

# Maximizing Polymer Value for Improved Sludge Dewatering

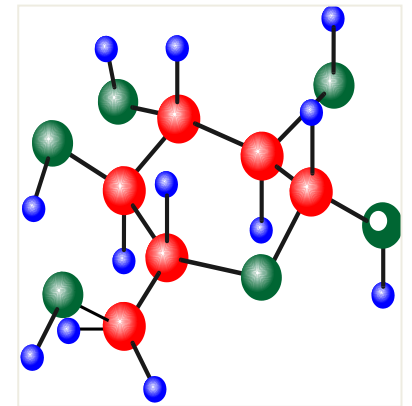
**Yong Kim, Ph.D.**

Technical Director

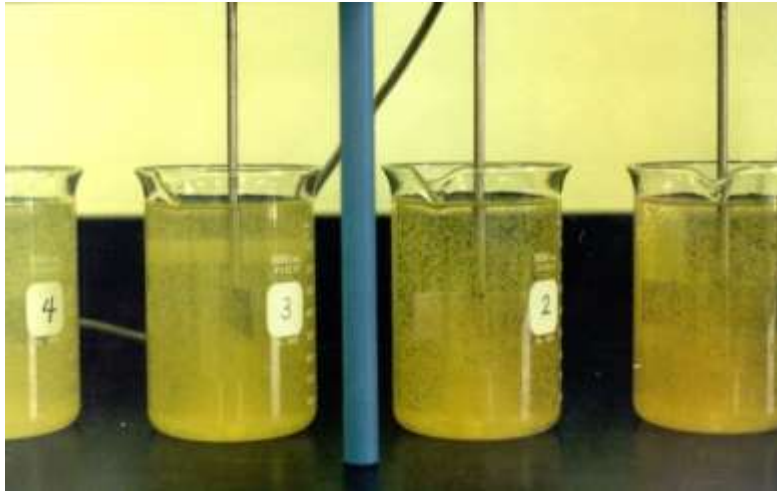
UGSI Chemical Feed, Inc.

# Presentation Overview

- Characteristics of Polymer
- Effect of Dilution Water Chemistry
- Effect of Mixing Energy/Strategy
  - Two-stage Primary Mixing
  - Primary Mixing then Post-Dilution
- Case Study at Fairfield WWTP

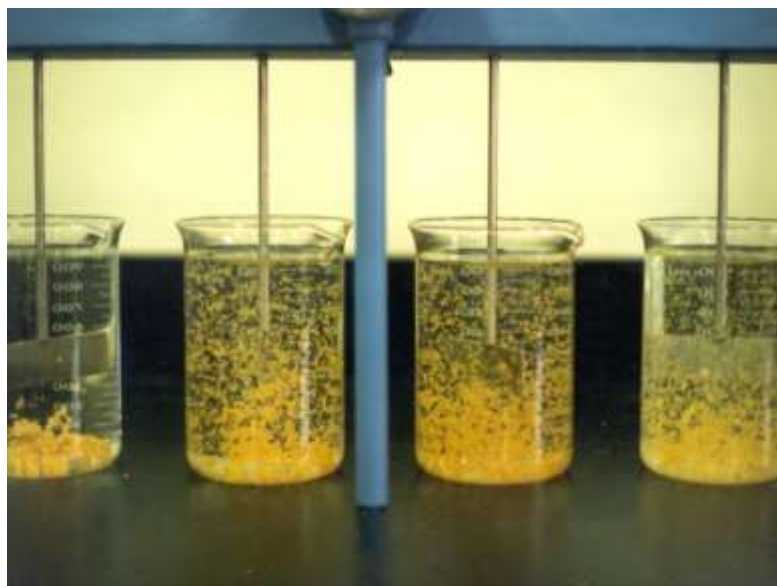


# Coagulation and Flocculation



## Coagulation

- Double-layer compression (charge neutralization)
- Enmeshment (sweep coagulation)
- Clay suspension + Ferric chloride (40 – 120 mg/L)

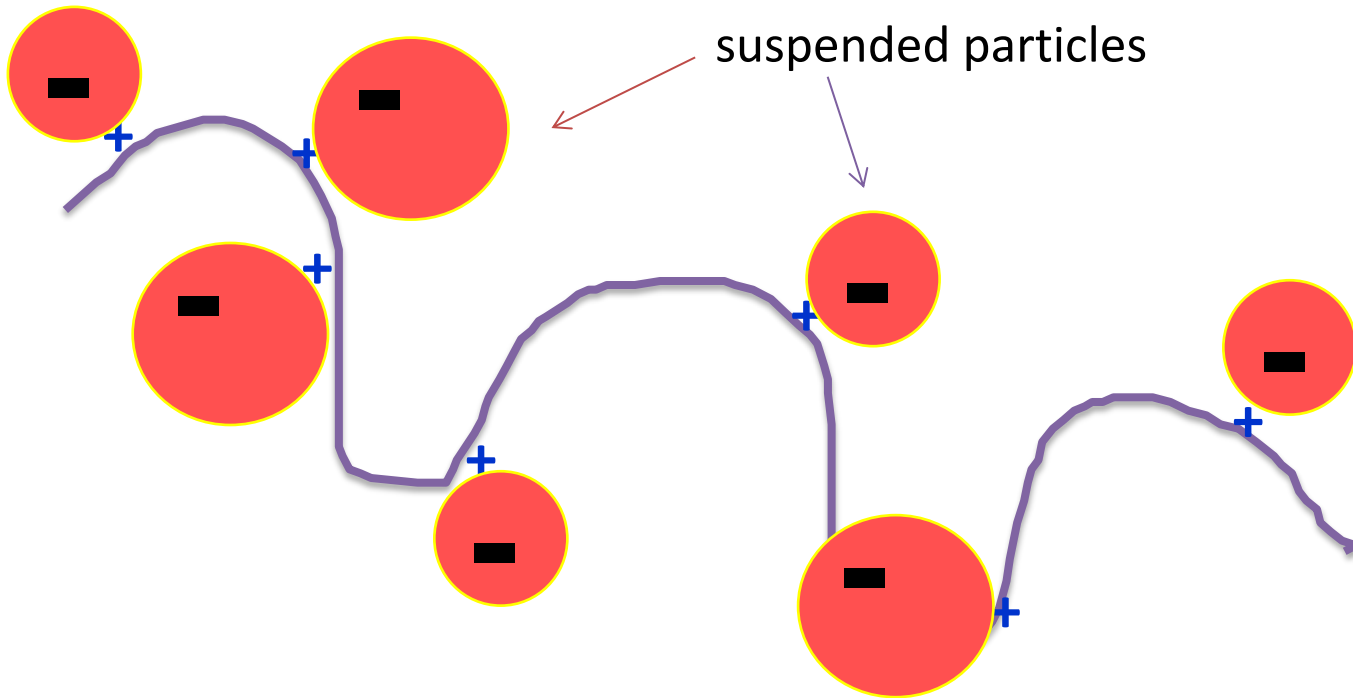


## Flocculation

- Polymer Bridging
- Clay suspension + Ferric chloride + Polymer (< 1.0 mg/L)

# Flocculation - Bridging by Polymer Molecules

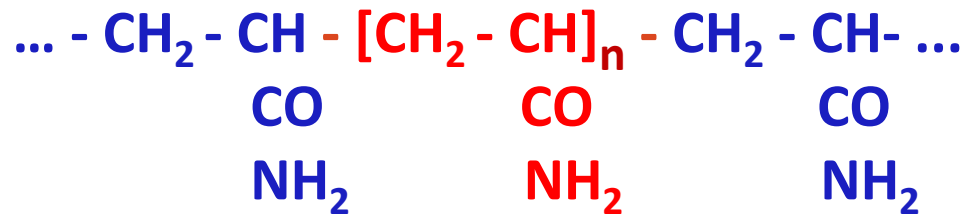
Extended cationic polymer molecule attracts negatively-charged suspended particles.



