NEWEA-NEBRA Specialty Conference 2019

Using Sludge Rheology in Solids Systems Design, Planning, and Operation

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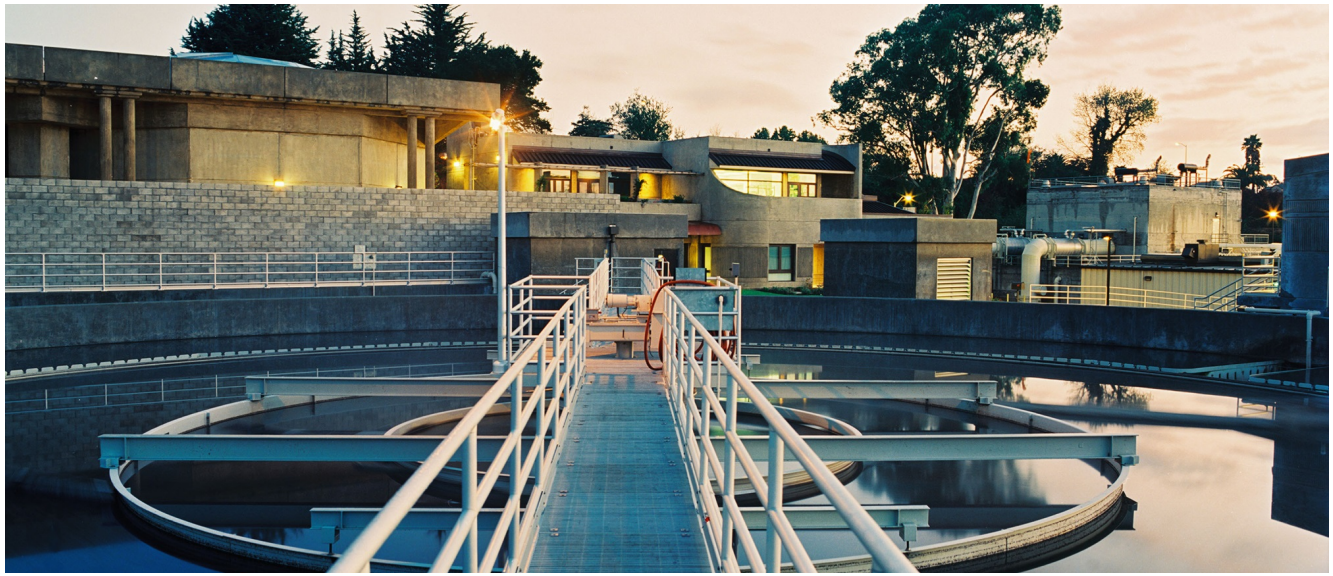


Overview

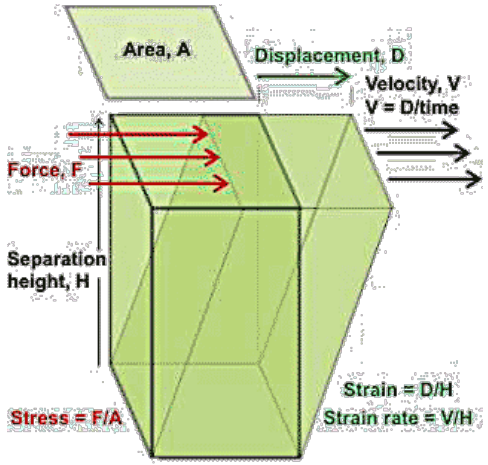
- Rheology basics
- Measuring rheology
- Factors that affect rheology
- When to measure rheology
- Implementing rheological data

Have you ever . . .

