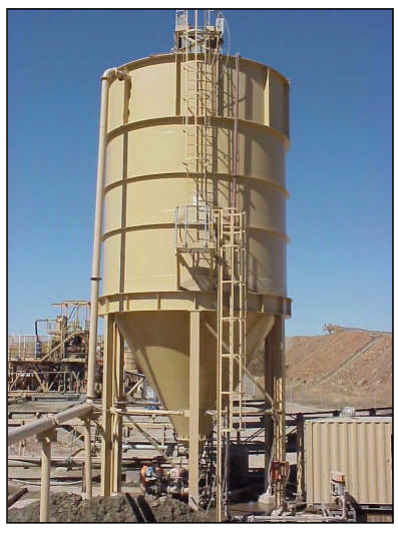
Thickener technology

Conventional



High Rate

Ultra High Rate

Paste

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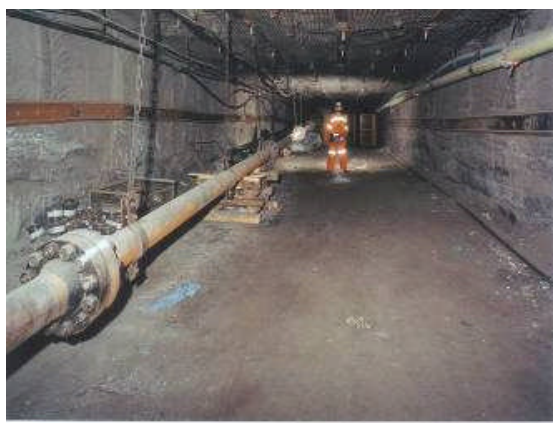
Underground Backfill



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Yield Stress Slurries

- **Operating velocity**
  - Laminar or turbulent flow
- **Laminar flow operation**
- **Residual pressure in pipeline**

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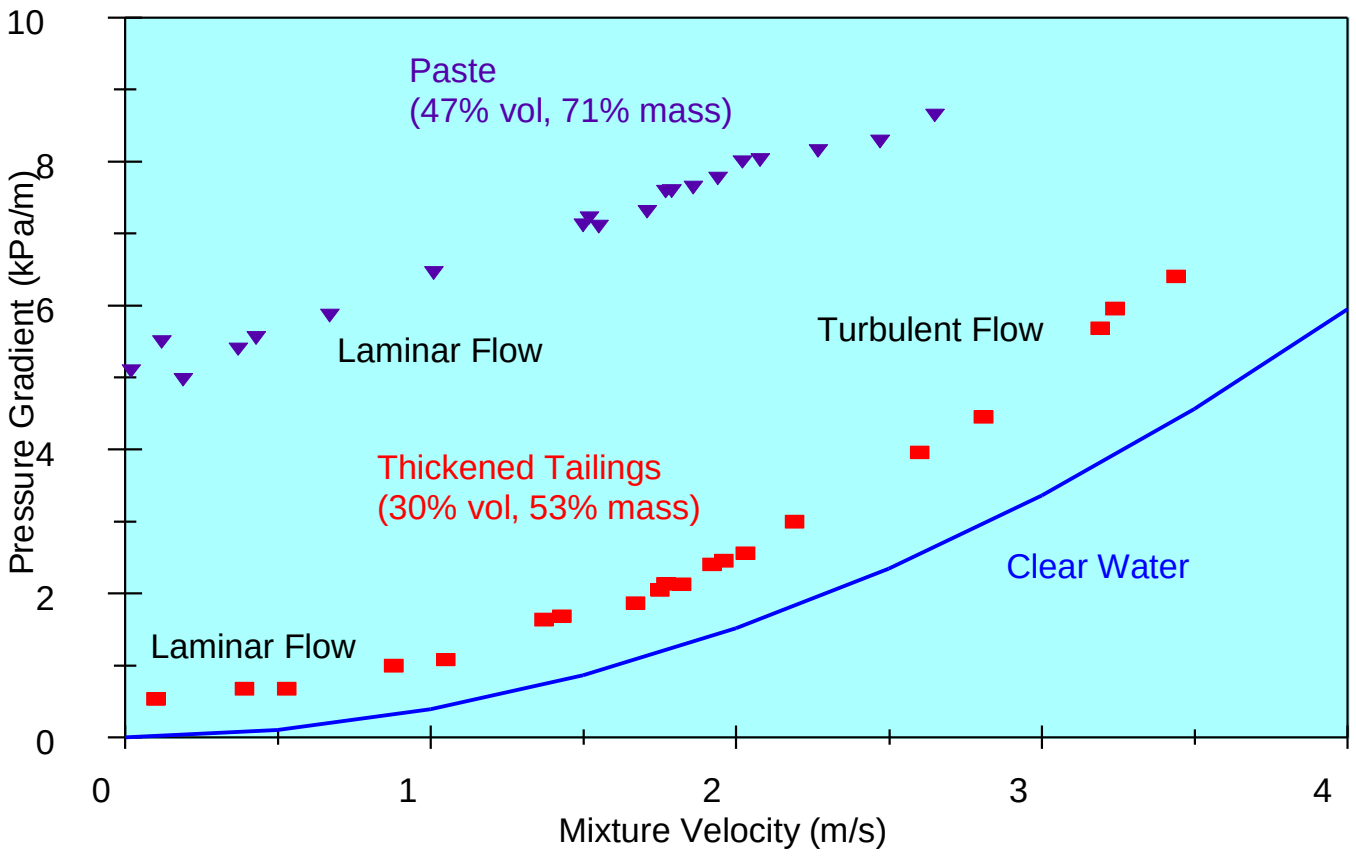