How to prevent long-chain polymer molecules from being damaged?

# Polymer Structure

- Polymeric Flocculant, Linear Polymer, Polyelectrolyte
- Chained Structure by Repetition of Monomers



Most polymers in water industry are acrylamide-based.

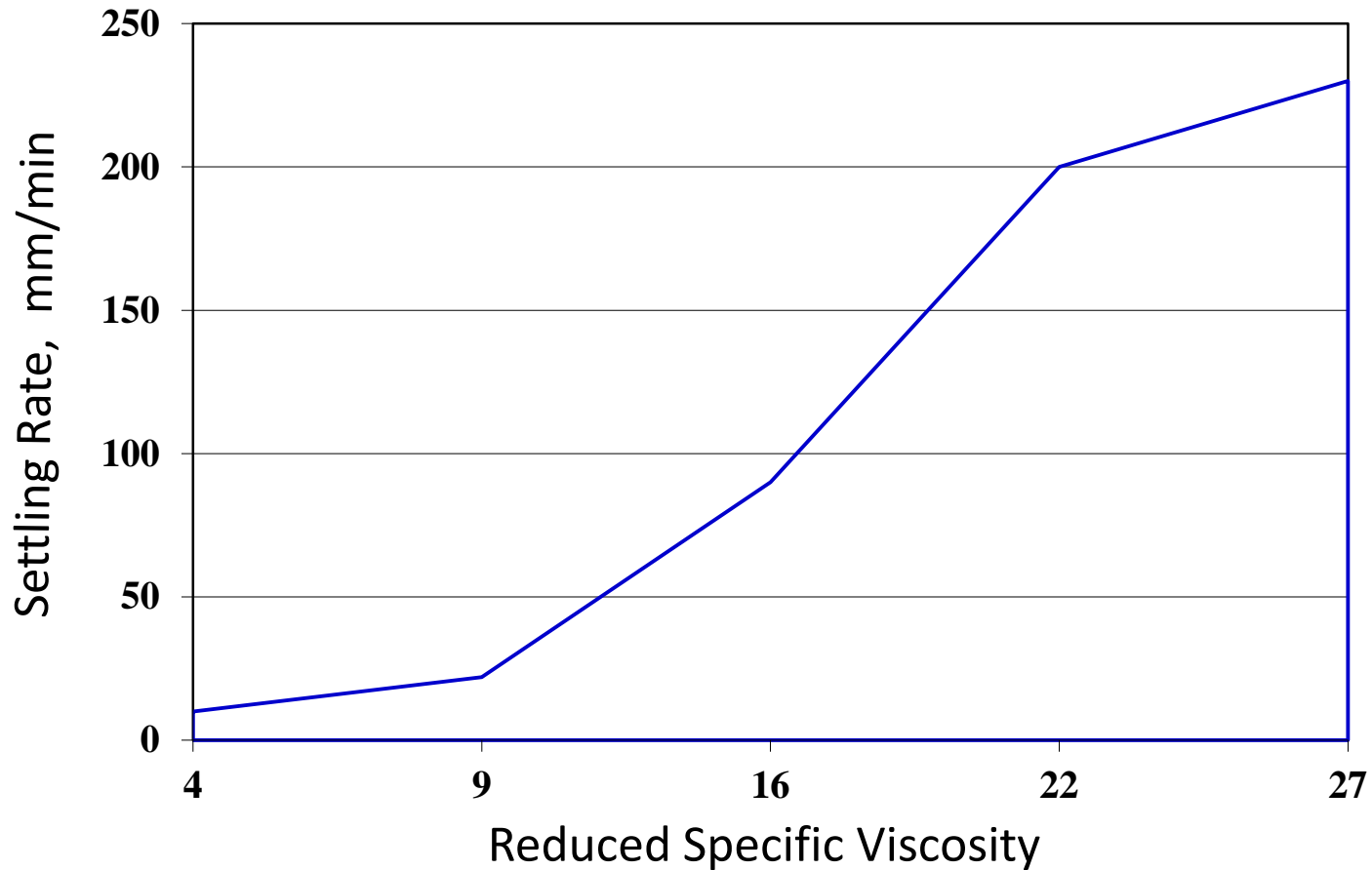
If molecular weight of polymer is 10 million,  
the number of monomers in one polymer molecule, “*degree of polymerization*”

$$\begin{aligned} n &= 10,000,000 / 71 \\ &= 140,850 \end{aligned}$$

(mol. wt. of monomer, acrylamide = 71)



## Measure of Polymer Activation - Polymer Solution Viscosity



Sakaguchi, K.; Nagase, K., Bull. Chem. Soc. Japan, 39, p.88 (1966)



# Effect of Dilution Water Quality on Polymer Activation

**Ionic strength (Hardness):** multi-valent ions; adverse effect

- Soft water helps polymer molecules fully-extend faster
- Hardness over 400 ppm may need softener

**Oxidizer (chlorine):** detrimental to polymer chains

- Should be less than 3 ppm

**Temperature\*:** higher temperature, better polymer activation

- In-line water heater for water lower than 40 °F
- Water over 100 °F may damage polymer chains

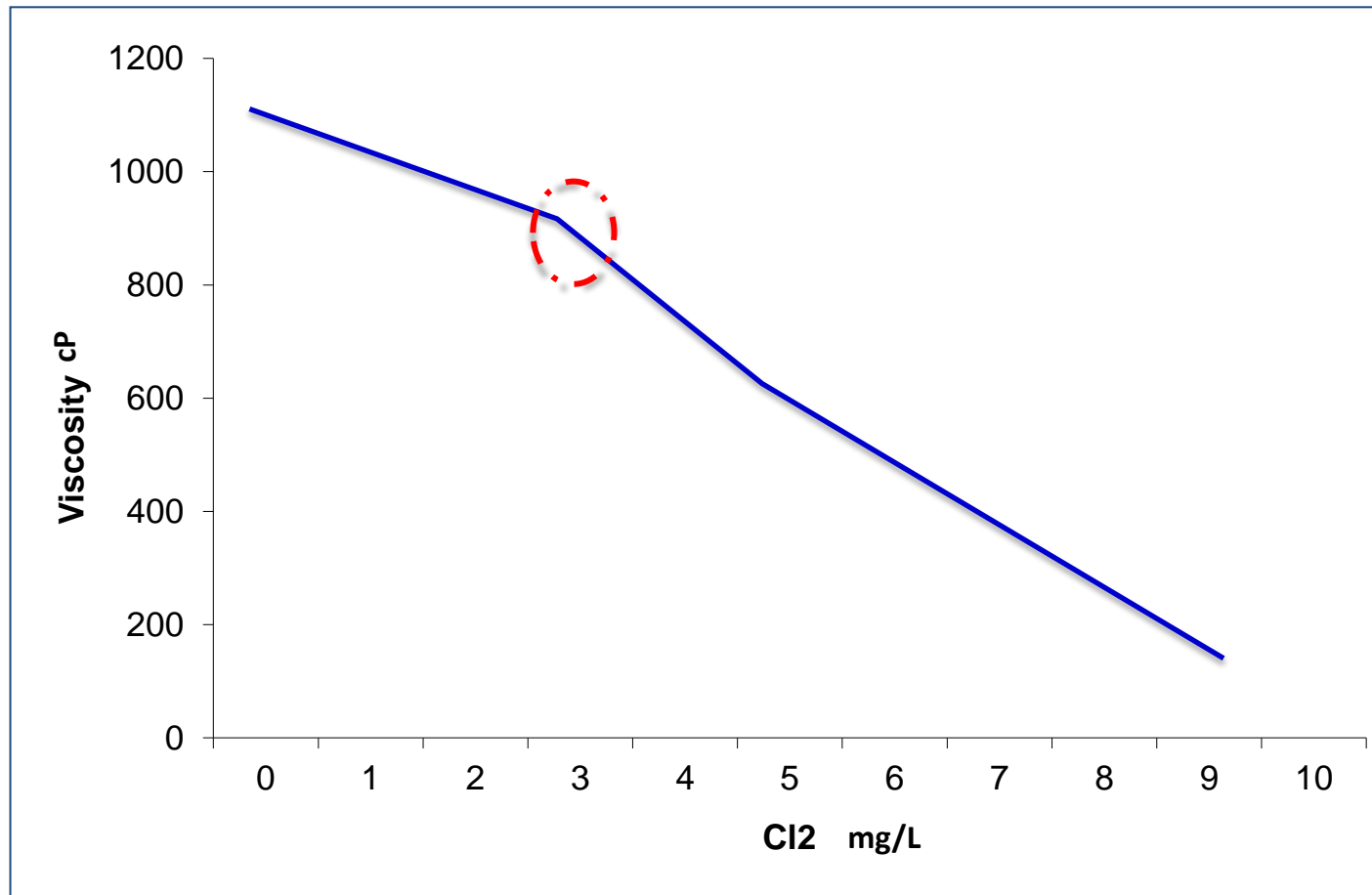
**Suspended solids:** strainer recommended if > 10 ppm