- video of overflowing digester

Rheology Fundamentals

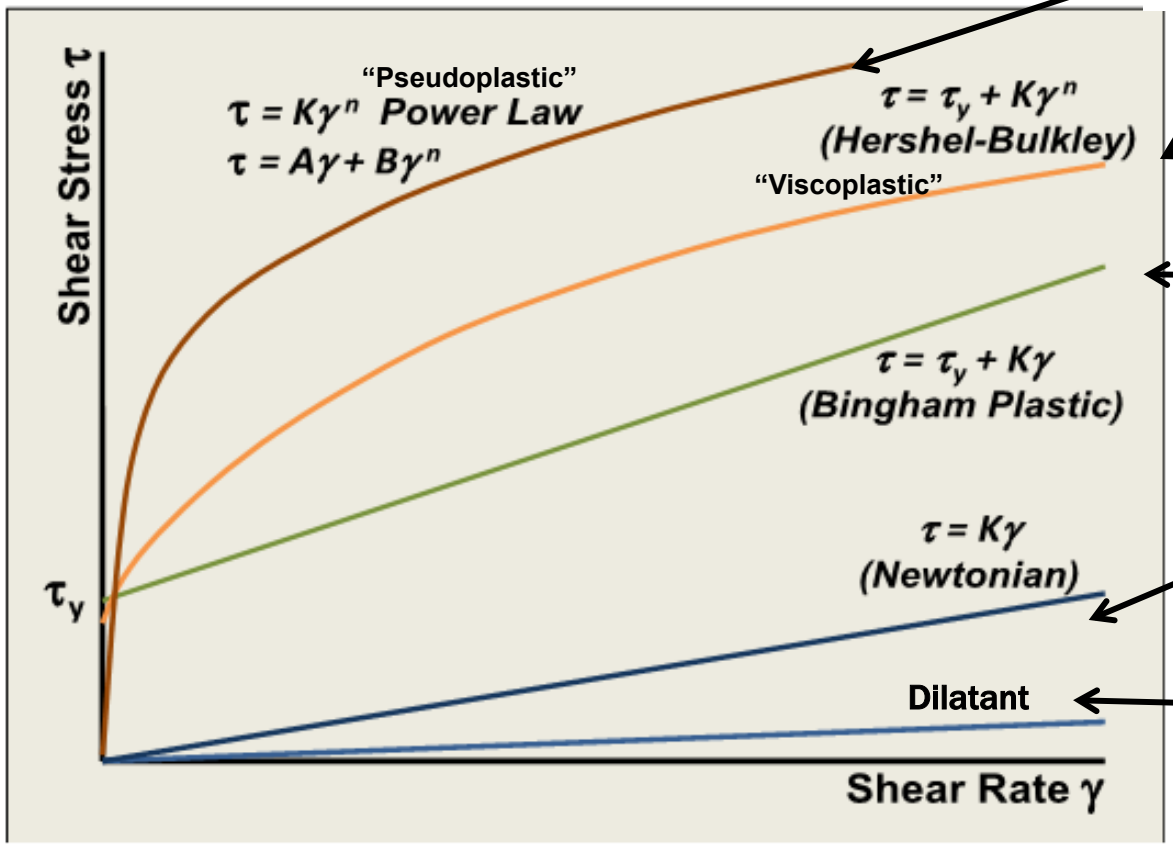
- video of different fluids' viscosities

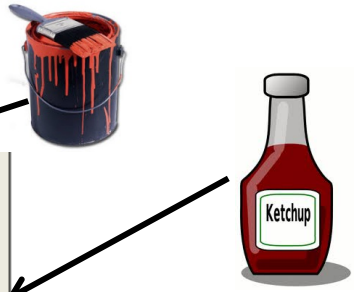


The Sci Guys: https://www.youtube.com/watch?v=f6spBkVeQ4w

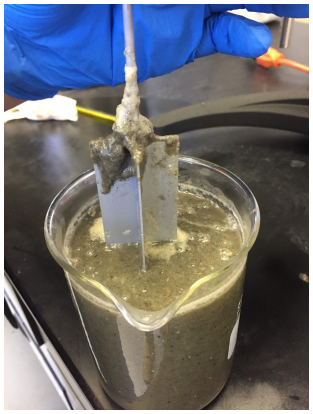
http://www1.lsbu.ac.uk/php-cgiwrap/water/pfp.php3?page=http://www1.lsbu.ac.uk/water/rheology.html

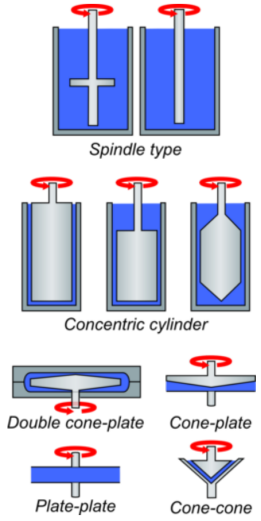
Rheology is going to matter in our new processes and efficient designs