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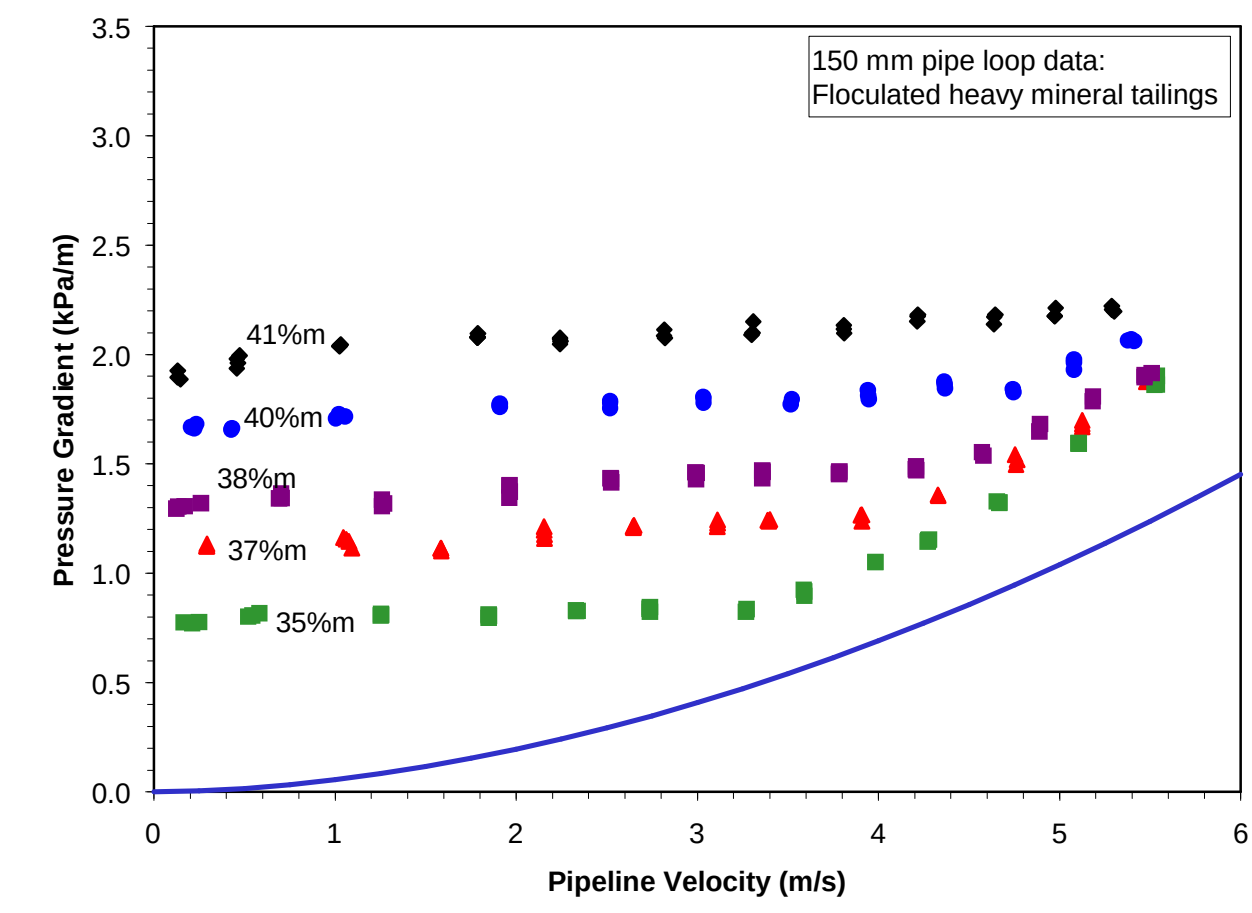

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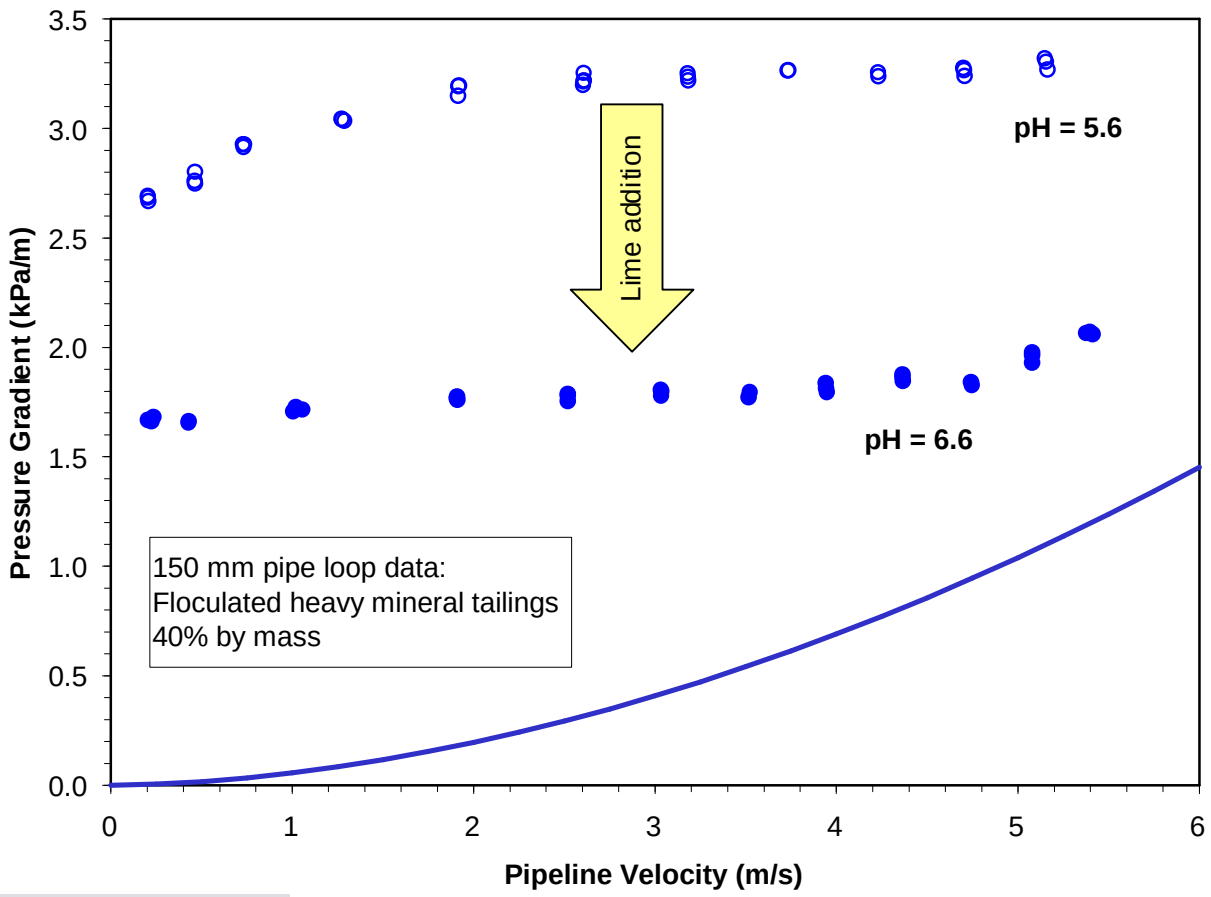
Design Considerations: Friction Loss



