Optimizing Polymer Mixing/Activation Improves Sludge Dewatering: Case Studies

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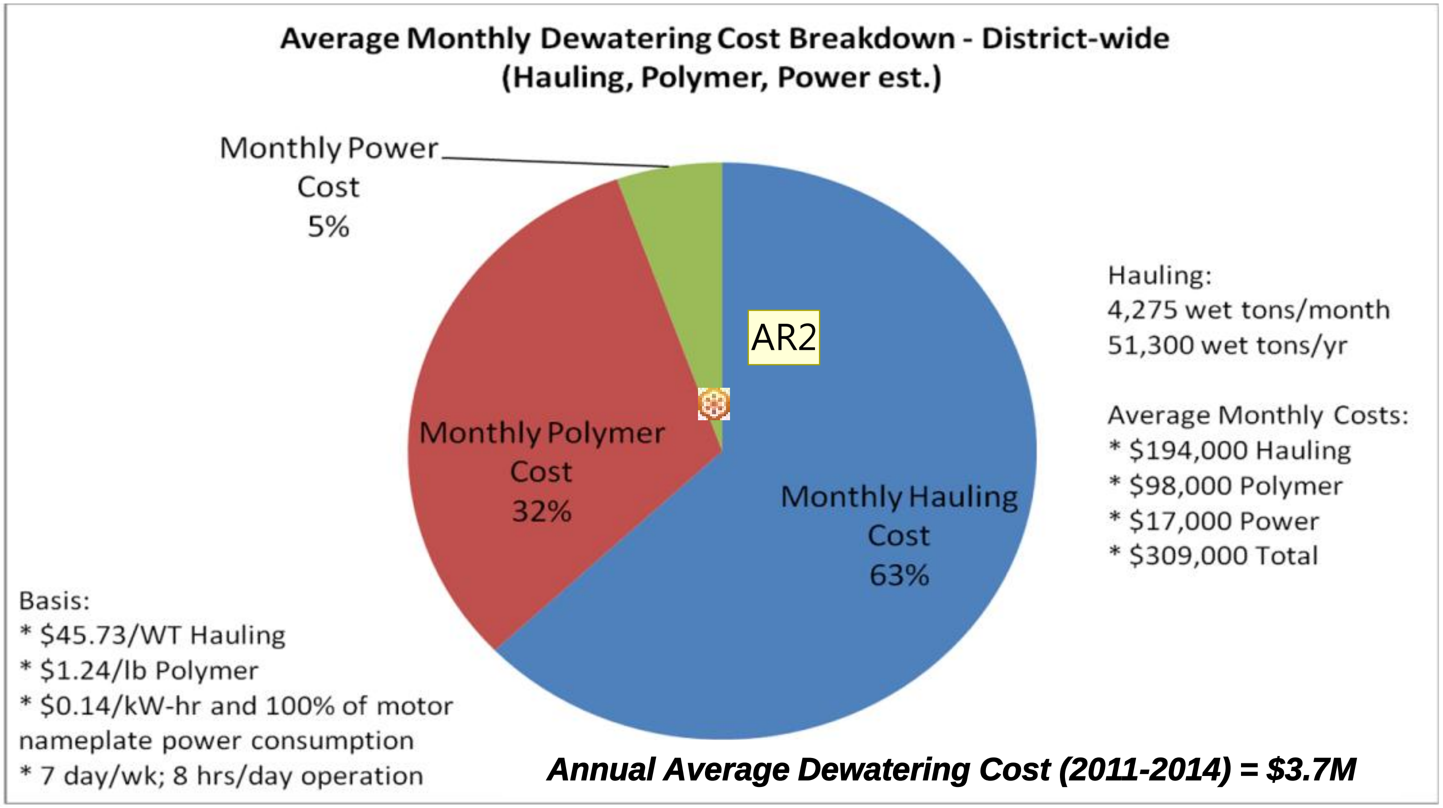
Dewatering Cost at EMWD - $3.7M/yr