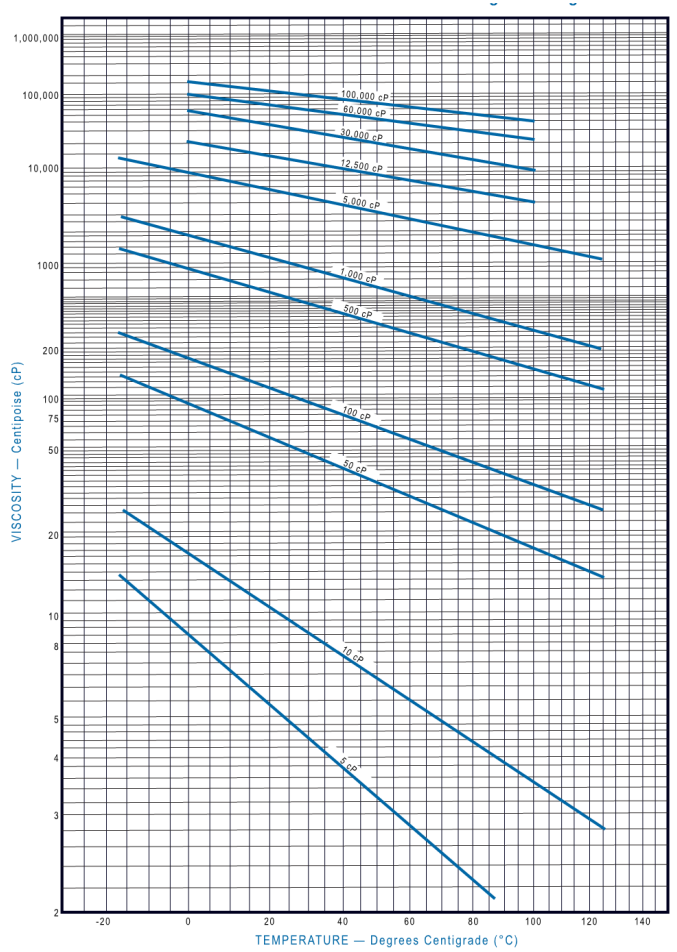
How to measure rheology?





Effects of temperature

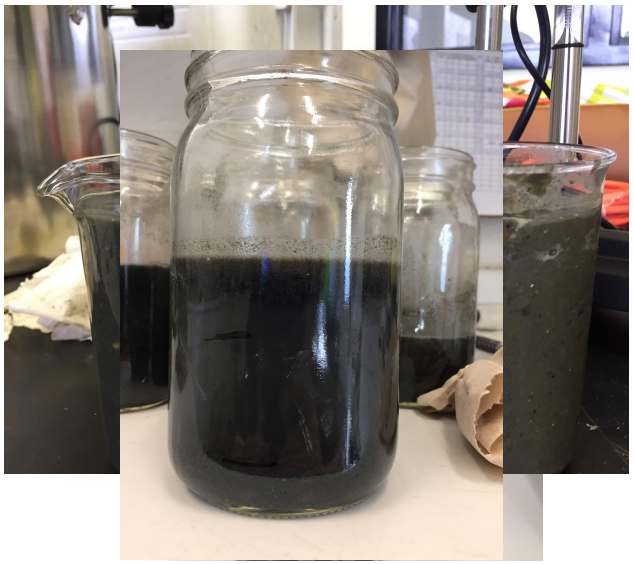
- As temperature increases viscosity decreases