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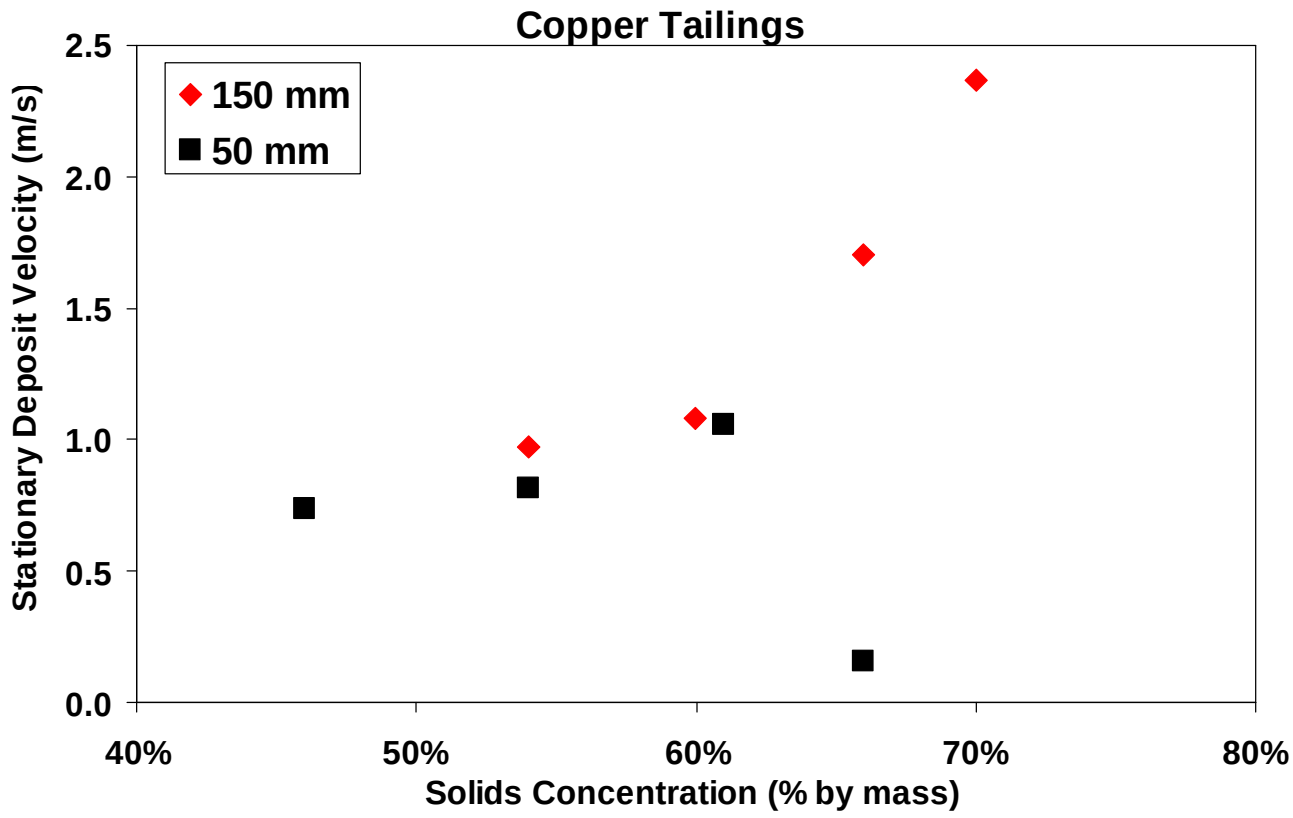

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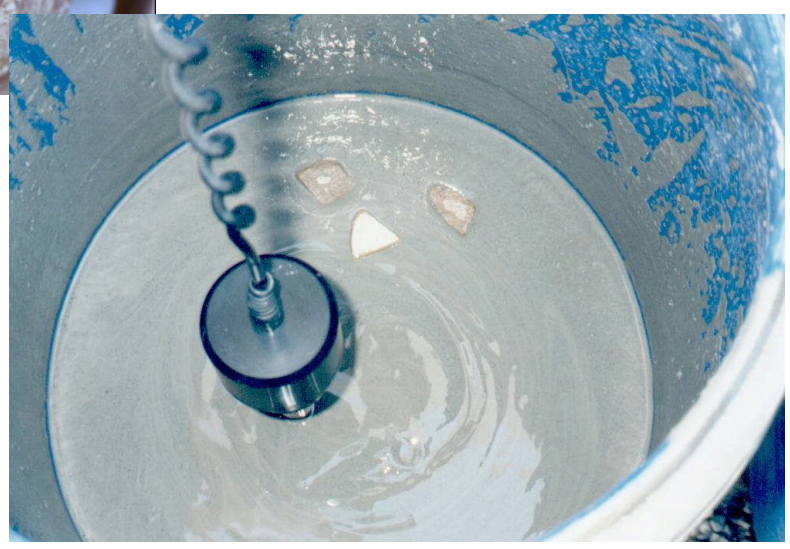

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Laminar Flow: Particle Settlement

- **Rugby Limestone pipeline**
  - Laminar flow operation
  - 92 km long, 250 mm diameter
  - Over 36 hours, 0.106 kPa/m to 0.121 kPa/m

Feed	Discharge
56.5%m	**54.5%m**
1.1% > 300 µm	**trace**
150 µm > 2.8% > 300 µm	**trace**

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Laminar Flow: Particle Settlement

- **Belovo-Novosibirsk pipeline (Siberia)**
  - Laminar flow operation (stabilized coal)
  - 262 km (164 mile) long, 530 mm diameter
  - Pipeline blocked during commissioning
  - Pressure gradient increased with time
  - Stationary deposit on pipe invert
  - Instabilities were not observed during loop tests using a 200 mm pipeline

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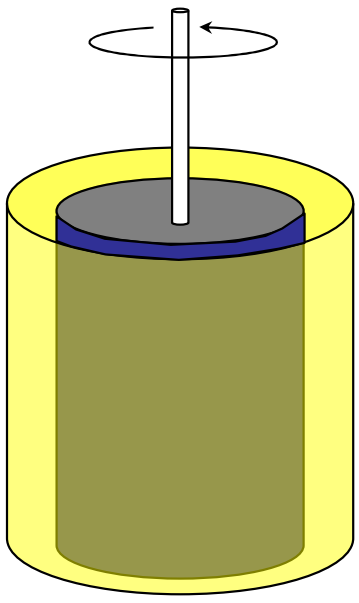
Laminar Flow: Particle Settlement