Polymer Cost - Average $1.2 M/yr



K. Tagney and R. Gupta, Reducing Dewatering Costs through Optimization Program, 2017 WEFTEC.

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Presentation Overview

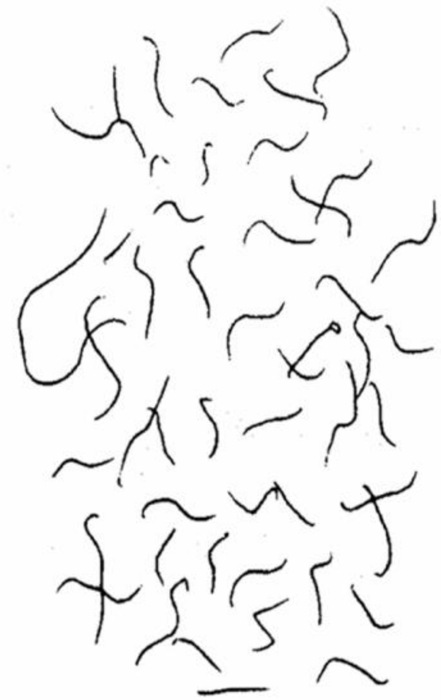
1. Science of Polymer Activation
   - Viscosity as an indicator of polymer solution quality
   - Effect of dilution water
   - Two-stage mixing for dry and emulsion polymers
   - Residence time sufficient for polymer uncoiling/dissolution
   - Weissenberg effect in dry polymer mixing
2. Case Studies
   - Water Treatment Plant, PA – emulsion polymer
   - Wastewater Treatment Plant, CA– dry polymer
3. Aging Issue in Dry Polymer Activation

Three Forms of Polymer Solutions

Neat polymer

Fisheyes due to poor initial wetting

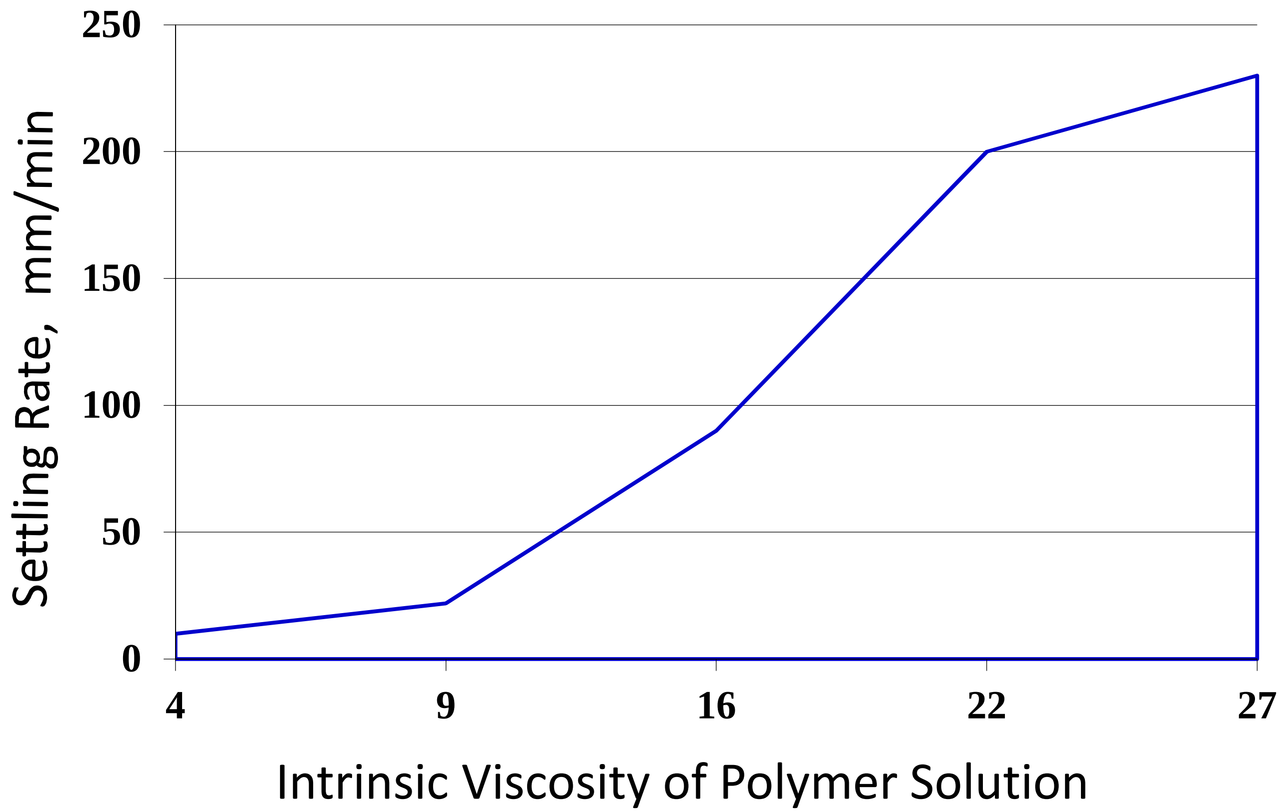
Ideal polymer chains by two-stage mixing