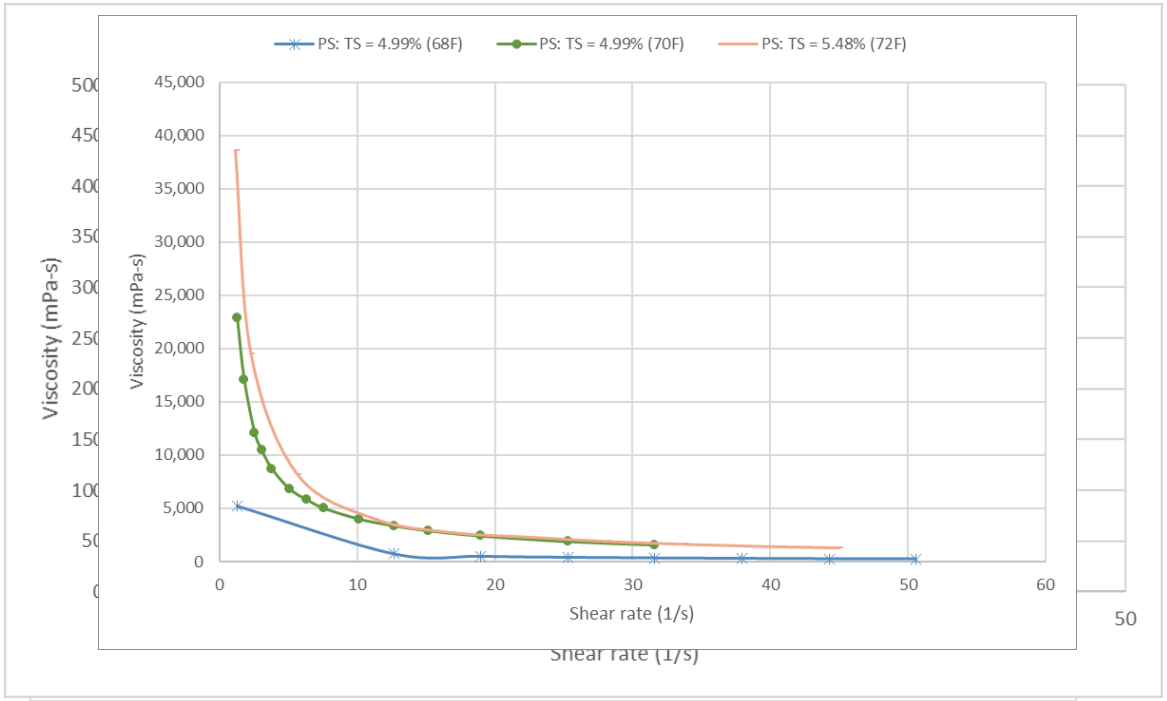


Brookfield

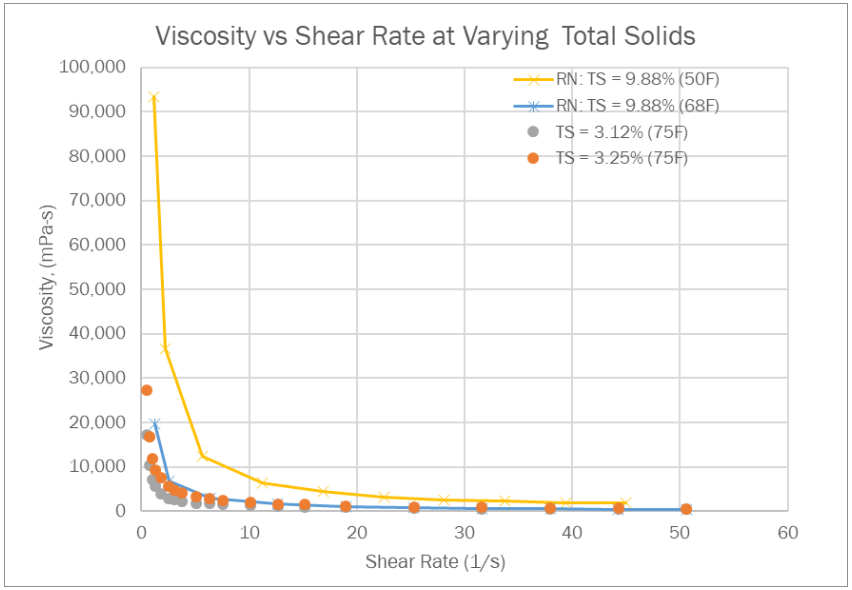
Factors that influence sludge rheology

- Temperature
- Solids content





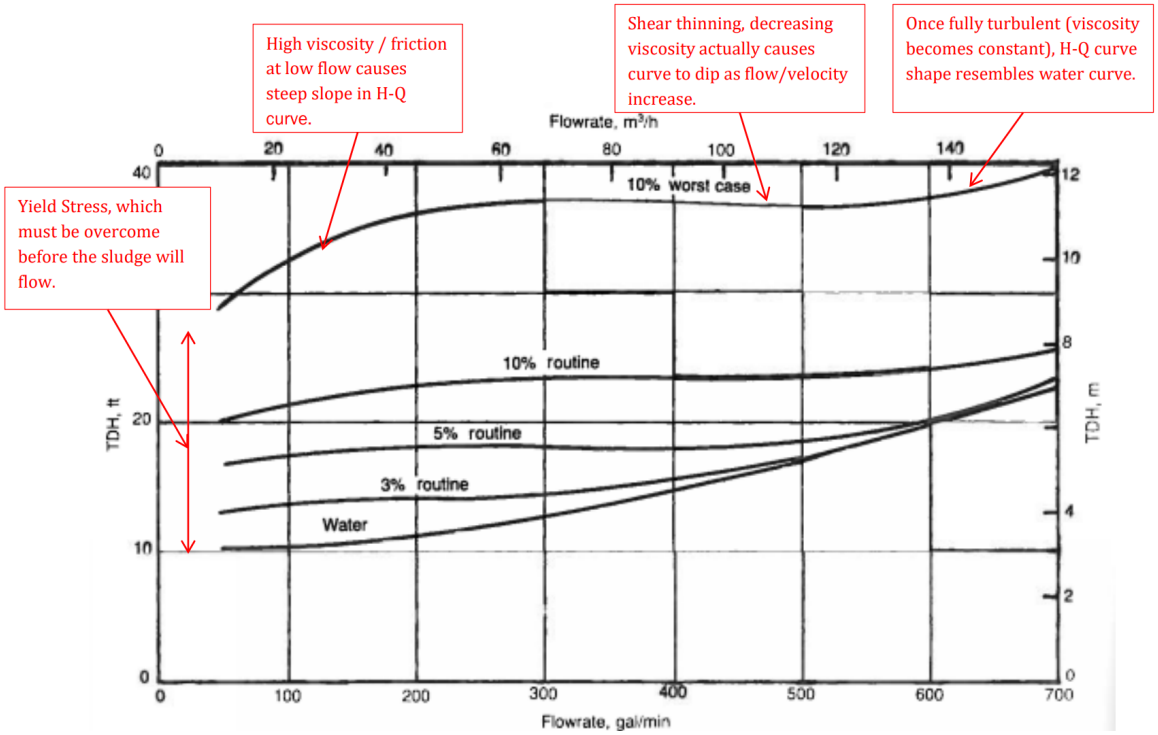

600mL
PYREX®
500 mL


Viscosity vs Shear Rate at Varying Total Solids
RN: TS = 9.88% (50F)
RN: TS = 9.88% (68F)
TS = 3.12% (75F)
TS = 3.25% (75F)
Viscosity, (mPa-s)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