**pH:** negligible effect within pH 3 - 10

\*David Oerke (CH2M), et al., 2014 Biosolids Conf. - 20% less polymer with warm water, 40% more polymer with 140°F sludge

# Effect of Chlorine (Oxidizing Chemical)

When effluent is used for polymer mixing, chlorine should be  $< 3$  mg/L



# Polymer Activation (Mixing, Dissolution)

## (I) Initial Wetting (Inversion)

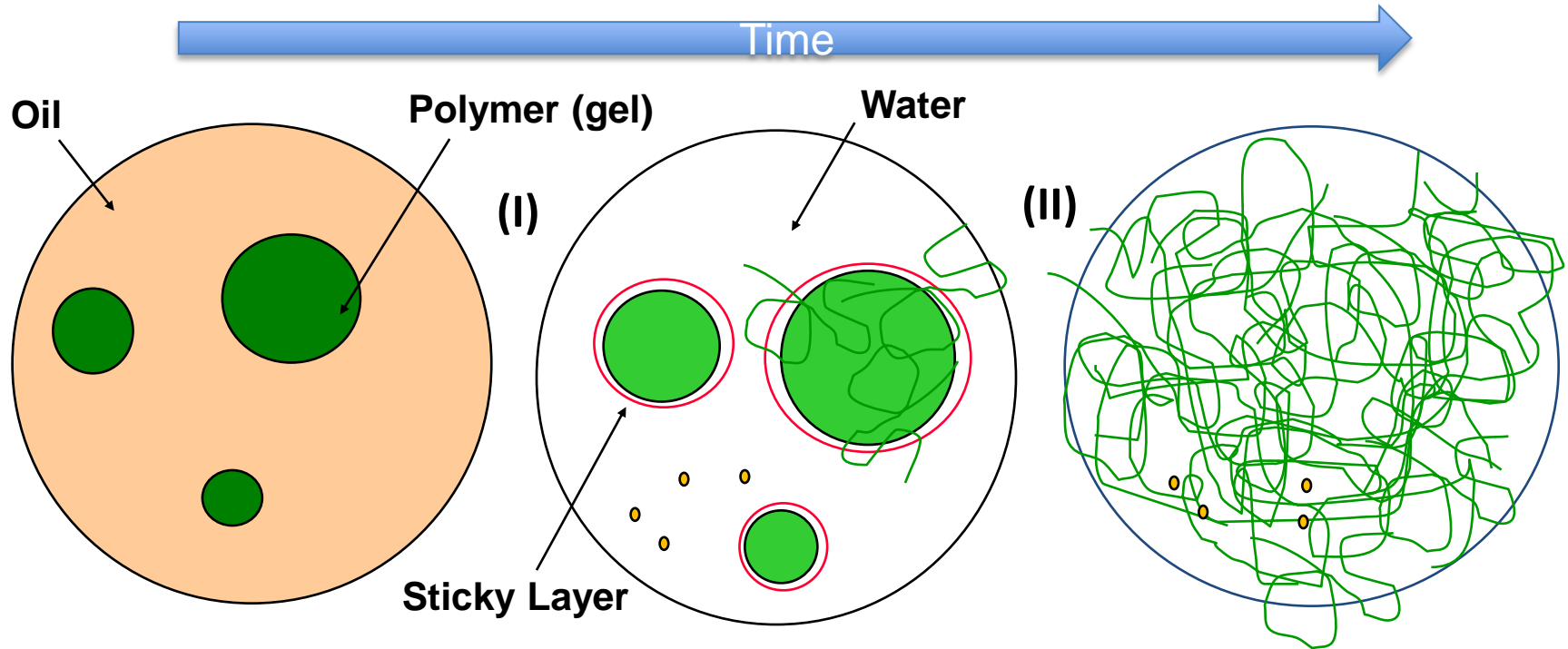
Sticky layer formed

High-energy mixing -> No fisheyes

## (II) Dissolution

Reptation\* or Uncoiling

Low-energy mixing -> No damage to polymer



\* de Gennes, P.G., *J. Chem. Phys.*, 55, 572 (1971)

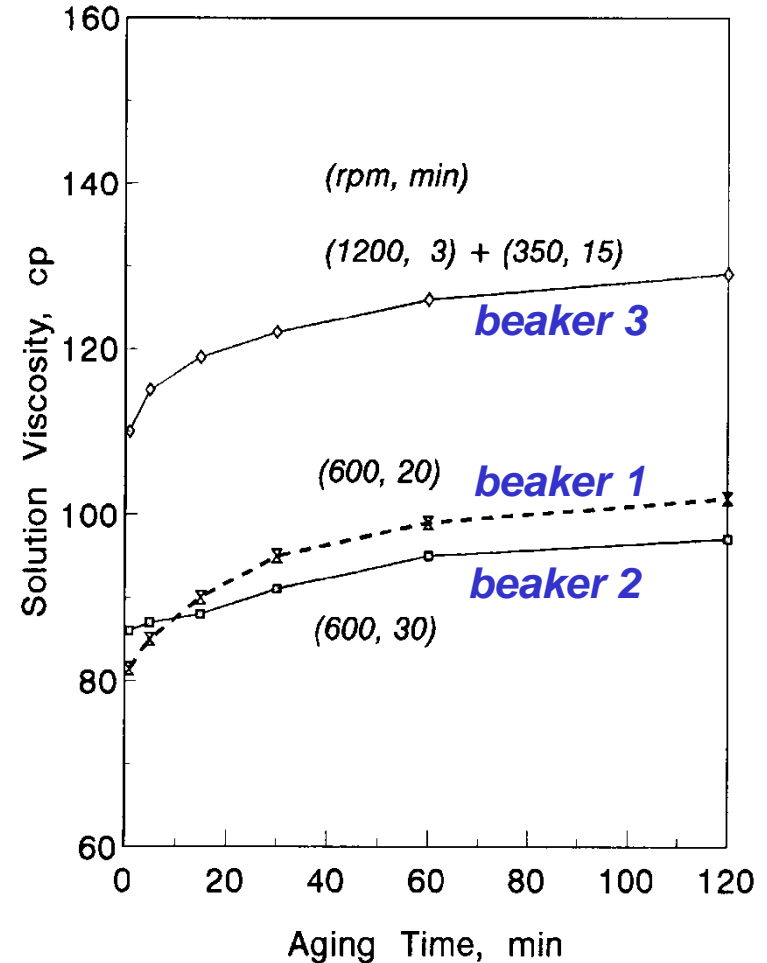
# Mixing Effect on Polymer Activation

Viscosity of polymer solution  
(prepared in 600 mL beakers)

