

Rheology Investigations with Sludges from Metro Vancouver (Annacis Island Plant) Revision 1

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operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

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Revision

| Date | Revision No. | Description |
|------------|--------------|---|
| 06-01-2023 | 0 | Original Issue of Presentation (PNNL-SA-185826) |
| 05-13-2024 | 1 | Excel Workbook with underlying rheology has been added, “Supplementary Information/Data to Rheology Investigations with Sludges from Metro Vancouver (Annacis Island Plant)” Disclaimer has also been added to this presentation and to the supplementary information. There has been no changes to the content of this presentation. |

Purpose and Outline

Purpose

- This document provides rheological data on wastewater treatment sludges collected at Metro Vancouver's Annacis Island Wastewater Treatment Plant

Contents

- General Sample Description and Test Matrix
- Rheology Test System and Measurement Approach
- Images of test material before and after temperature ramp
- Results
- Comparison to other data.
- Potential Additional Testing

Sample Information & Test Matrix

| | 1° Primary | 2° Secondary | 50/50 1°2° Blend |
|---|----------------|----------------|------------------------|
| Date received at PNNL | 3/30/23 | 3/30/23 | Mix prepared as needed |
| Storage before testing | Frozen | Frozen | Refrigerated |
| Sample Preparation | Needs dilution | Used as is | Mixed no dilution |
| Wt% Solids as reported by Metro Vancouver | 21.8% | 10.4% | 16.1% |
| Wt% Solids, measured at PNNL | 15.9%, 16.4% | 5.5%, 5.5% | 11.3%, 11.2%, 10.3% |
| Wt% Ash in dry solids at PNNL | 7.4%, 7.6% | 15.8%, 15.1% | 9.0%, 9.4%, 9.9% |
| Objectives for rheology data | Ratios w/ °2 | Ratios with °1 | Baseline & Comparison |
| Rheology Measurements Acquired | | | |
| Flow curve at 25 °C | TBD | Data lost | 3 runs |
| Viscosity vs. Temp | TBD | 1 run | 3 runs |
| Flow curve at 300 °C | TBD | Data lost | 2 runs |
| Flow curve after cooling to 25 °C | TBD | Data lost | 2 runs |

Rheological Characterization Methods

- Anton-Parr MCR301 bench-top rheometer equipped with a pressure cell rated to 150-bar and 300 °C coupled with a 300 °C capable electrical temperature controller.
- Loading approach, prior to measurement & heating:
 - Sample loaded into cell
 - Cell sealed
 - Head-space purged and filled with high-purity N₂ to an overpressure of 19.3 bar (~280 psig)
- Overpressure was maintained and monitored for leaks for the duration of rheometric characterization and heating to ensure the sample remained in a condensed state.



Rheological Characterization Approach

- The specific measuring routine employed for each sample included:
 - Flow curve spanning shear rates from 0 to 1000 s⁻¹ at 25 °C for both the up and down ramps
 - Temperature sweep spanning 25 to 300 °C at a fixed shear rate (50 s⁻¹)
 - Flow curve measurement (again over 0 to 1000 s⁻¹) at 300 °C
 - Post temperature treatment flow curve (again over 0 to 1000 s⁻¹) at 25 °C
- Four steps outlined above were performed on the same sample aliquot
- Each flow curve consisted of three segments: a 5-minute up ramp over 0 to 1000 s⁻¹, a 60 second hold at 1000 s⁻¹, and a 5-minute down ramp from 1000 to 0 s⁻¹

Primary Sludge

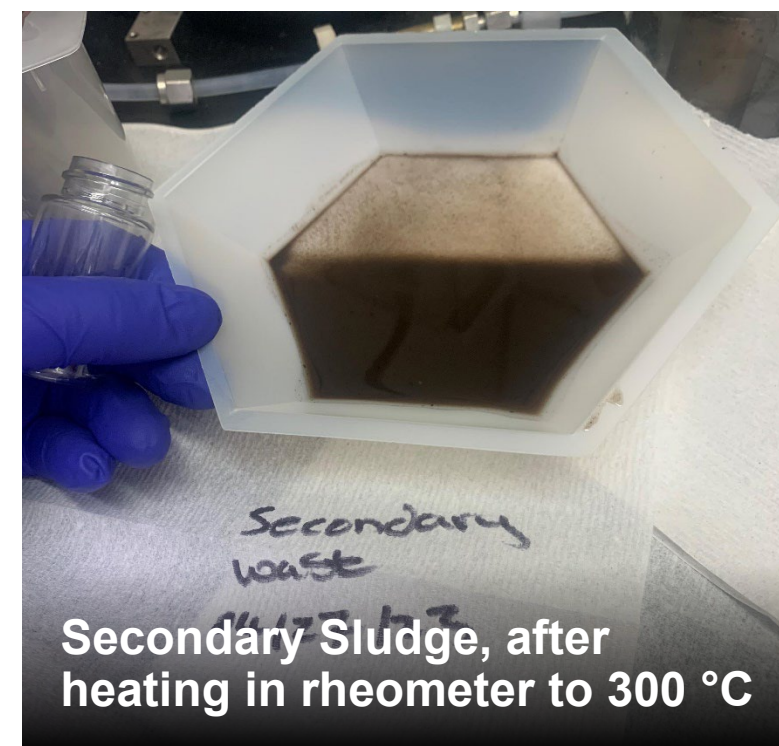
- Could not load into cell (no flow), will need to dilute and measure later.
- Samples need to yield to the measuring geometry as it is inserted into the sample for a successful measurement.
- If sample dewateres with applied pressure it cannot be loaded into the pressure cell.



