Slurry Retrieval, Pipeline Transport & Plugging, and Mixing Workshop

Critical Velocity w/ Viscosity Adjustment

River Protection Project

WASTE TREATMENT PLANT

MN Hall

1-16-98

Department of Energy

Office of River Protection

Bechtel National, Inc.

Hanford Waste Treatment Plant (WTP)

Introduction

- Largest nuclear facility under construction in the world.
- Will process 120 Million gal of defense nuclear waste over 30-40 yrs.
- 70 Mgal of High Level Waste (HLW) and 50 Mgal Low level waste (LAW)

Newtonian Fluids

BECHTEL

24590-WTP-GPG-M-0058, Rev 0
Minimum Flow Velocity for Slurry Lines
Effective Date: 27 November 2006

R10738865

Prepared By: Date 11-27-06
MN Hall, Mechanical Systems, Senior II Engineer

Approved By: Date 11/27/06
MW Hoffmann, M&PE Design Support Supervisor

Design Guide:
Minimum Flow Velocity for Slurry Lines

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Non-Newtonian Fluids

Chemical Plugs

24590-WTP-GPG-M-0059, Rev 0
Avoiding Chemical Line Plugging - Plant Design Considerations
Effective Date: 15 November 2007

Prepared By: MN Hall
Approved By: MW Hoffmann, M&PE Deputy Discipline Production Engineering Manager — 11/14/07 Date

Design Guide:

Avoiding Chemical Line Plugging - Plant Design Considerations

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Bingham Plastics

R10764695

24590-WTP-GPG-M-016, Rev 2
Pipe Sizing for Lines with Liquids Containing Solids - Bingham Plastic Model
Effective Date: 8 August 2007

Prepared By: MN Hall
Approved By: MW Hoffmann, M&PE ~~Design Support Supervisor~~ Deputy DPEM — 8/6/07 Date

Design Guide:

Pipe Sizing for Lines with Liquids Containing Solids - Bingham Plastic Model

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Power Law Fluids

R10797334

24590-WTP-GPG-M-039, Rev 2
Determination of Pressure Drop for Lines with Liquids Containing Solids - Power Law Fluids
Effective Date: 7 June, 2007

Prepared By: MN Hall
Approved By: MW Hoffmann, M&PE Design Support Supervisor — 6/7/07 Date

Design Guide:

Determination of Pressure Drop for Lines with Liquids Containing Solids - Power Law Fluids

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Risk Management

- Due to unknown rheology
  - Lack of comprehensive characterization
  - Blending issues
  - Changing waste forms (hydrates, reactions, concentrations)
- High dilution rates
  - to cause Newtonian like behavior – add water
  - Force waste to behave like model – can predict
- Evaporation at destination
  - Usually storage tank
  - Unknown rheology
- Interface Control Documents (ICD-19 – Waste Feed Criteria)

Slurry Flow In Pipelines

- Data Conversion is Important Issue
- wt% solids measured many different ways (25 C, 105 C, 1200 C)
- Bulk density reconciliation

$$\rho_s = \frac{\rho_b - \rho_L + \rho_L C_{vSludge}}{C_{vSludge}}$$

where ρ_s = Density of Solids, (g/mL)
ρ_L = Density of Liquid, (g/mL)
ρ_b = Bulk density of sludge, (g/mL) (Note: Not Slurry, sludge only)
$C_{vSludge}$ = Solids fraction of sludge, vol% (Note: Not slurry, sludge only)

$$C_v = \frac{(0.001)C}{\rho_{solid}}$$

where C_v = Solids fraction of Slurry, vol%
C = Grams of dry solids per liter of slurry, g
ρ_{solid} = Dry-base solids density, g/mL

Newtonian Mixture Viscosity

- As the fluid increase in solids concentration, or the shear rate, the viscosity changes: Thomas (1965)