- Beakers 1, 2: one-stage mixing
- Beaker 3: two-stage mixing

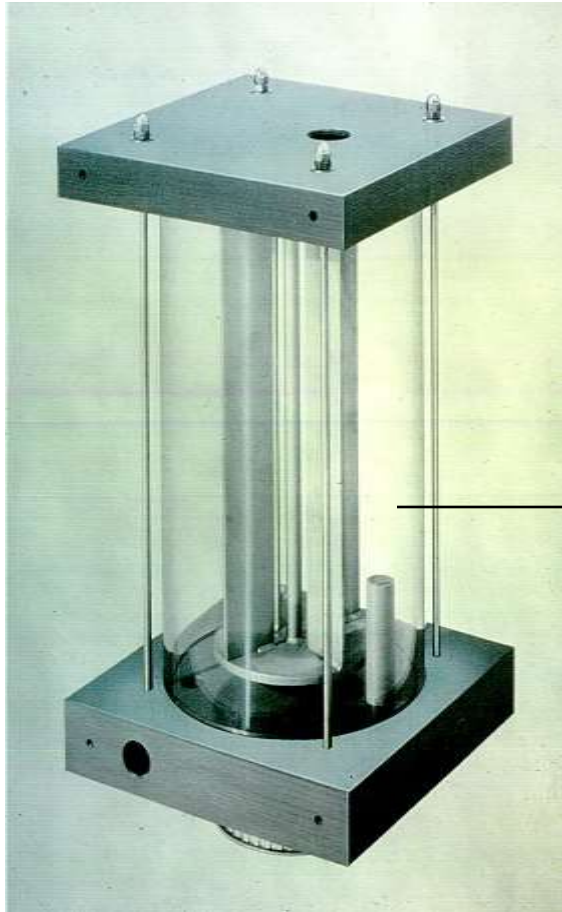
Two-stage mixing resulted in polymer solution of much better quality

- \* High energy first: prevent fisheye formation
- \* Low energy followed: minimize polymer damage



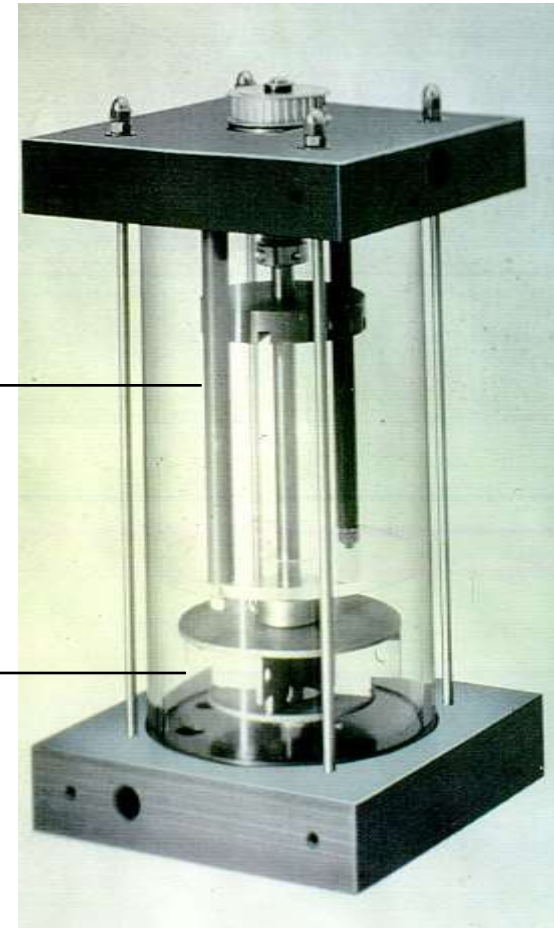
# Development of Two-stage Mixer

1- stage mixer (EC)



1,700

2- stage mixer (PB)



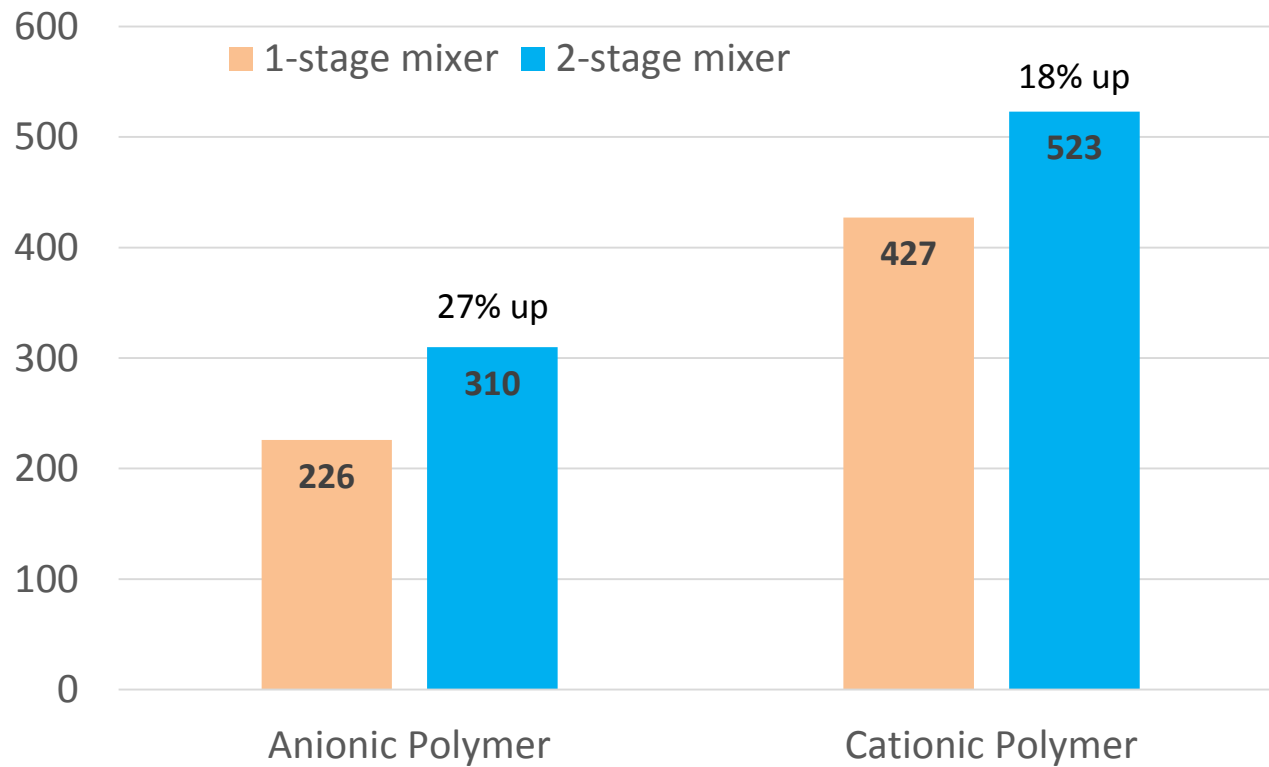
1,100

4,000

G-value, mean shear rate ( $\text{sec}^{-1}$ )