- **Will particles settle?**
  - Small-scale tests under sheared conditions



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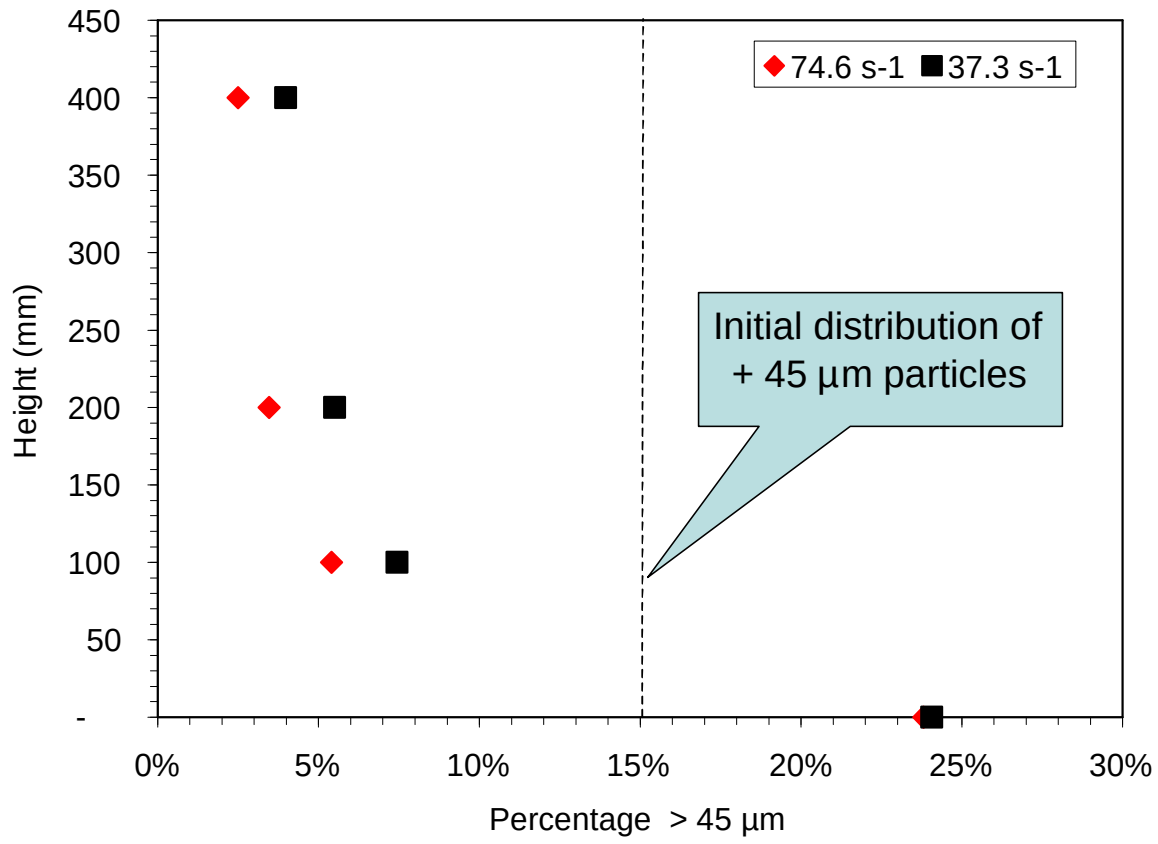
Laminar Flow: Particle Settlement



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Laminar Flow: Particle Settlement

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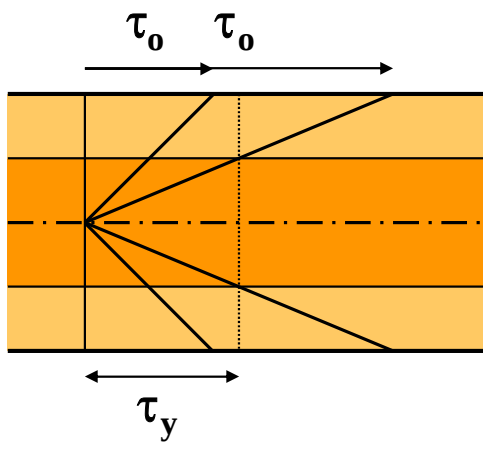
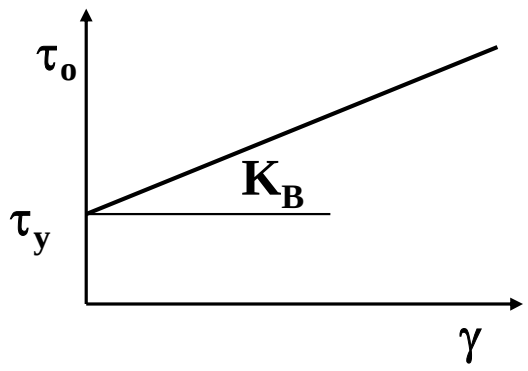
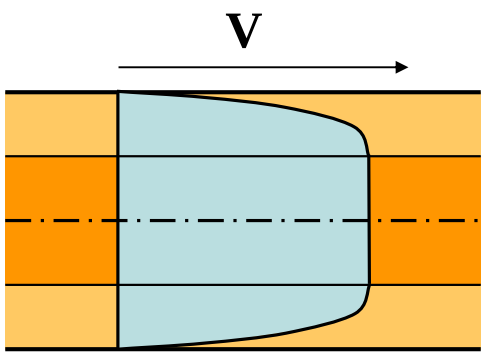
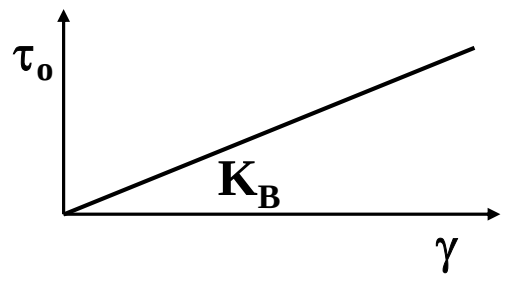
Laminar Flow: Particle Settlement