10
20
30
40
50
60
Shear Rate (1/s)

When to do Rheology Testing?

- Pumping design
  - Especially for really thick or unusual sludge characteristics where data isn't available.
- Mixing designs
  - Confirm how much energy is needed and if the sludge will mix

What does that look like on system curve?



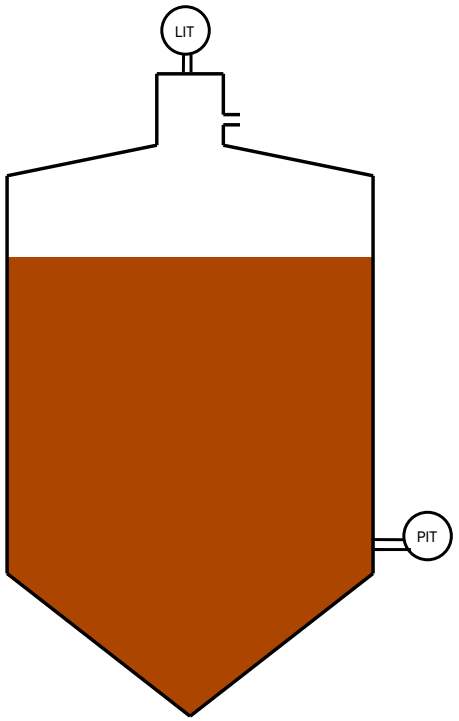
Digester Sludge Rheology and RVE - No Mixing