$$\mu_M = \mu_L \left[1 + 2.5C_V + 10.05C_V^2 + 0.00273 \exp(16.6C_V)\right]$$

where μ_M = Slurry viscosity, cP
C_v = Solids fraction of Slurry, vol%

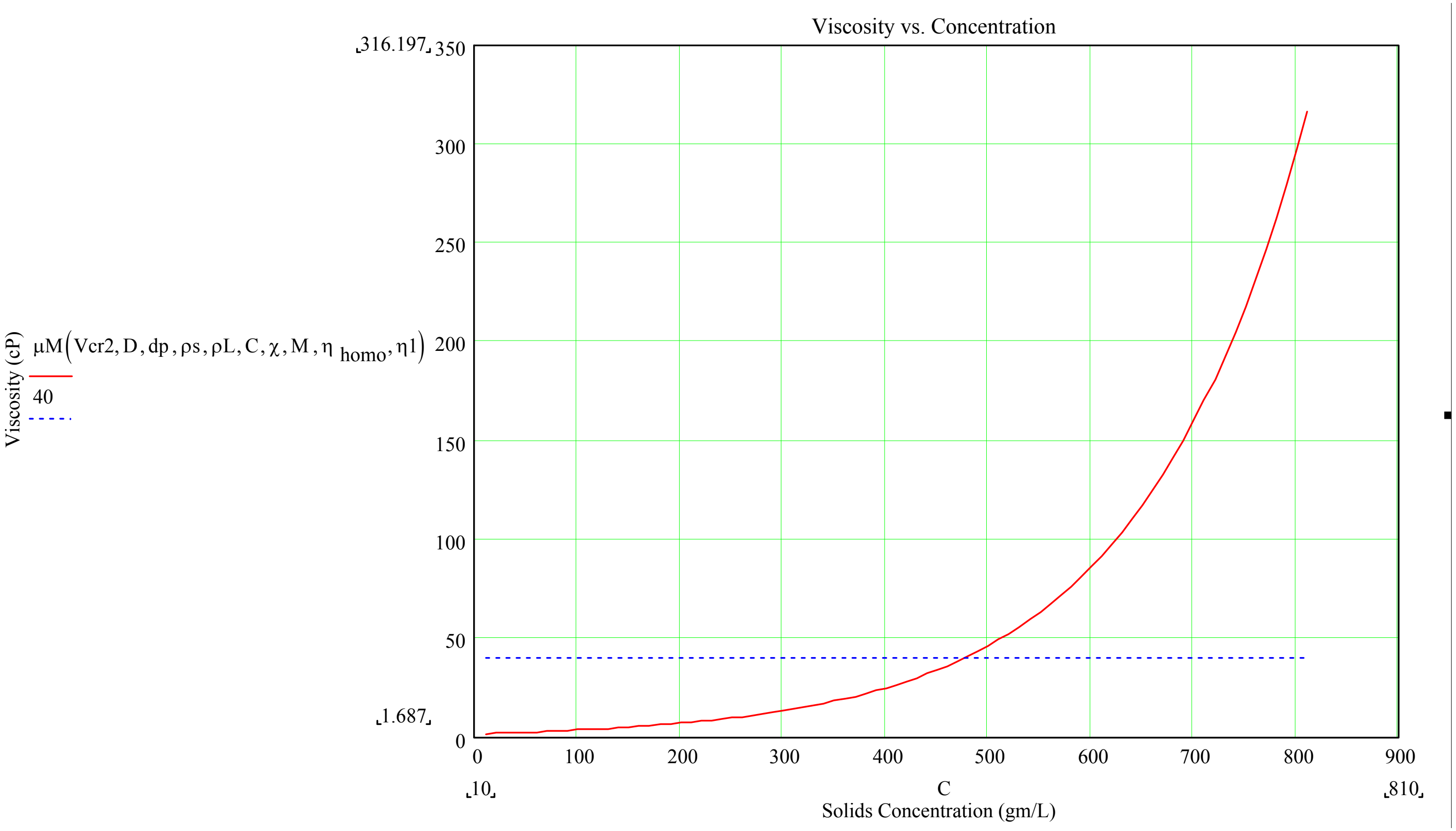
$$\mu_L = \mu_{water}\left[x_{salt}\left(1 + 1.071\left(\frac{\rho_L}{\rho_{water}}\right)\right) + x_{caustic}\exp\left(\left(7.143\left(\frac{\rho_L}{\rho_{water}} - 1\right)\right)^{1.15}\right)\right]$$

If the strain rate is expressed by $\gamma = 8\frac{V}{D}$

$$\mu_M = 2.0(1 + 2.5C_V + 10.05C_V^2 + 1.3(\exp(17C_V) - 1))\gamma^{-0.6}$$

Viscosity Results

Generally goes up with solids concentation



Newtonian - Critical Velocity in Pipe Lines

- Oroskar & Turian (1980)
- Function of 7 waste parameters (most descriptive)

$$V_{crOT} = \sqrt{g d_p \left(\frac{\rho_s}{\rho_L} - 1 \right)} \, 1.85 C_s^{0.1536} C_L^{0.3564} \left(\frac{d_p}{D} \right)^{-0.378} \left[\frac{D \rho_L \sqrt{g d_p \left(\frac{\rho_s}{\rho_L} - 1 \right)}}{\mu_L} \right]^{0.09} \chi^{0.30}$$

Combined Correlations

- Combination of OT Correlation w/ Jewett's Viscosity (reconciled with Hanford waste)