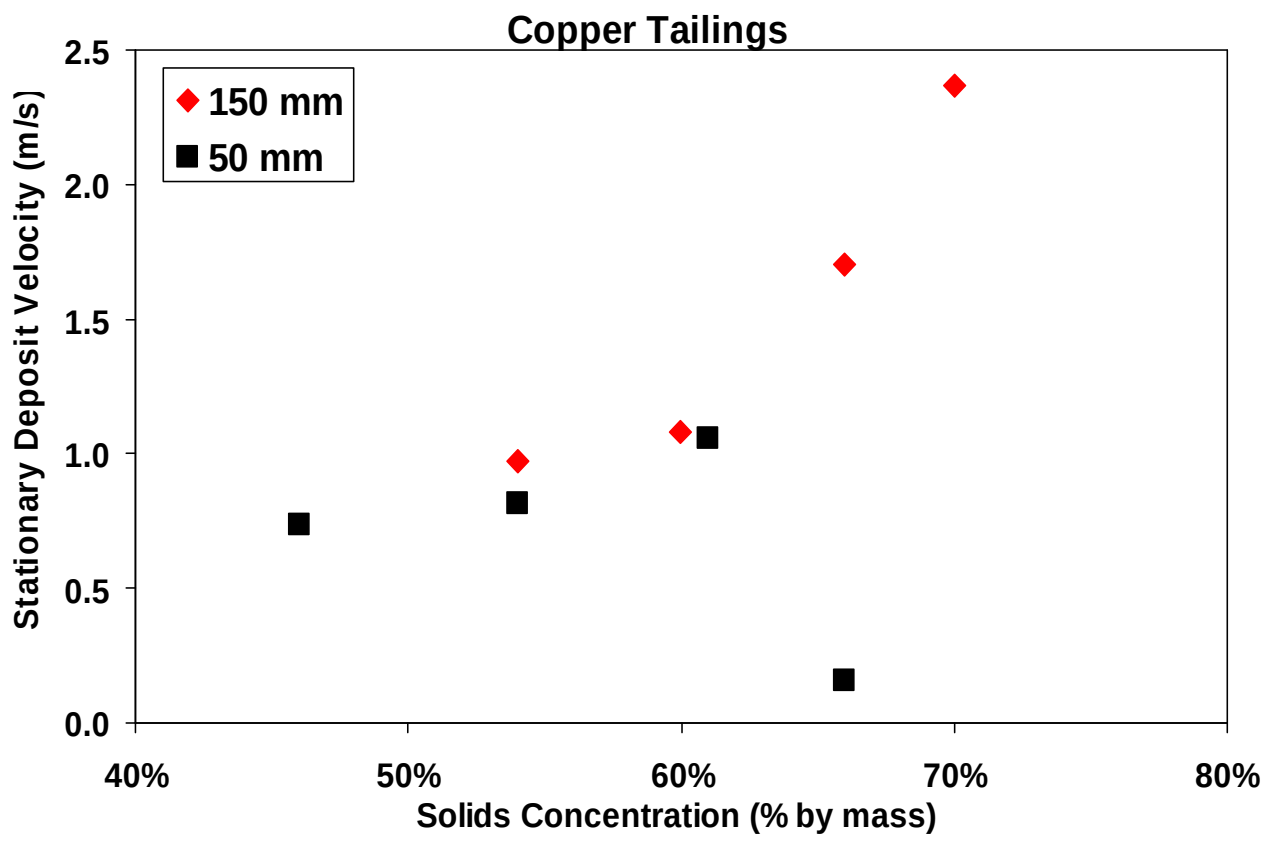








Laminar Flow: Particle Settlement



Laminar Flow: Particle Settlement

- **Under what conditions will the particles be transported?**
- **Thomas (1977)**
  - Deposition occurs at a constant pressure gradient regardless of pipe size.
- **Gillies *et al* (1999)**
  - Pressure gradient of about 2 kPa/m required to transport sand particles in a viscous Newtonian oil.
- **Gillies *et al* (2007)**
  - Propose that the criterion for transport is based on the ratio of the mean wall shear stress to the mean surficial particle stress.
- **This is an area of ongoing research**

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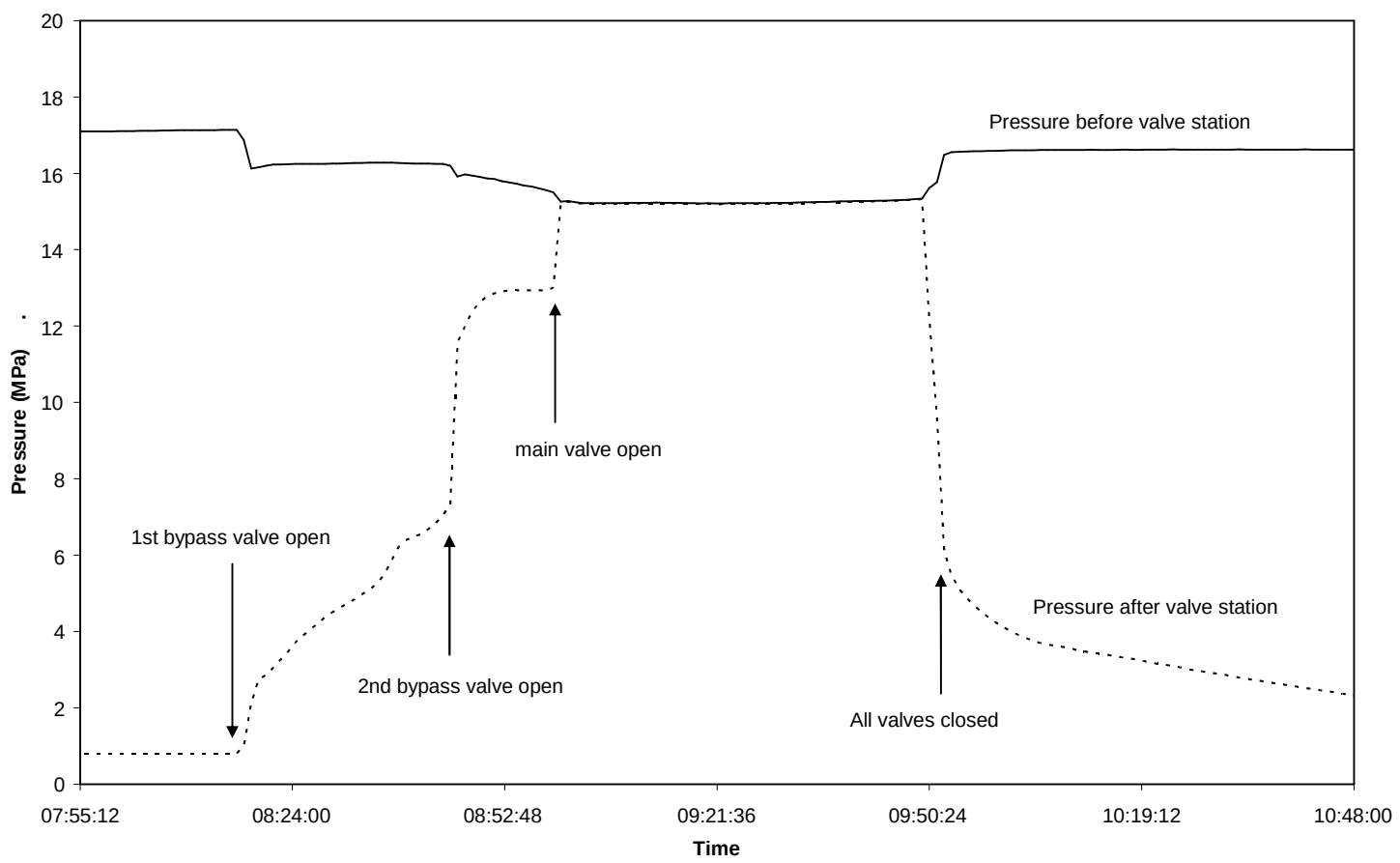
Residual Pressure