Too thick to load into pressure cell without some dilution and perhaps formatting

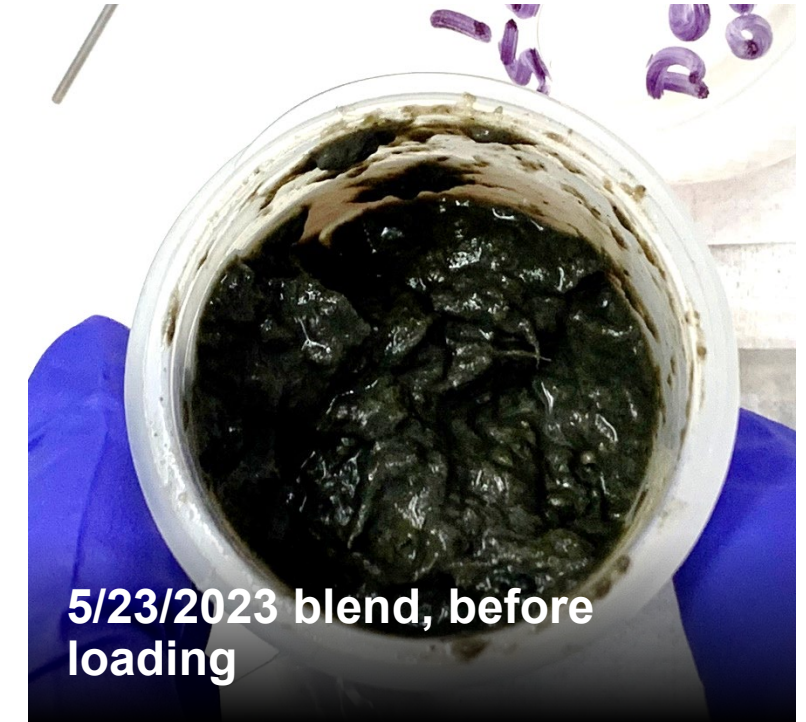
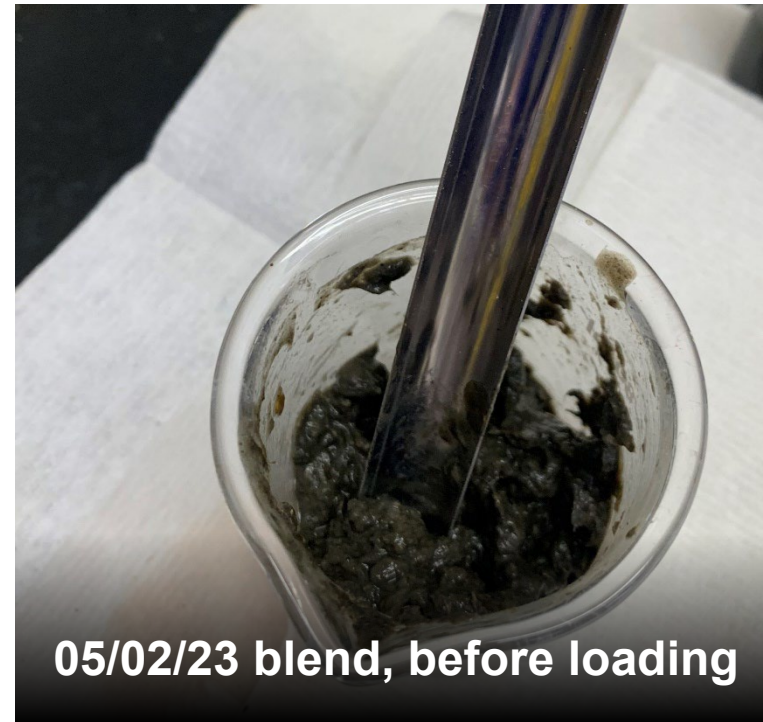
Secondary Sludge

- Slurry was relatively thin, free flowing pourable in its as received state.
- Viscosity was less than 10 cp (observed while measuring).
- Post temperature ramp the sample was water like.



