



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)

Newtonian Fluids

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)



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Minimum Flow Velocity for Slurry Lines
Effective Date: 27 November 2006



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Design Guide:

Minimum Flow Velocity for Slurry Lines

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Non-Newtonian

Non-Newtonian Fluids

Chemical Plugs



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Design Guide:

Avoiding Chemical Line Plugging - Plant Design Considerations

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Bingham Plastics



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Design Guide:

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

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Power Law Fluids



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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%

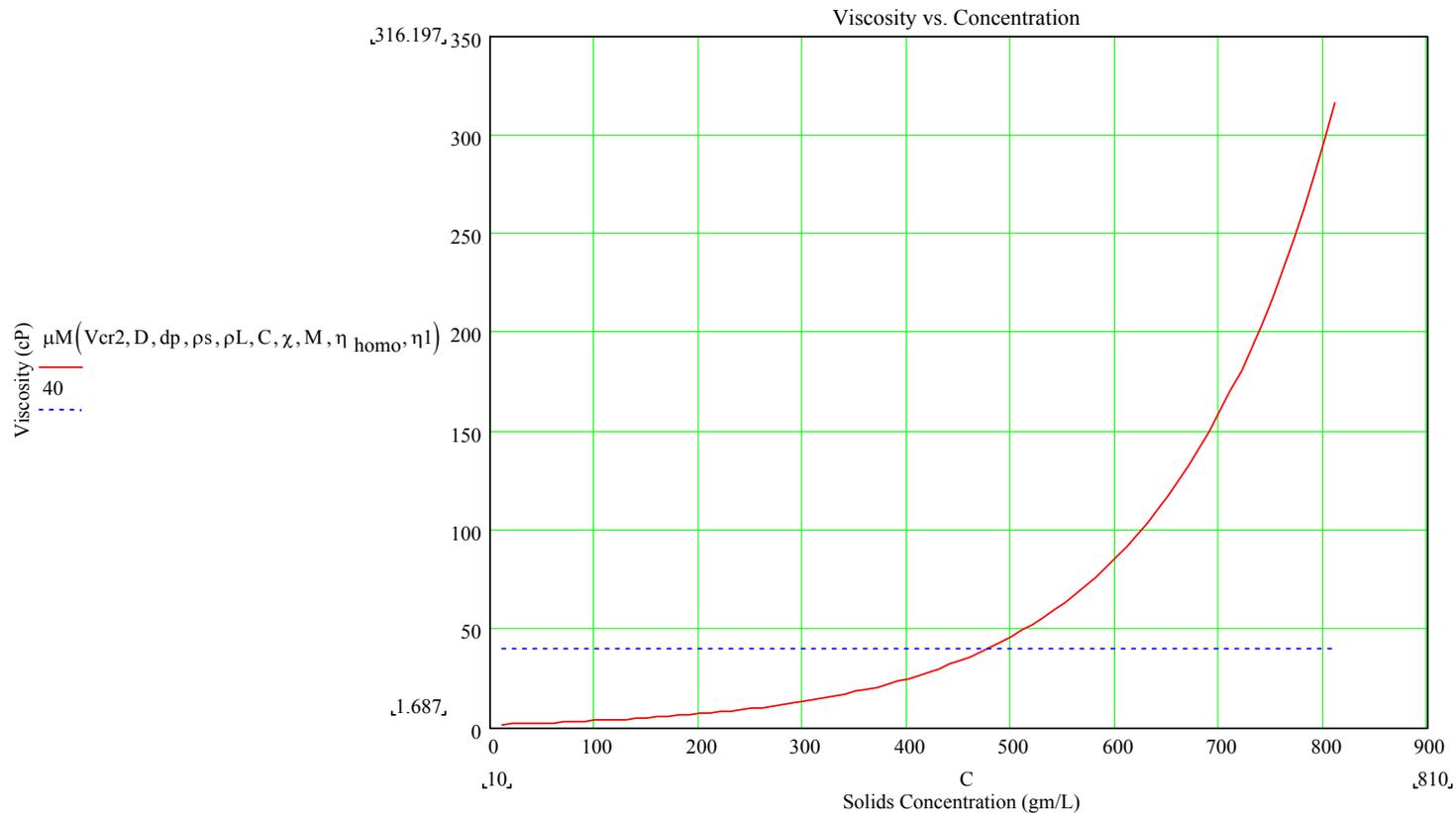
$$\mu_L = \mu_{water} \left[x_{salt} \left(1 + 1.071 \left(\frac{\rho_L}{\rho_{water}} \right) \right) + x_{caustic} \exp \left(\left(7.143 \left(\frac{\rho_L}{\rho_{water}} - 1 \right) \right)^{1.15} \right) \right]$$

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

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

Viscosity Results

Generally goes up with solids concentration



Newtonian - Critical Velocity in Pipe Lines

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

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

Combined Correlations

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