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Engineering Slurry Systems

- **Design criteria / basis**
- **Slurry test requirements**
- **Minor losses**
- **Pump performance**
- **Hydraulic tools**
  - System curve
  - Hydraulic gradeline
- **Transient conditions**
- **P&ID Review**
- **Pigging**
- **Instrumentation**

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Design Criteria / Basis

- **Client/owner requirements**
- **Site conditions**
- **Material properties**
- **Design methodology**
- **Standard and codes**

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Slurry Test Requirements

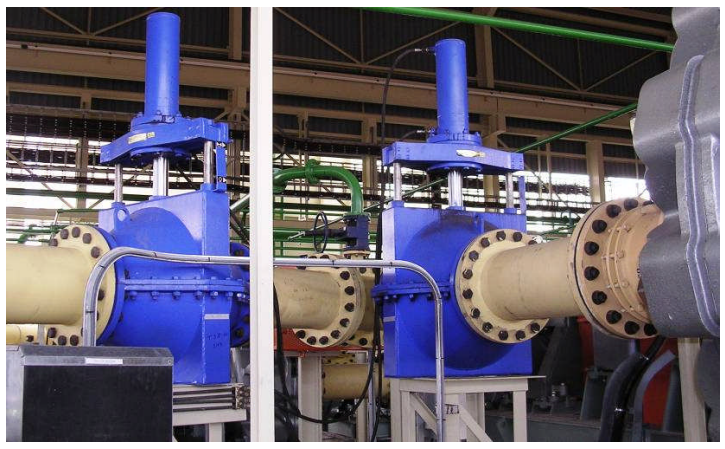
- **Information regarding the design of a slurry system is based on knowledge of the slurry flow behavior.**
- **The sources of information include:**
  - Practical experience
  - Empirical correlations or information
  - Two layer predictive models
  - Historical test data
  - Specially commissioned project specific test work
- **Yield stress slurries:**
  - There is no method for predicting the rheology of high concentration slurries.
  - The behavior of flocculated slurries is complex.

When is Test Work Required?

- **Test work is expensive:**
  - Sample collection (for green fields projects this may require that samples are generated from ore).
  - Time delays to project.
  - Actual test work costs.
- **Test work reduces risk:**
  - Reduced design factors (over design)
  - Reduced potential for design failures or extensive post commissioning modifications
- **It is the responsibility of the Designer to balance**

Information Required versus Risk

Minor Losses



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Pump Peformance

- Performance derating
- Pump suction conditions
- Pump blockage

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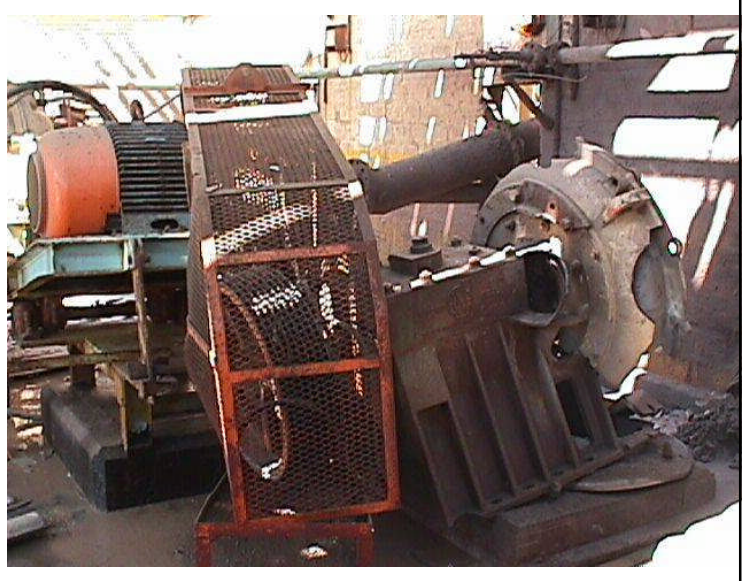
Centrifugal Pump Explosions



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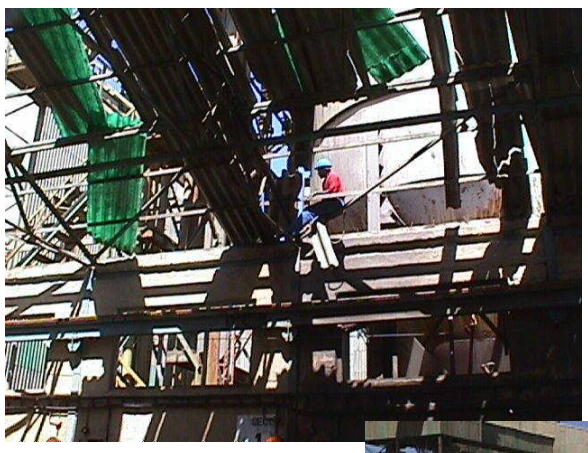