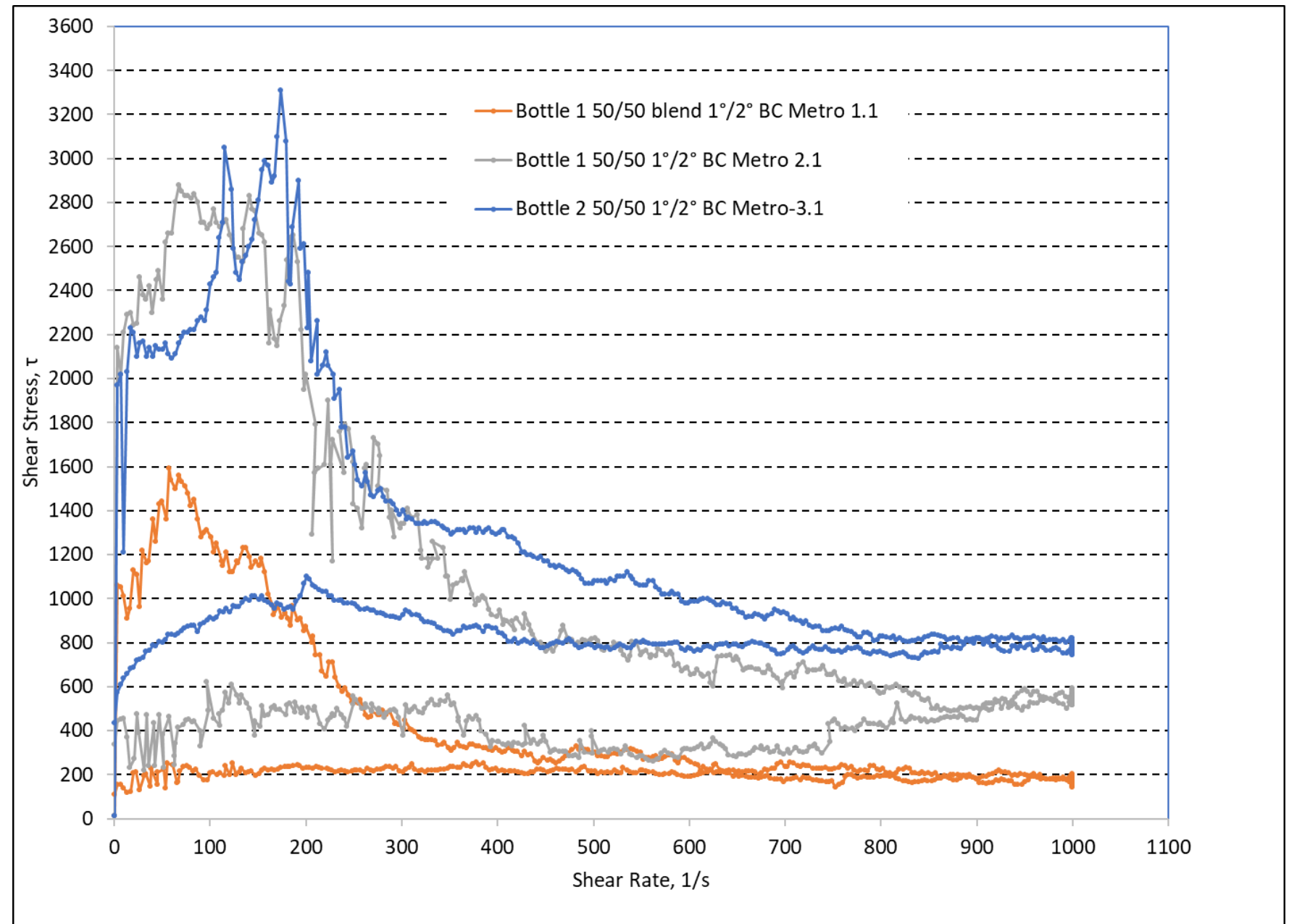
50/50 Mix of Primary and Secondary

- 50/50 blend gave a pumpable slurry, no dilution required
- Some tar & chunks observed after temp ramp to 300 °C
- Flow curve at temp and after cool down may have been affected by chunks



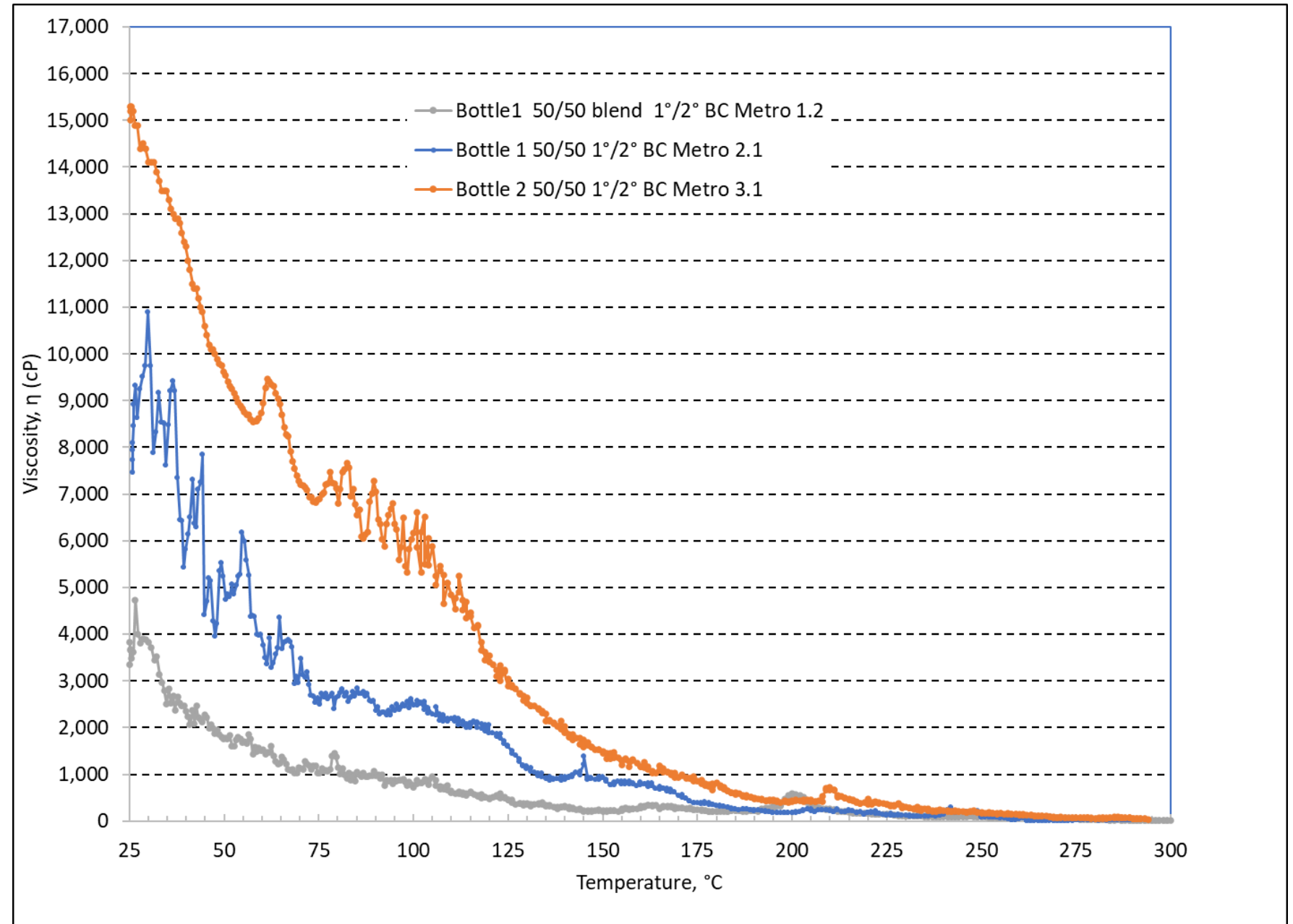
Flow Curves at 25 °C for 50/50 primary/secondary