# Mixing Effect on Polymer Activation

Two-stage mixing → significant increase in polymer solution viscosity

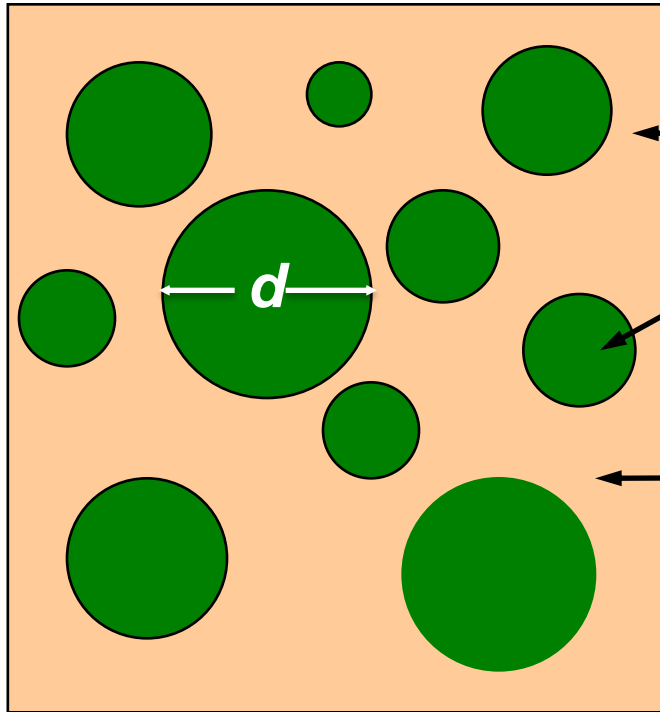


Viscosity of 0.5% Emulsion Polymer Solution, cP



# Why Primary Mixing followed by Post-Dilution?

Inverting Surfactant helps to invert w/o emulsion to o/w emulsion



Hydrocarbon Oil: 30%

Polymer Gel: Polymer 40%  
Water 30%

- Stabilizing surfactant

- Inverting (breaker) surfactant\*

To maximize the value of Inverting Surfactant,

\* 0.75% - 1.0% primary mixing

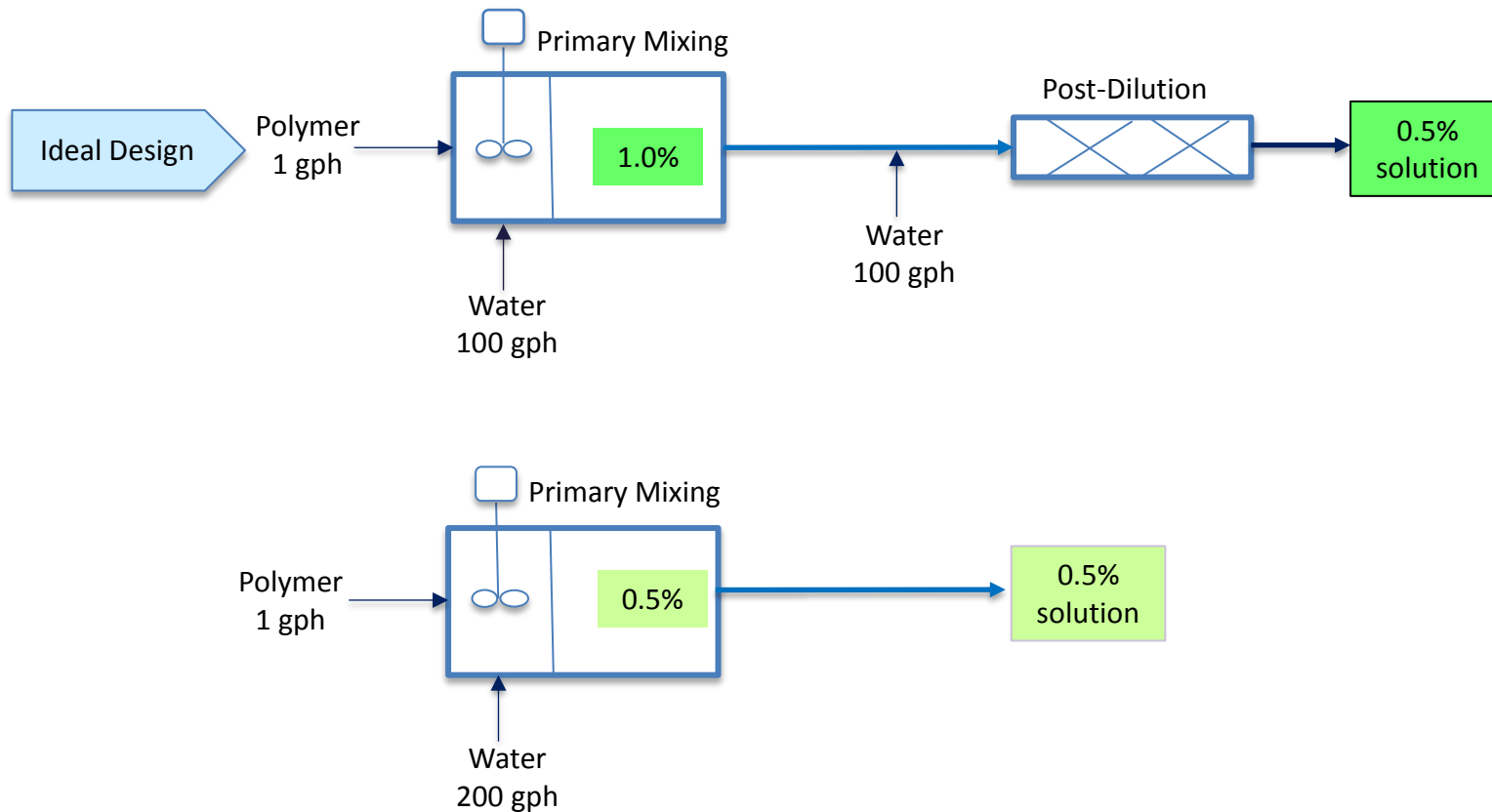
\* 0.25% - 0.5% secondary mixing (dilution)

$d = 0.1 - 2 \mu\text{m}$

\* AWWA Standard for Polyacrylamide (ANSI-AWWA B453-06), 11, 2006

# How to Maximize the Value of Inverting Surfactant?

Primary mixing at high % + Post-dilution at feed %



# PolyBlend Polymer Mixing Systems



Two-stage mixing in mix chamber  
Primary mixing followed by post-dilution



# Dry Polymer Mixing System

## Two-stage Mixing

High Energy Mixing  
(3,450 rpm, < 0.5 sec)

Initial Wetting

Low Energy Mixing  
(60 rpm, 20 min)  
(0.5% - 0.75%)

Mixing Tank

Post-dilution  
(0.1% - 0.2%)