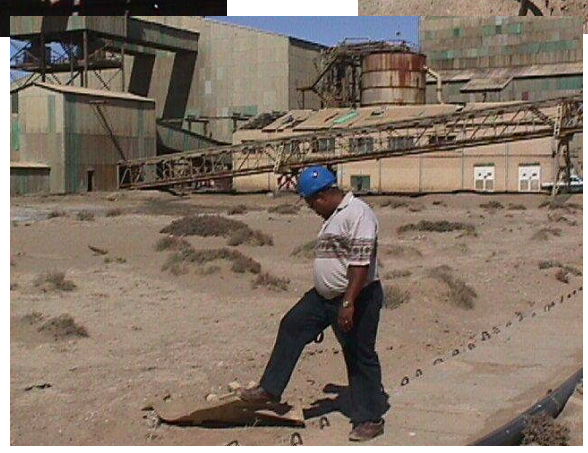

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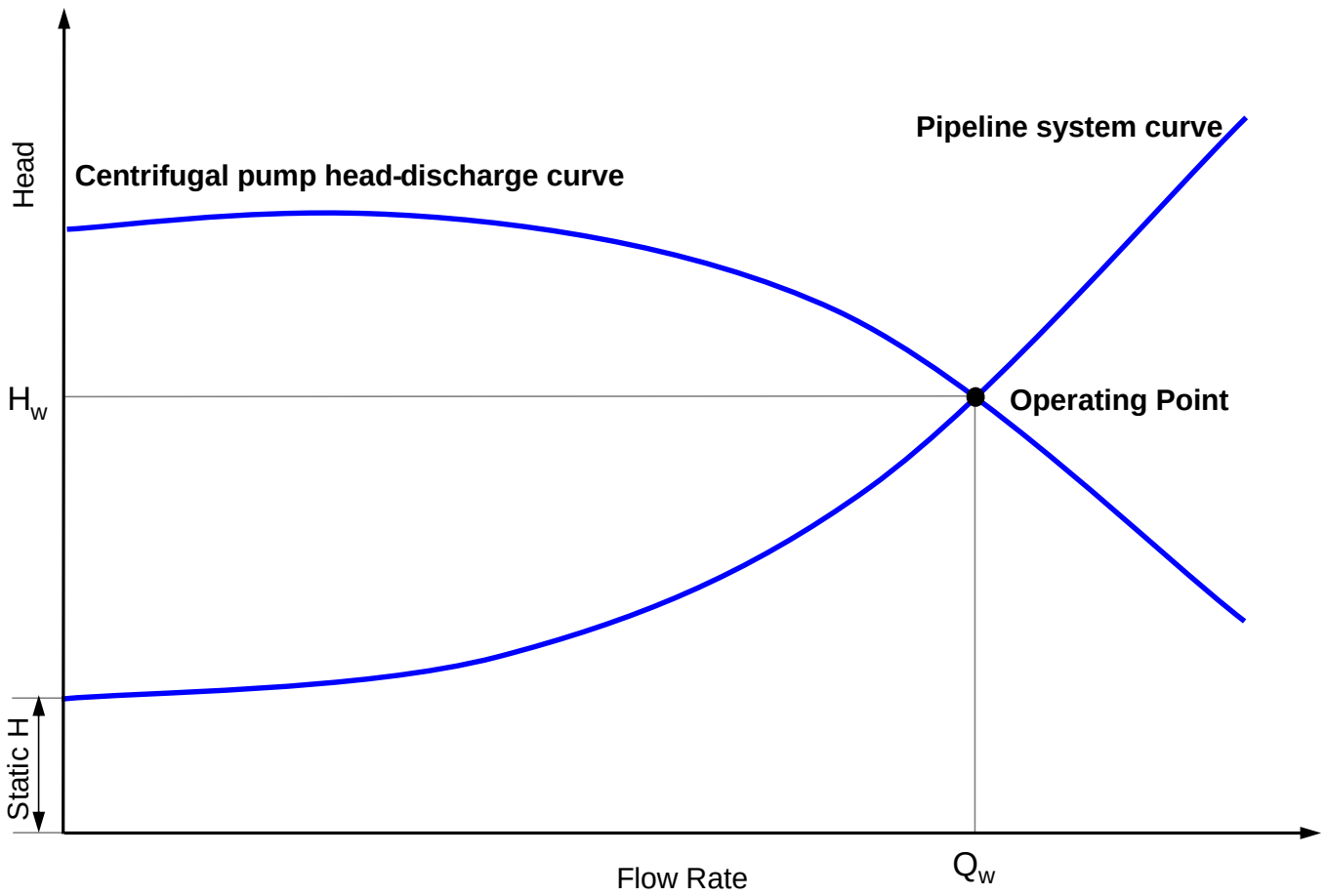
System Curve



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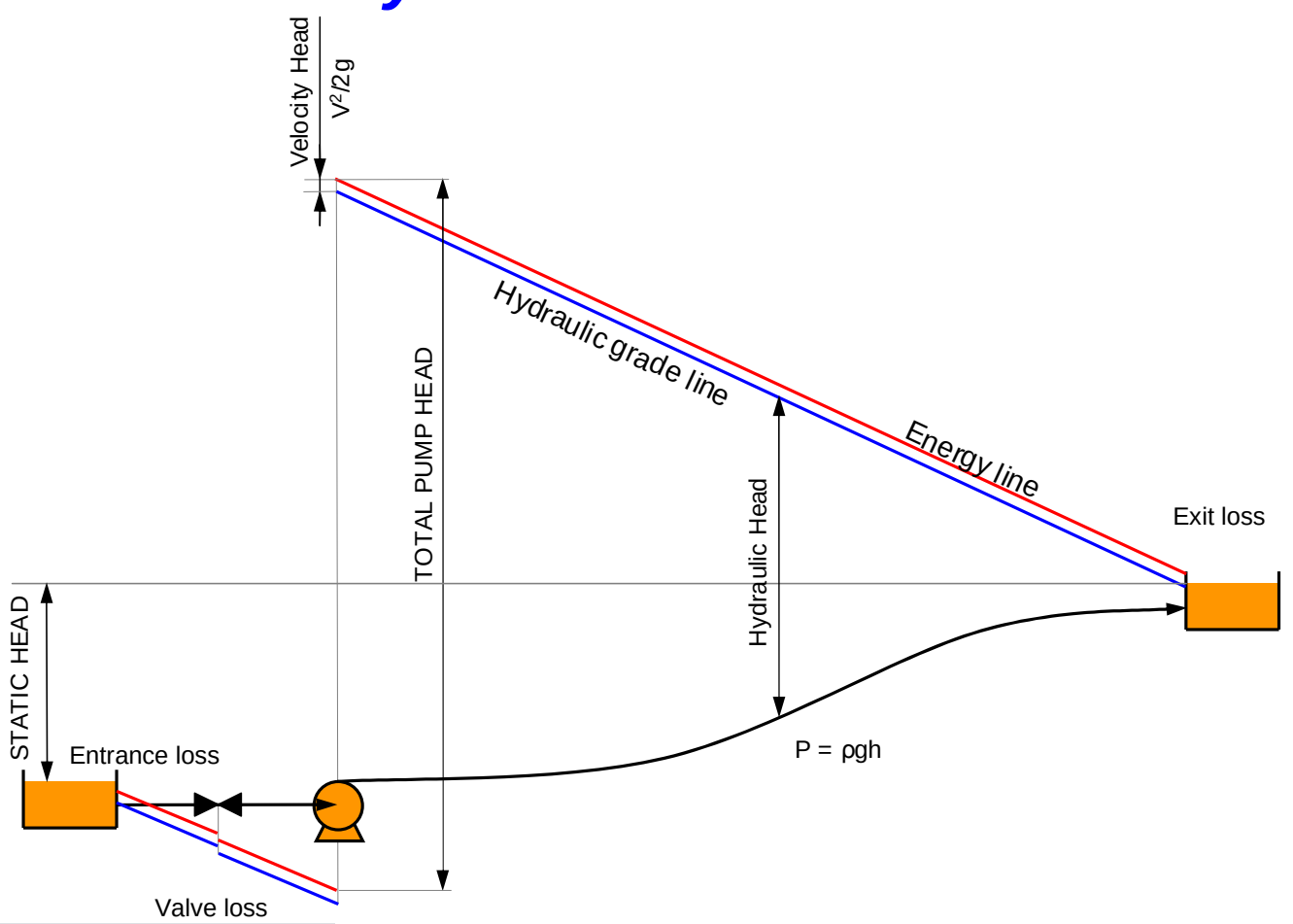
Hydraulic Gradeline