- Flow curves, prior to temp ramp
- Flow curves were done with blends made from different sample bottles provide by Metro Vancouver
- Curves include up ramp and down ramp

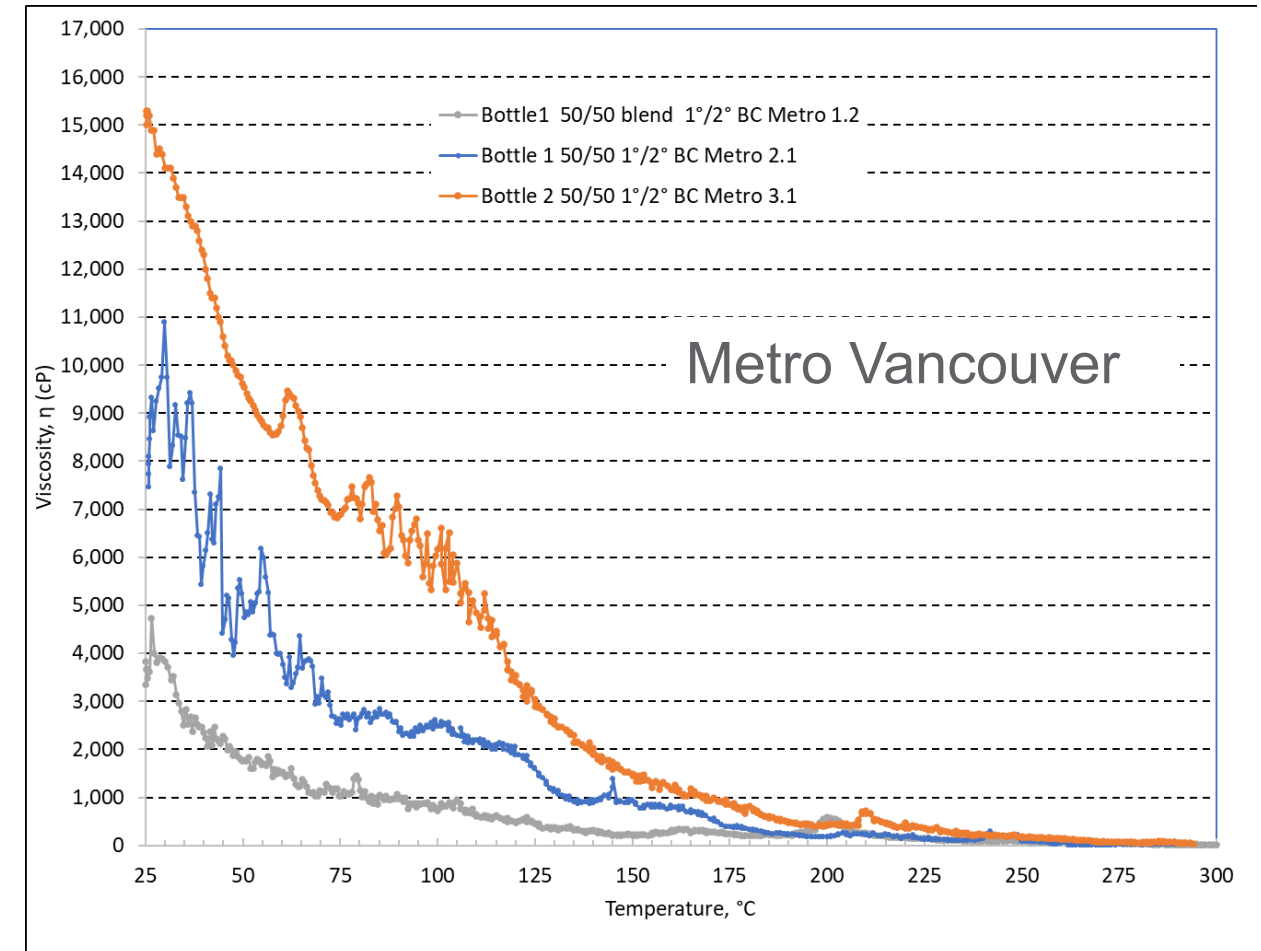
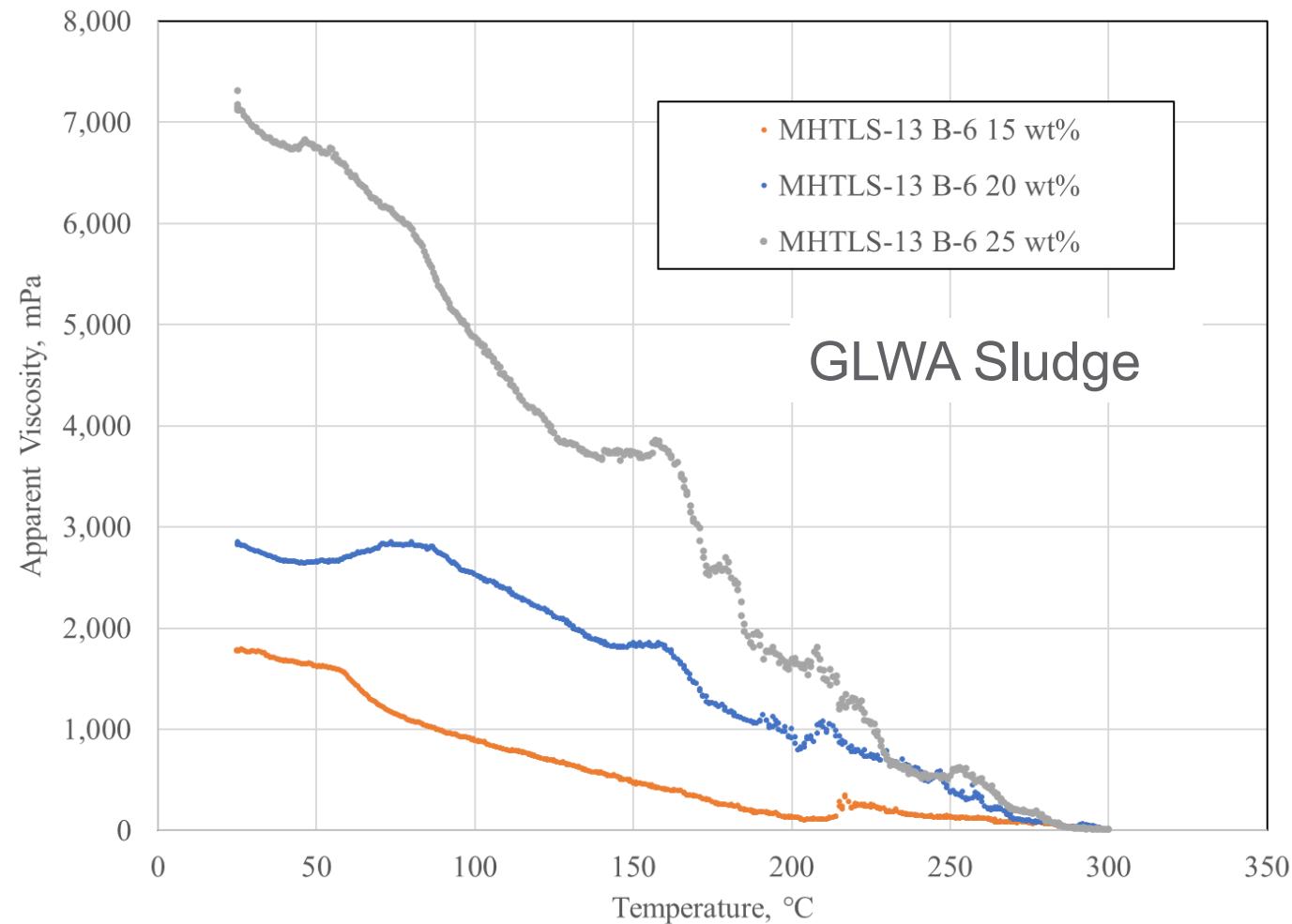