Solution Feed



# Dry Disperser (DD4) for Initial Wetting

Very High-Intensity Mixing for Short Time

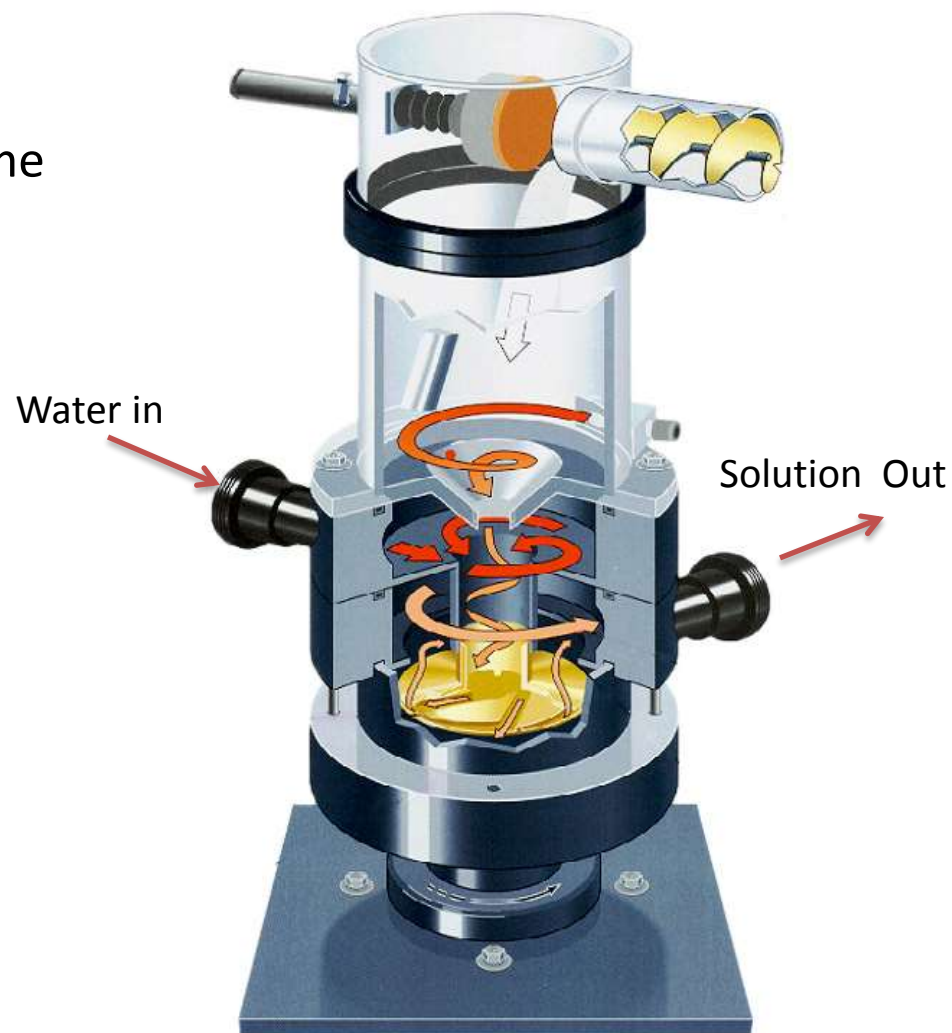
$G = 15,000$  /sec

@ 3,450 rpm

for < 0.5 sec

Disperses Individual Polymer Particles

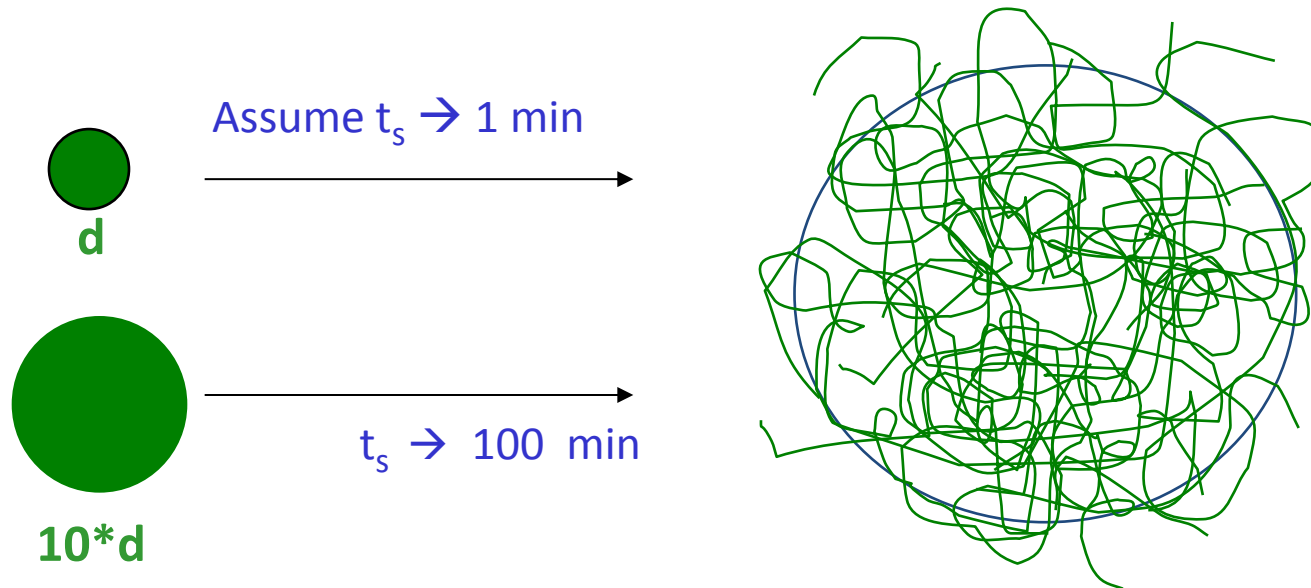
- \* No Fisheye Formation
- \* Shorter Mixing Time in Next Stage



# How to Reduce Mixing/Aging Time in Polymer Mixing?

## initial high-energy mixing is critical

Polymer dissolution time,  $t_s \sim (\text{diameter})^2$  *Tanaka (1979)\**



Initial high-energy mixing (DD4)  $\rightarrow$  **No fisheye formation**  $\rightarrow$  Significantly shorter mixing time  $\rightarrow$  Minimum damage to polymer structure  $\rightarrow$  Better quality polymer solution  $\rightarrow$  Less Polymer Usage

\* Tanaka, T., Fillmore, D.J., *J. Chem. Phys.*, 70 (3), 1214 (1979)