Brown AND Caldwell

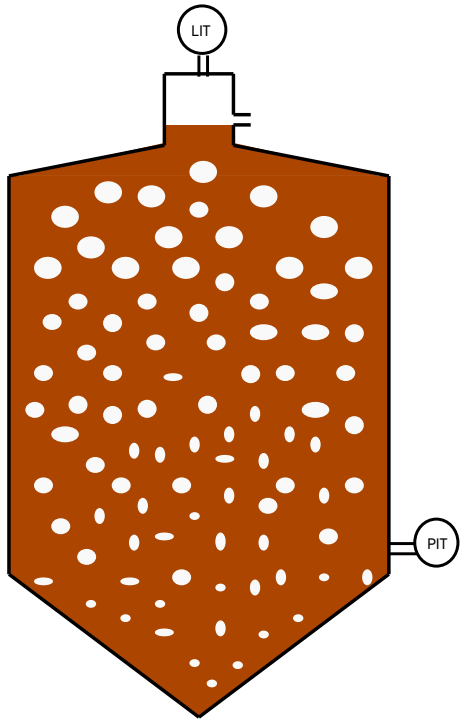
Rapid Volume Expansion (RVE) Definition

- A rapid change in liquid volume driven by a sudden change in conditions of gas holdup, the volume of gas retained within a volume of liquid
- Rapid rise or fall of tank level can occur

The Principle of Gas Holdup



NO GAS



WITH GAS

Biogas bubbles overcoming yield stress

Rapid Volume Expansion (RVE) most severe without mixing

Gas holdup and RVE are most severe when mixing stops

In the absence of mixing, digester sludge exhibits a yield stress (force)

Therefore,

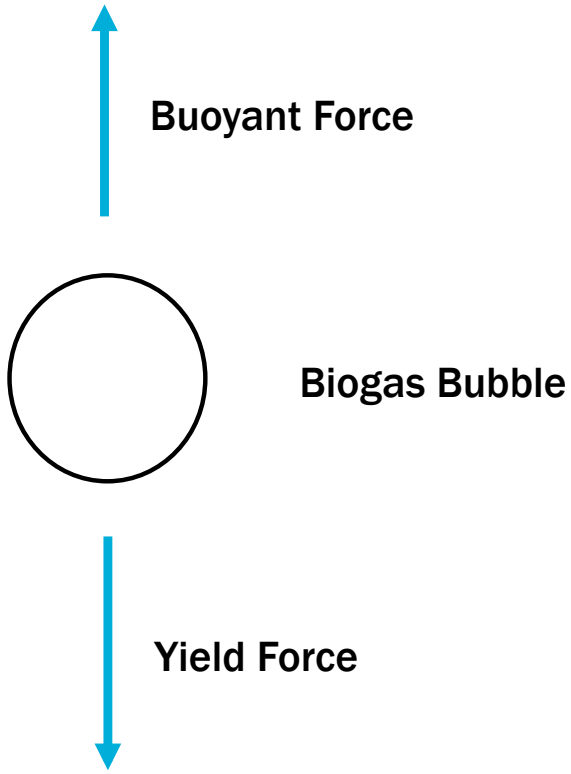
- Biogas bubbles must generate a buoyant force to overcome the yield force (function of yield stress)

Otherwise:

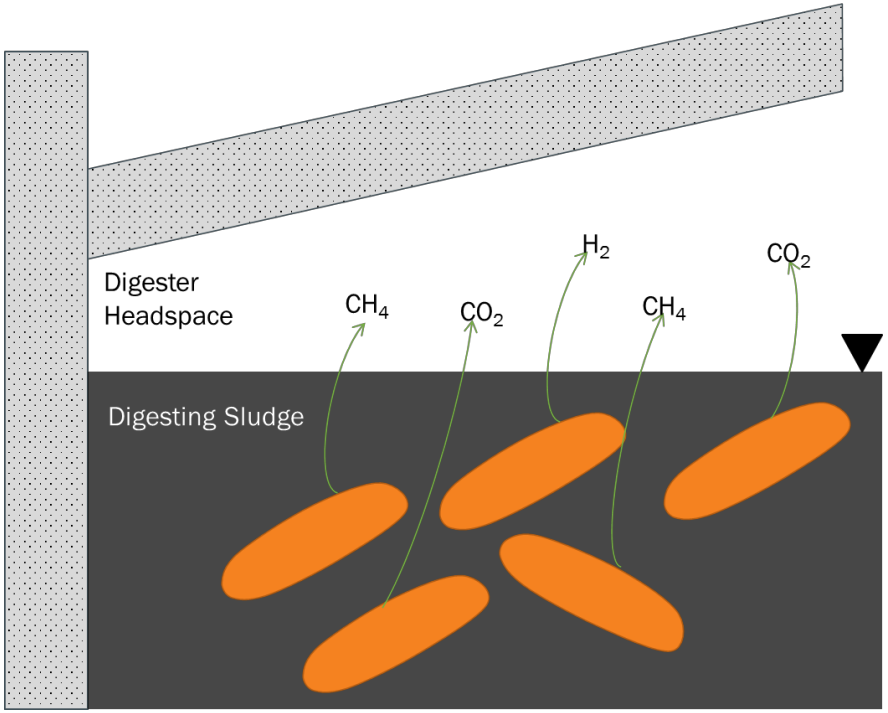
- Biogas bubbles will remain in suspension
- Biogas bubbles will continue to grow and remain in suspension
- Digester contents will expand

Until

- Biogas bubbles grow to a sufficient size to escape suspension
- Or, mixing is restored