Temperature Ramp with 50/50 Blend

- 3 temperature ramp rheology trails with 50/50 blends.
- Constant shear rate at 50 1/s
- Viscosity drops rapidly by 150 °C
- By 250 °C, viscosity has dropped to ~80 cP for runs 1 and 2, and below 200 cP for run 3



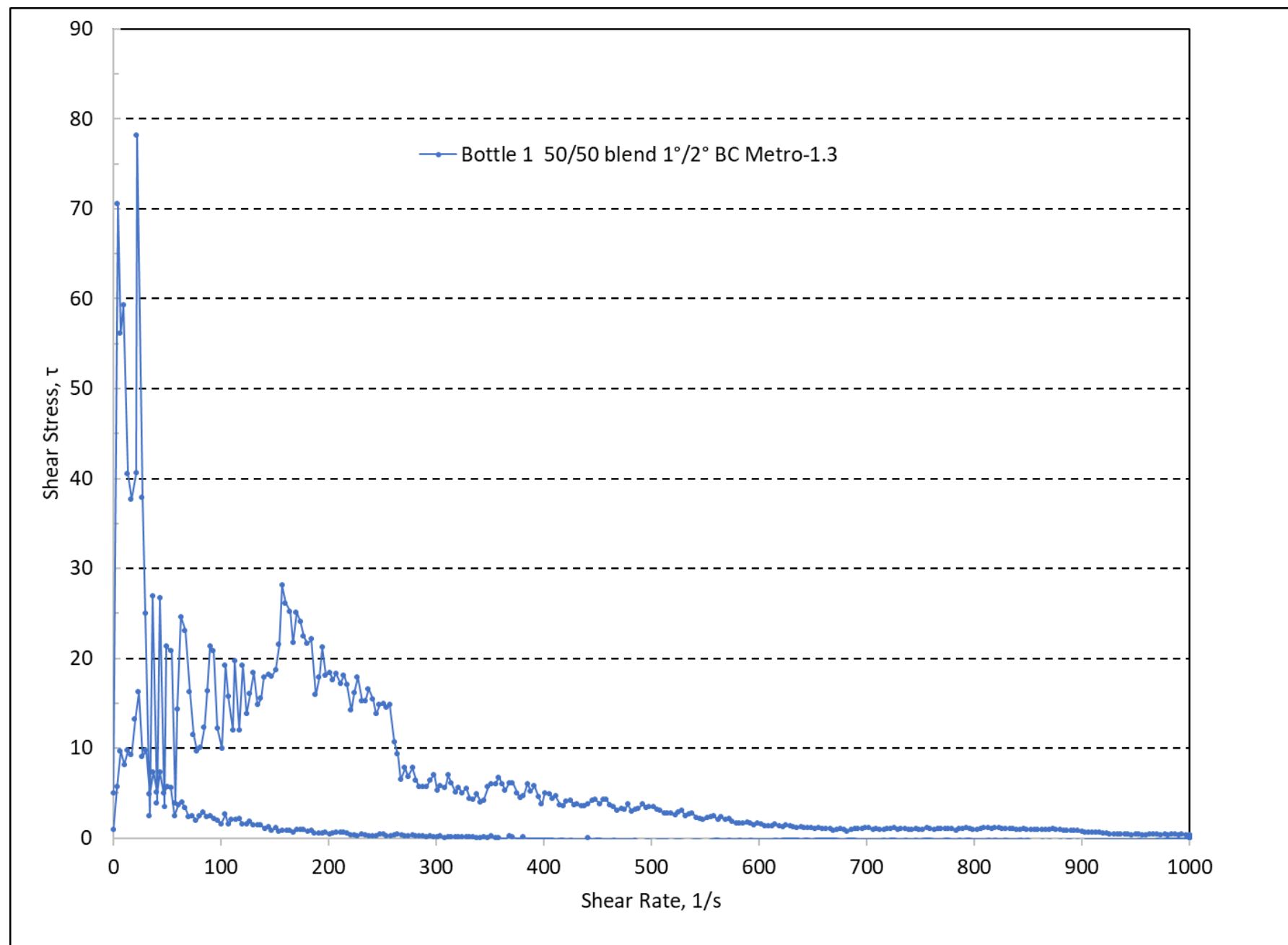
Comparison of Metro Vancouver Sludge to Sludge from GLWA