# Mixing Tank for Dissolution of Dry Polymer

Patented Hollow-Wing Impeller

- No Weissenberg Effect

Large Impeller,  $d/D > 0.7$

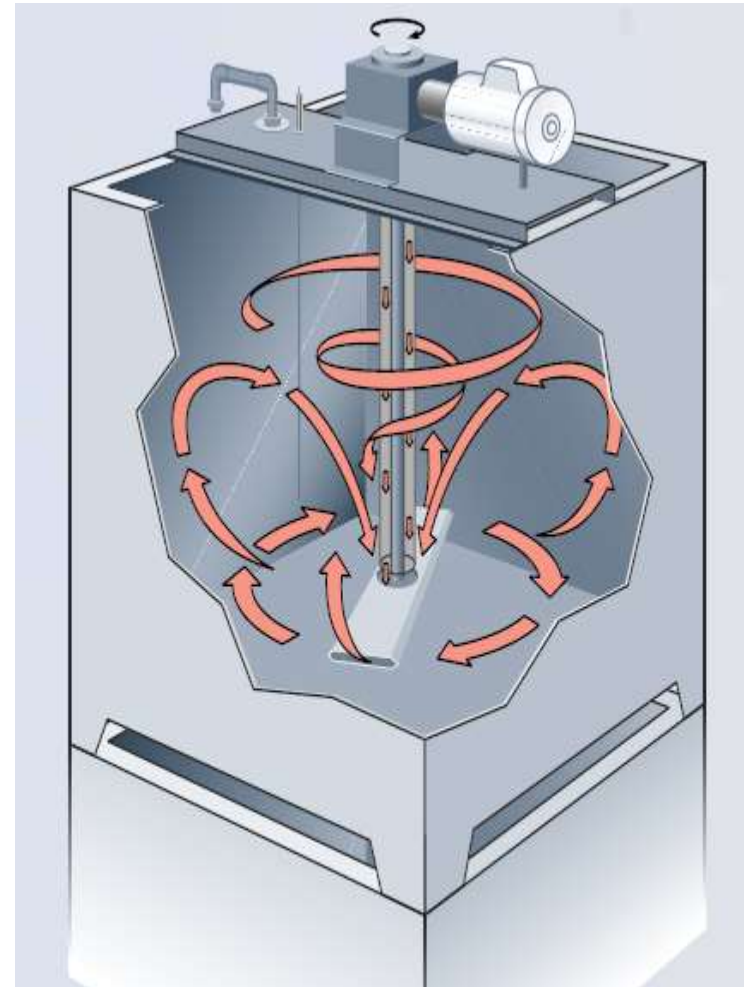
- **Uniform** Mixing Energy

Low RPM, 60 rpm

- **Low-intensity** Mixing
- Minimize Damage to Polymer Chain

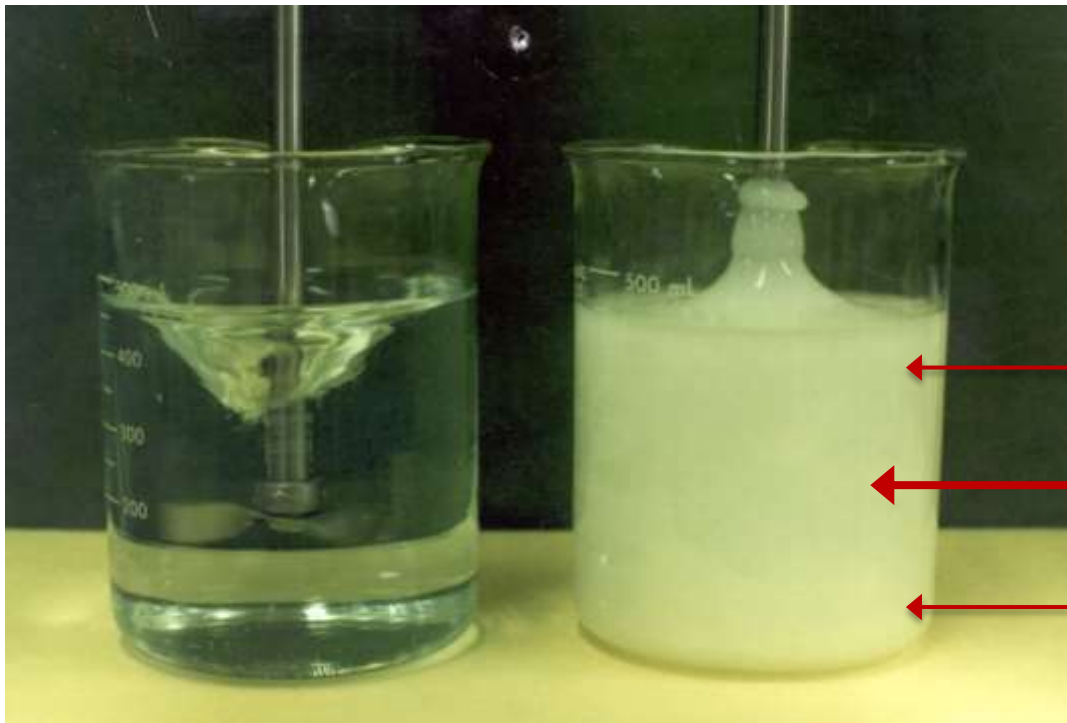
Shorter Mixing Time – Due to DD4

- **20 Minutes** for Cationic Polymer
- 30 Minutes for Anionic Polymer
- Minimize Damage to Polymer Chain



# Weissenberg Effect

- \* Polymer solution exceeding “critical concentration” climbs up mixing shaft
- \* Extremely non-uniform mixing
- \* Critical factor for conventional polymer mix tank → **max 0.25% limit** for HMW polymer



← extremely low mixing

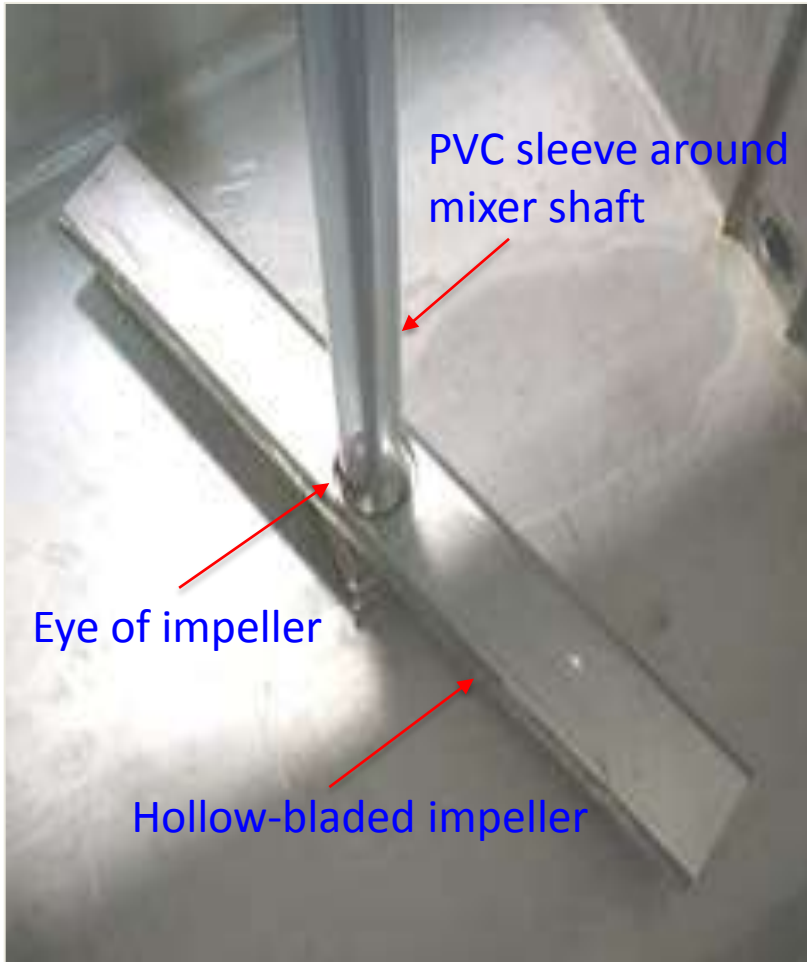
← very high mixing

← extremely low mixing

Water  
(Newtonian)

Polymer Solution  
(Non-Newtonian, Pseudoplastic)