What does volume expansion look like in real life

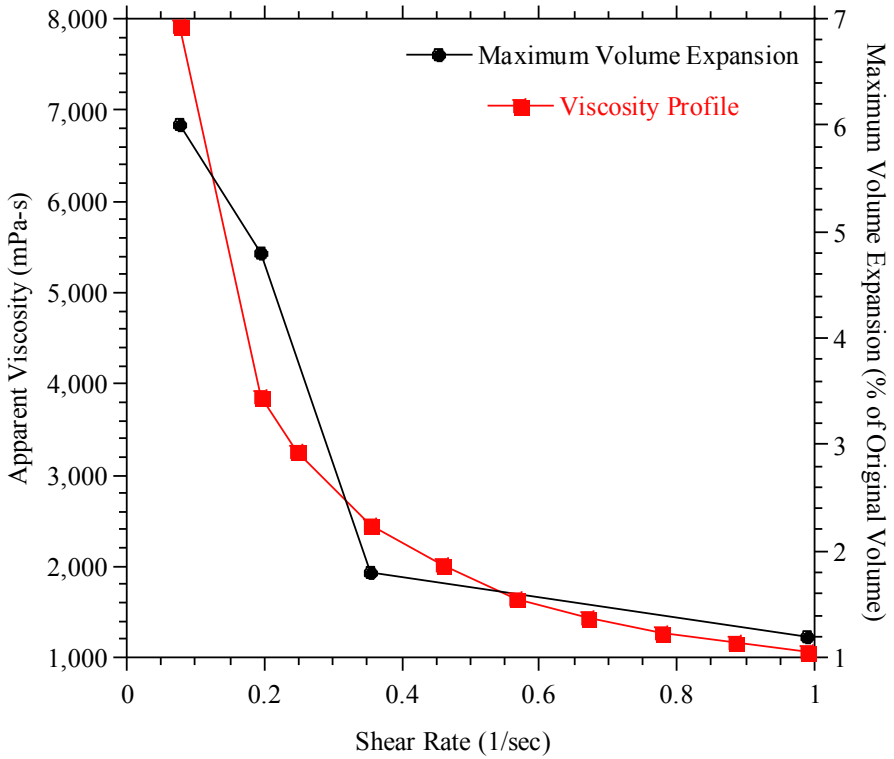


- video of overflowing digester

Viscosity and max extent of RVE trend

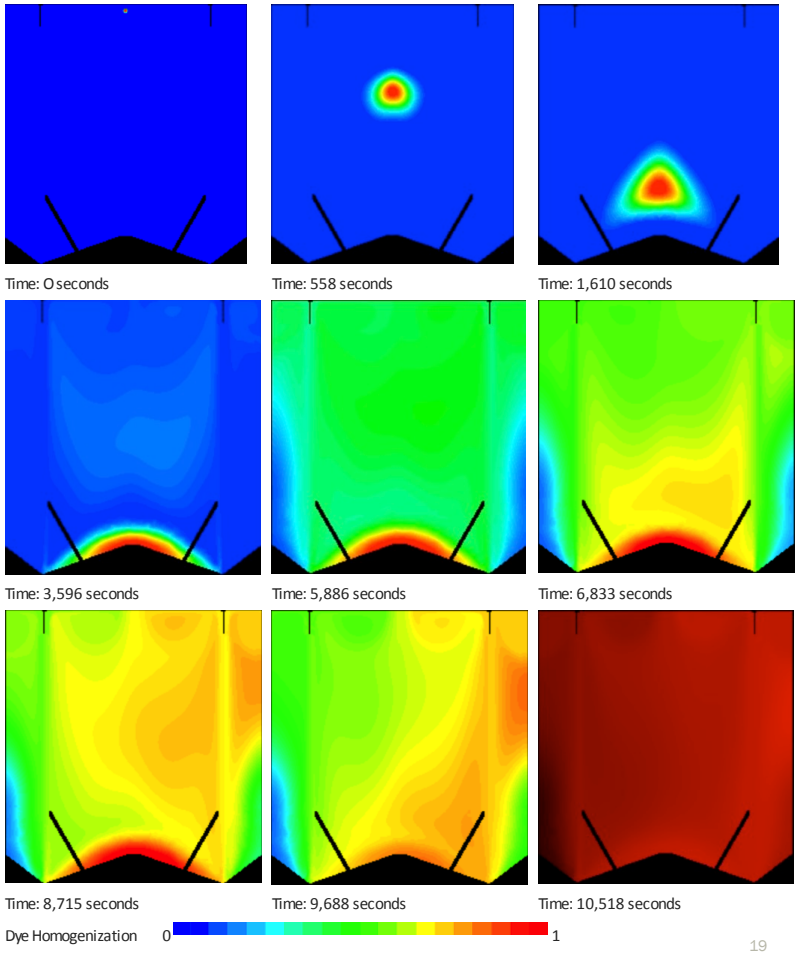
Main observations:

- Viscosity and maximum extent of RVE follow a similar trend
- Small increases in mixing result in significant decreases in sludge viscosity
- Small decreases in sludge viscosity result in significant increase in bubble rise velocity
- Increases in bubble rise velocity result in less gas holdup and RVE



Feed dispersion modeling

- Using shear stress data from viscosity testing, demonstrates that mixing is not “complete mix” (i.e. instantaneous Incorporation)
- Comparison
  - Design Criteria= 1 hour turn over
  - Modelled Result= 2.92 hours



Things to think about . . .

- Common sludges like raw, or digested, less than 5-6% TS – “textbook” or simplified approaches likely OK.
- If data exists for a “similar” sludge use it with caution.
  - KNOW your sludge
- Hydraulic modeling software come with sludge correction/rheology models – apply with engineering judgement (do some homework on limitations/ applicability).

Summary

- Sludge is shear thinning, non-Newtonian
- In digesters with low or no mixing, rapid volume expansion can occur
  - Mixing decreases viscosity, reduces trapped gas bubbles
- Increased viscosity = decreased heat transfer
- Yield stress can influence pump size, which influences pipe selection

Thank you! Any Questions?

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Brown AND Caldwell

Rheology basics

- Rheology is the study of the flow of matter, particularly liquid or semi-solids materials.
- Viscosity is how quickly material moves or resistance to flow
  - High viscosity – slow moving
  - Low viscosity – fast moving
- Newtonian – viscosity constant, independent of shear rate
  - water, milk, oil

Rheology basics (Cont'd)

- Non-Newtonian - viscosity not constant with change in shear rate
  - Ketchup, sludge, yogurt, toothpaste
- Shear rate is the resulting velocity gradient when shear force is applied
- Shear-thinning: viscosity decreases as shear-rate increases.
- Shear-thickening: viscosity increases as shear-rate increases.
- Yield Stress: minimum amount of force (shear) applied to initiate flow.

Simplified biogas balance

To prevent gas holdup and RVE:

Rate of bubble nucleation and growth **=** Rate of bubble rise and evolution into headspace

IF

Rate of bubble nucleation and growth **>** Rate of bubble rise and evolution into headspace → **Gas Holdup and RVE!**