- The temperature ramp behavior of sludges of 50/50 sludge from Metro Vancouver is similar to that of the mostly primary sludge from Great Lake Water Authority

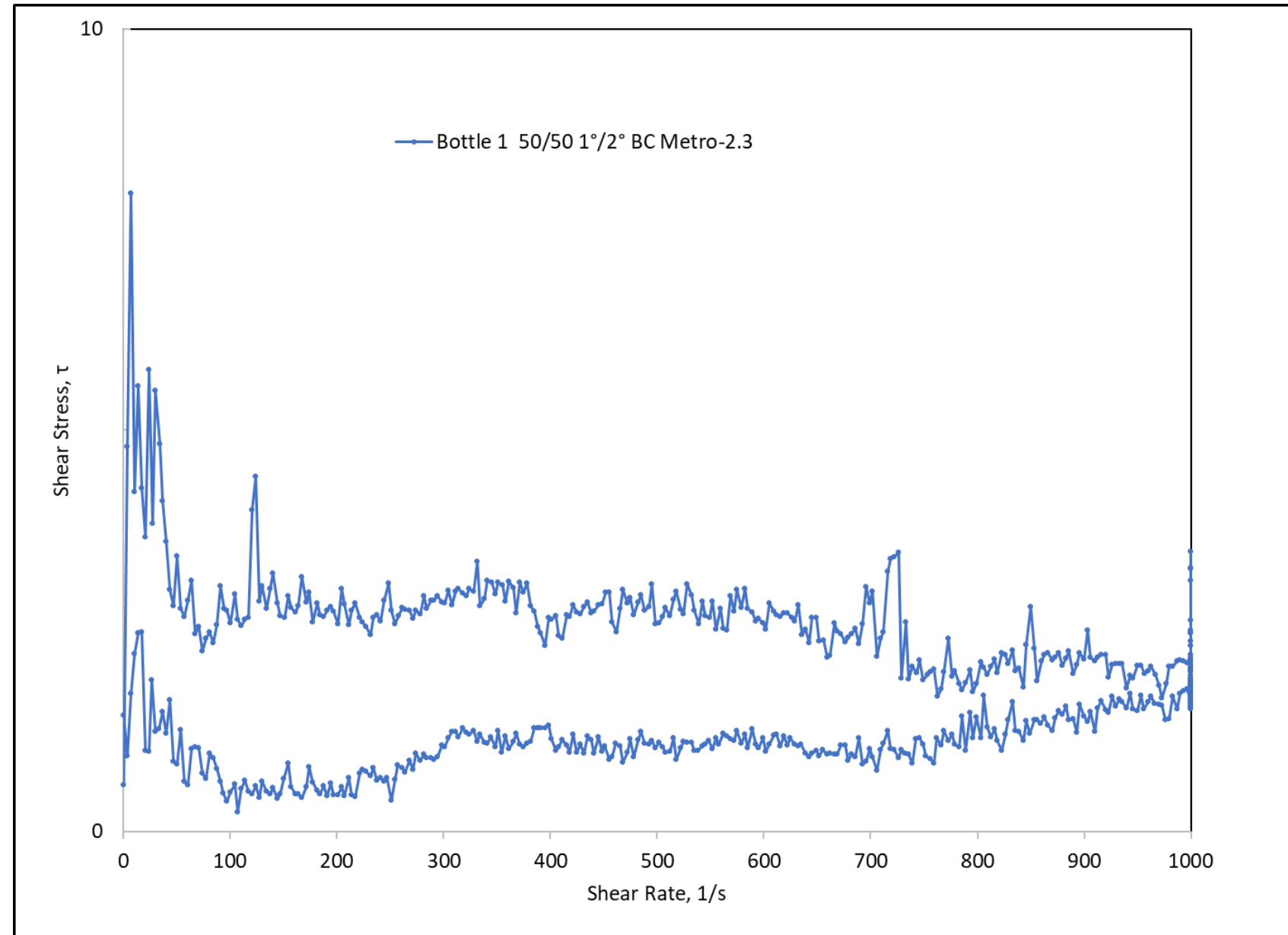
Flow Curves at 300 °C for 50/50 primary/secondary

- Run 1
- At 300° C, post temperature ramp, most of the sludge like structure is gone (see images).