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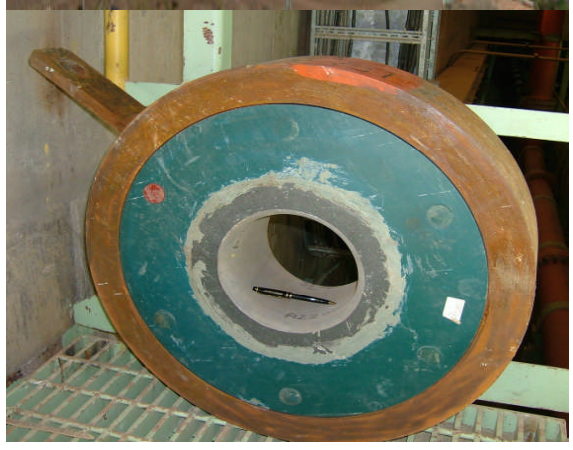
Choke Station



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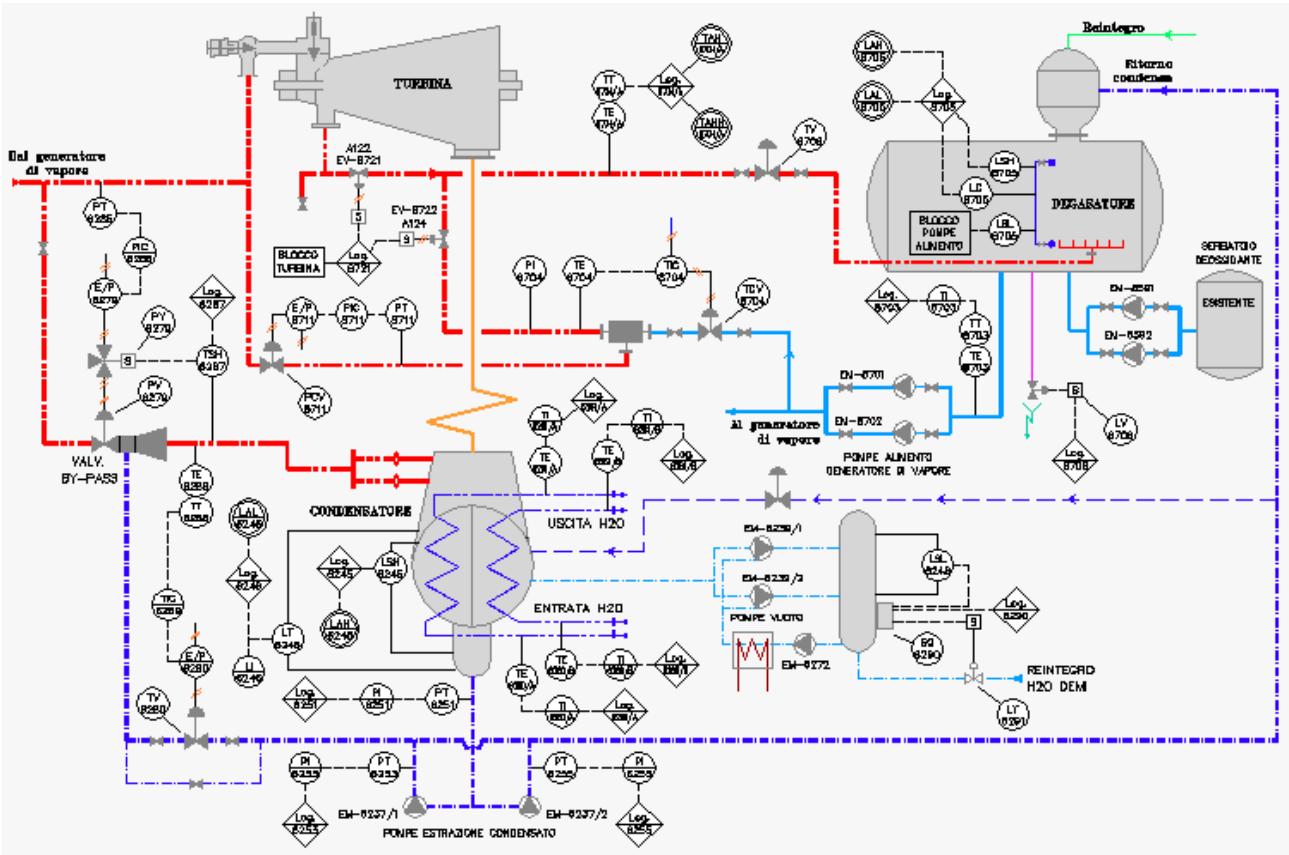
P&ID Review



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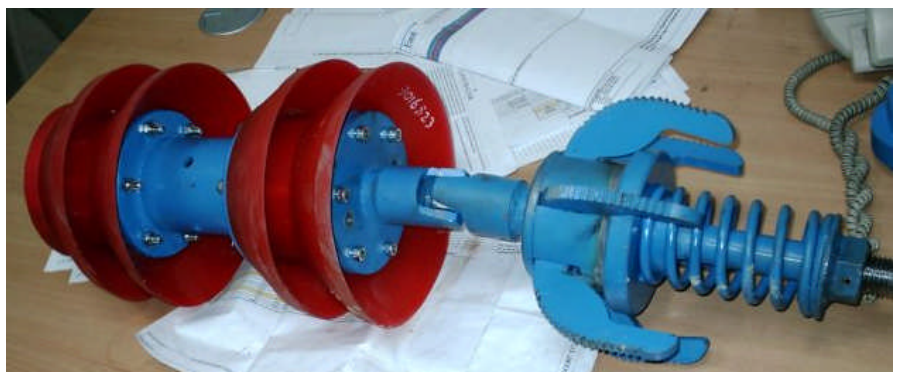
Pigs



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Instrumentation

- **Simple**
- **Control and Measure**

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Conclusion

“The conviction was that the key to the design of slurry systems which would operate reliably lay, not in the selection of exotic materials or the design of special equipment, but in the *<u>understanding</u>* and control of the slurry environment”

EJ Wasp

PATERSON & COOKE

DOE Slurry Retrieval, Pipeline Transport & Plugging and Mixing Workshop, January 2008