# PolyBlend<sup>®</sup> DP Series Tank Mixing



Impeller diameter/ tank diameter > 0.7

Cationic Polymer Solution @ 0.75%

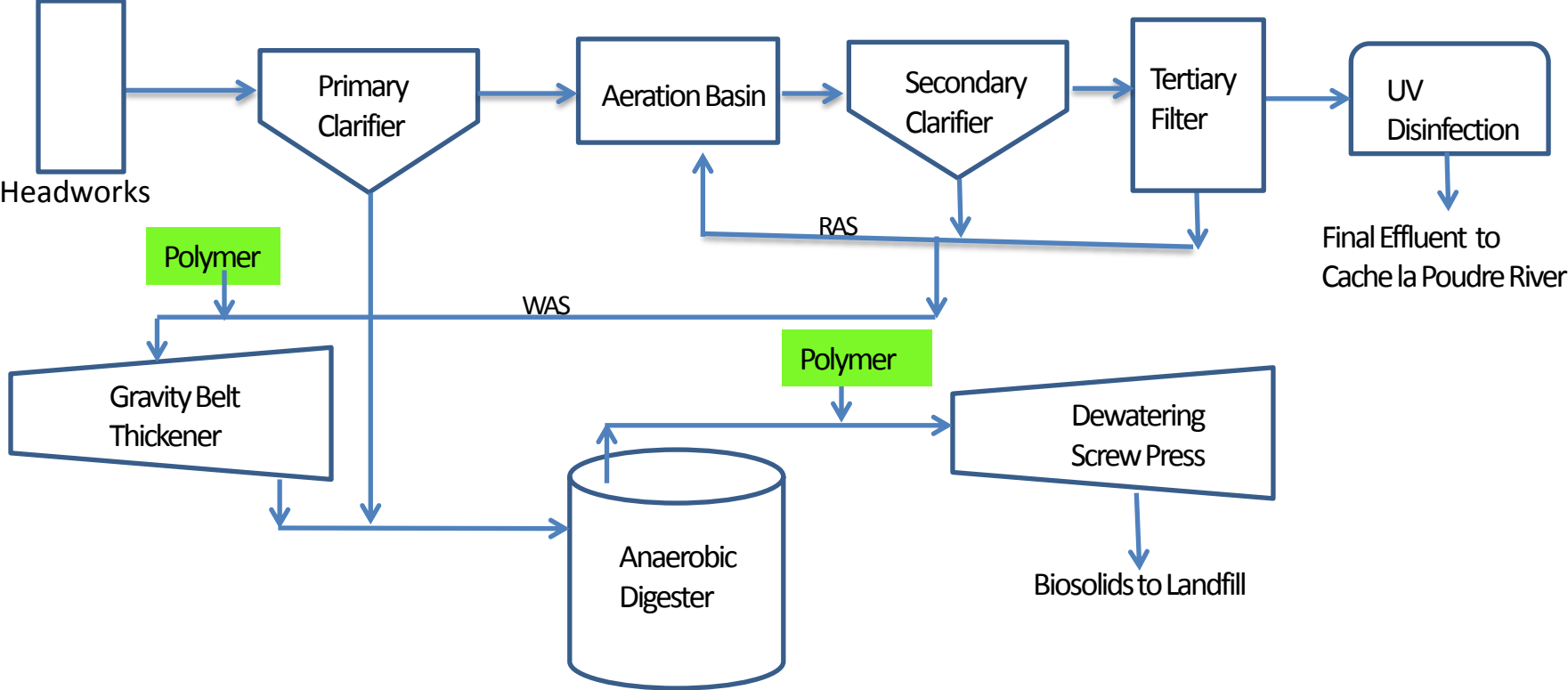
# Fairfield-Suisan, CA - Sewer District

- Solano County, CA, 40 miles North San Francisco
- Design capacity: 24 MGD
- Population served: 135,000
- Tertiary treatment/ UV disinfection
- Polymer use for dewatering (screw press) and thickening (GBT)
- Problems with existing polymer system
  - Struggled to make proper polymer solution
  - Polymer performance inconsistent
  - Frequent maintenance issues



# Fairfield-Suisun Wastewater Treatment Plant

## Advanced Tertiary Treatment Facility



# Pilot Testing with Two Polymer Mix Equipment



## Existing Polymer System

- Initial wetting: educator-type hydraulic mixing
- Mixing: two (2) > 3,000 gal mix/age tanks



## UGSI PolyBlend Dry Polymer System

- Initial wetting: high-energy mechanical mixing
- Mixing: two (2) 360 gal mix tanks with hollow-blade impeller

# Fairfield-Suisan SD – Pilot Test Results

- **Dewatering by Screw Press** (3/21 – 4/21)
- **Less** polymer consumption
  - \* Daily usage from 255 lbs to 200 lbs
  - \* 22% polymer savings
- **Better** cake solids
  - \* 14% - 16% to average 16.4%
  
- **Thickening by GBT** (4/24 – 5/23)
- **Less** polymer consumption
  - Daily usage from 29 lbs to 20 lbs



DP800/DD4 demo trailer at Fairfield

# Various Forms of Polymer Solution



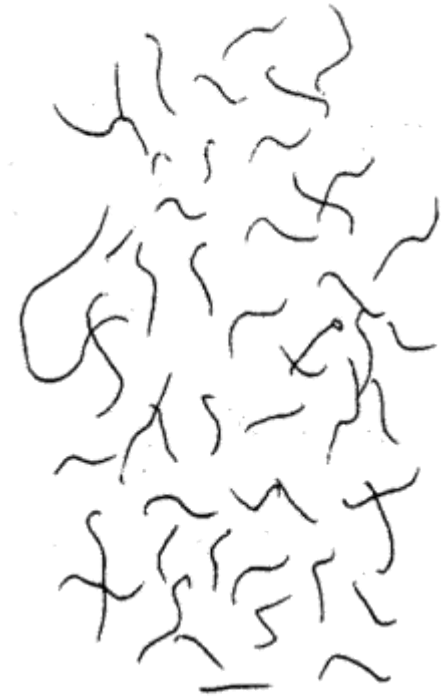
Neat polymer



Fisheyes due to poor initial wetting



Ideal polymer chains by two-stage mixing



Broken polymer chains by longer mixing time

# Thank You

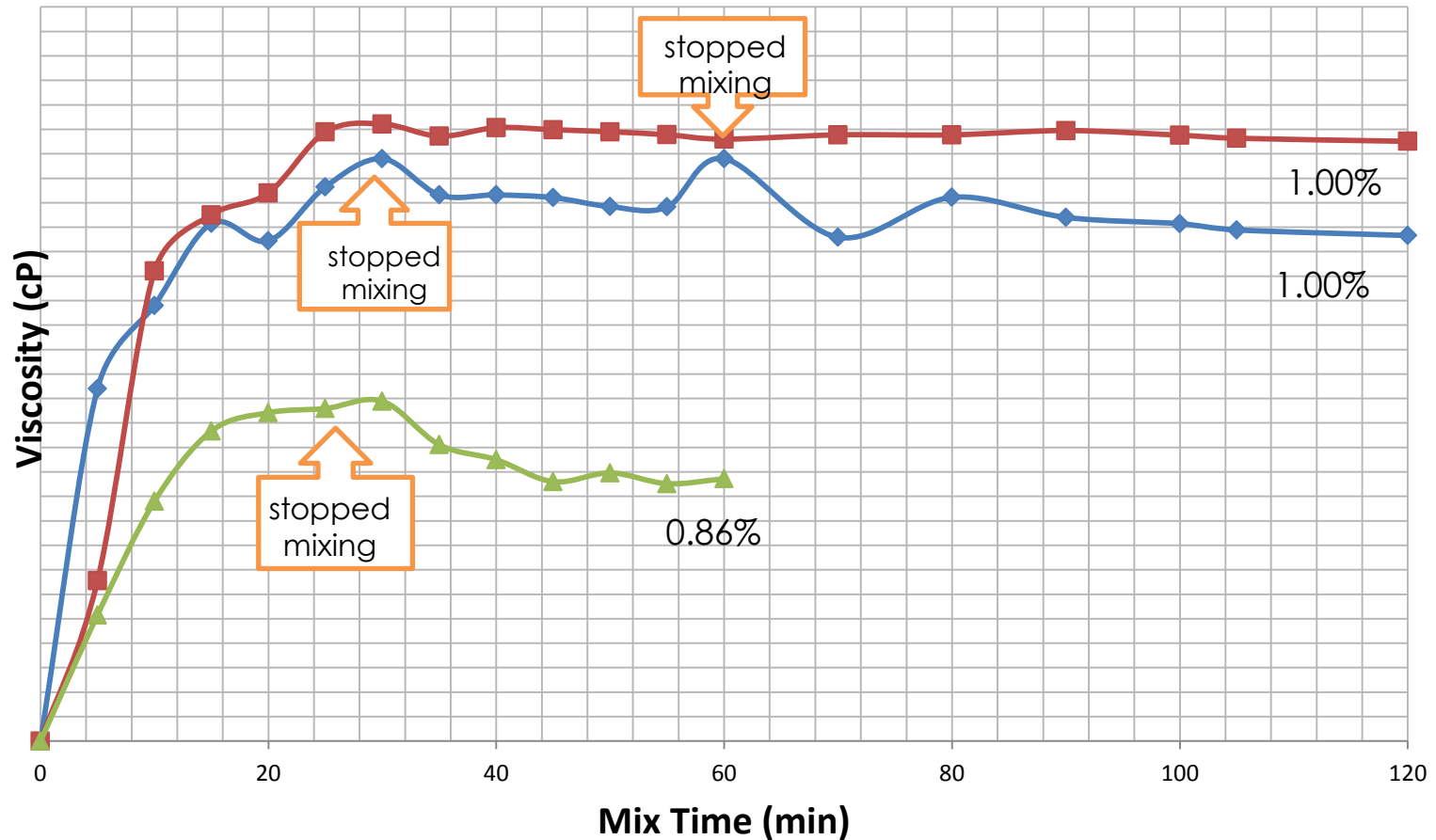
Please contact Yong Kim with any questions

**Yong Kim, PhD**  
UGSI Chemical Feed, Inc.  
1901 W. Garden Road  
Vineland, NJ 08360  
Phone: 856-405-5756  
E-mail: [ykim@ugsi.com](mailto:ykim@ugsi.com)



# How Much Aging Time is Required for Dry Polymer?

PolyBlend® DD4/DP-series do not need additional aging



Rao, M, *Influents (WEA Ontario, Canada)*, Vol. 8, 42 (2013)