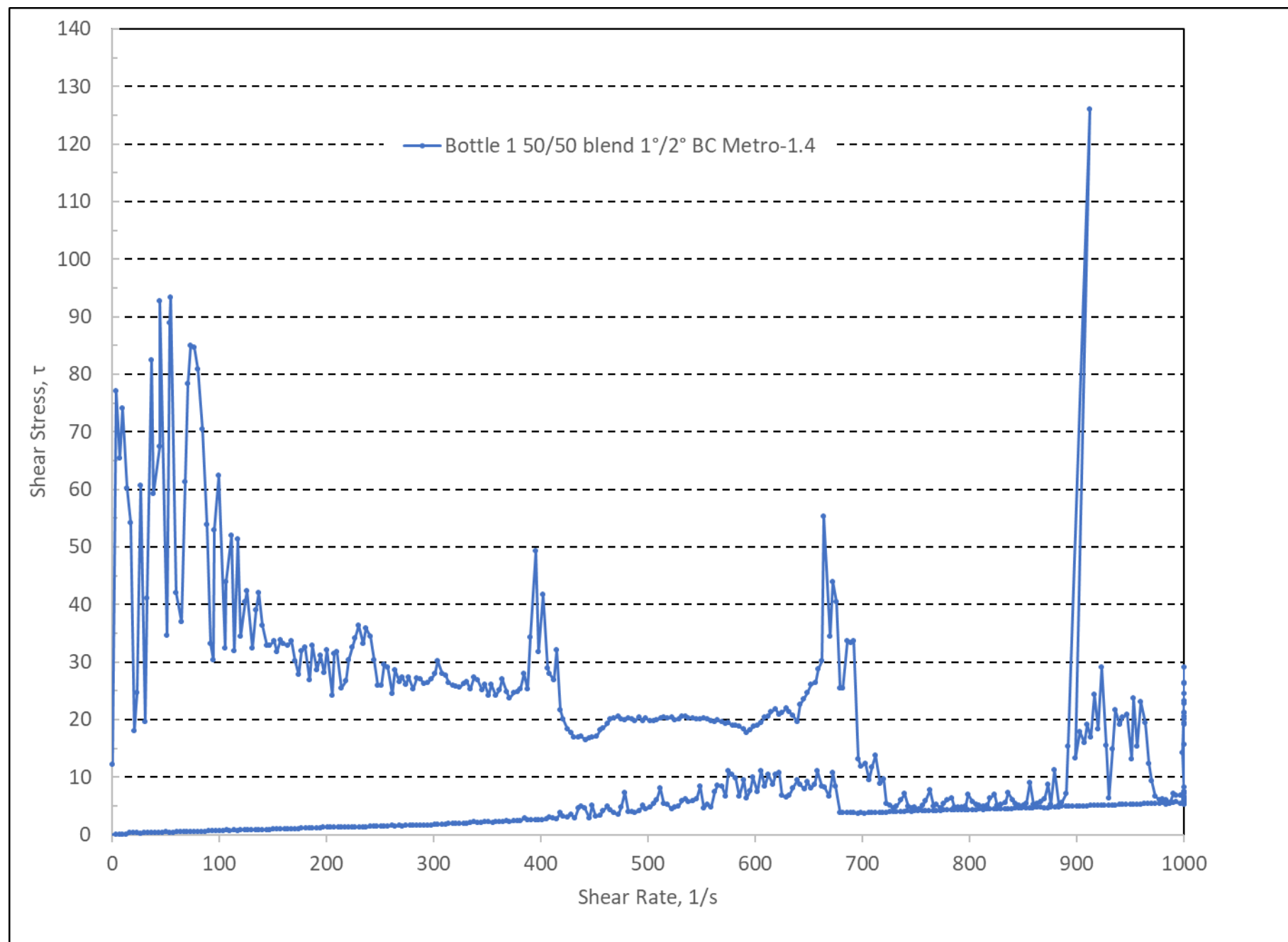
Flow Curves at 300°C for 50/50 primary/secondary

- Run 2
- At 300 °C, post temperature ramp, most of the sludge like structure is gone (see images).
- Note shear stress scale.



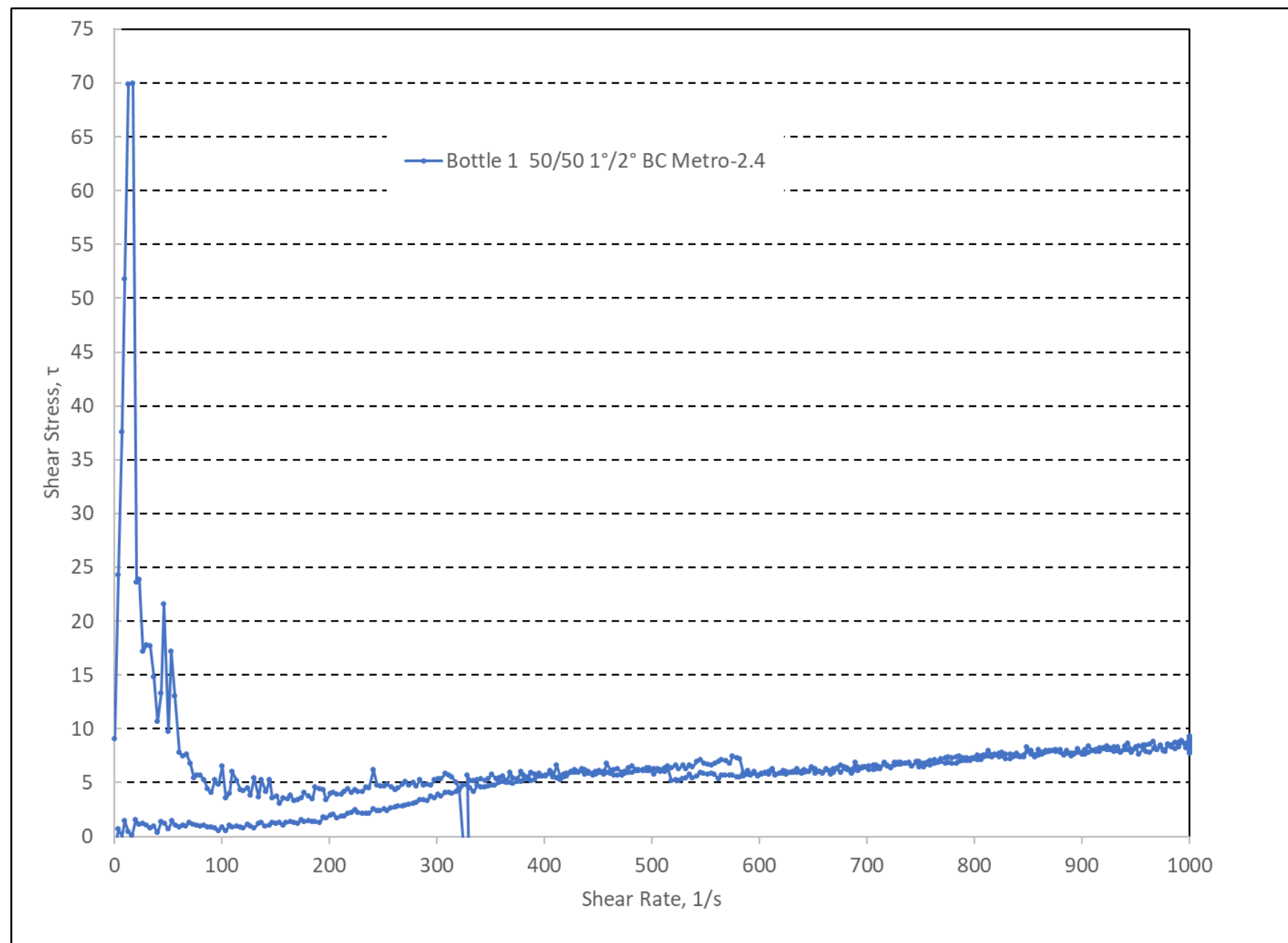
Flow Curves at 25° C, AFTER temperature ramp, 50/50 primary/secondary

- Run 1
- After temperature ramp, and cooling back to 25 °C, most of the sludge-like structure is gone (see images).



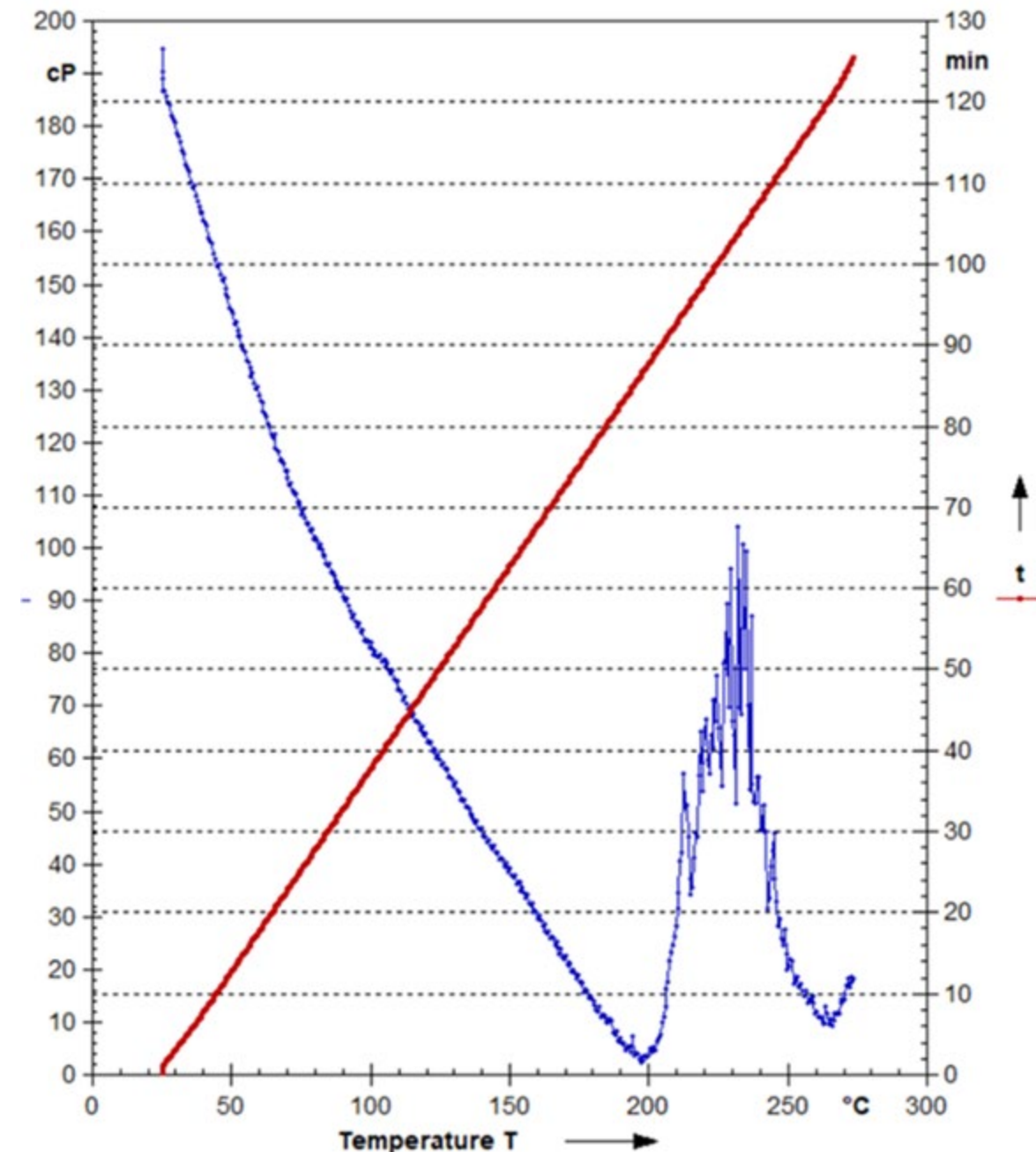
Flow Curves at 25C, AFTER temperature ramp, 50/50 primary/secondary

- Run 2
- After temperature ramp, and cooling back to 25 °C, most of the sludge like structure is gone (see images).



Temperature Ramp with Secondary Sludge

- At room temp, viscosity of secondary sludge very low, and dropped to ~2 cP at 200°C.
- Cause of increase between 200°C and 260°C not understood. Could be real, could be particulate, or could have been bearing failure at 200°C
- Data from pretest flow curve lost. Post treatment flow curve looked like water (no remaining structure).



Considerations and Future Options

- Multiple equipment failures occurred during measurements.
 - 3 bearings failed – cause is uncertain
 - Computer failed, losing data on secondary sludge
- Frozen sludge from batch received on 3-30-23 was archived and is available
 - Wt% solids between Metro Vancouver and measured by PNNL differed significantly
 - For measurements on primary sludge, proceed with sample on hand (dilute and measure, or start with new samples?)

Thank you