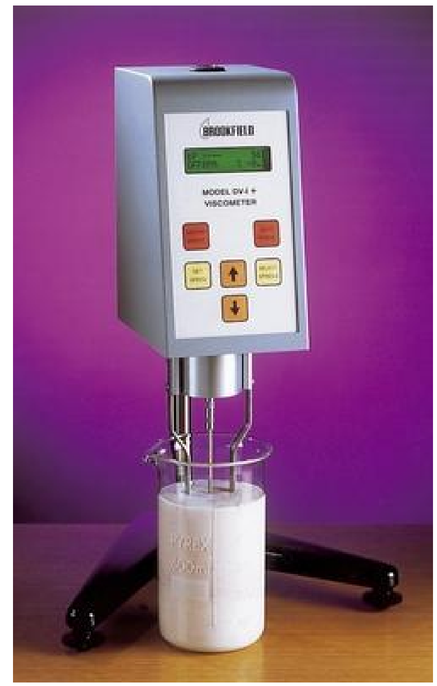


Broken polymer chains by excessive mixing

Viscosity – Indicator of Polymer Solution Efficiency

- Quantity of friction as measured by the force resisting a flow in which parallel layers have at unit speed relative to one another





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

Polymer supplier data sheet provides a starting point for viscosity – critical factor for polymer efficiency

Solenis, Inc.

Table of Properties - PRAESTOL® Cationic Polymers (Emulsion)

PRAESTOL POLYMER GRADE	CATIONIC CHARGE	ACTIVE CONTENT	DENSITY (GR/ML)	PRODUCT VISCOSITY (CP)	SOLUTION VISCOSITY 1% IN DIST. WATER[1] (CP)	SOLUTION VISOCITY 1.0% in 10% NaCl-Brine [2] (CP)	FREEZING POINT (°C)	EFFECTIVE pH RANGE
K105L	Low	30%	1.04	<4000	>5000	>2000	-15	1-10
K110FL	Low	35%	1.03	<4000	>3000	>1000	-15	1-10
K120L	Low-Medium	40%	1.03	<4000	>7000	>500	-15	1-10
K226FLX	Medium	29%	1.03	<4500	>8000	>400	-15	1-10
K111L	Medium	40%	1.03	<4000	>7000	>500	-15	1-10
K122L	High	43%	1.04	<4000	>9000	>300	-15	1-10
K128L	High	43%	1.04	<4500	>9000	>900	-15	1-10
K132L	High	35%	1.01	<5500	>8000	>300	-15	1-10
K133L	High	44%	1.05	<4000	>8000	>150	-15	1-13

Effect of Dilution Water Quality

Ionic strength (Hardness): multi-valent ion hinders polymer activation
- Soft water helps polymer molecules fully-extend faster
- Hardness over 400 ppm may need softener

Oxidizer (chlorine): chlorine attacks/breaks polymer chains
- Should be less than 3 ppm
- Caution in using recycled water for polymer mixing
    + Serious negative impact on aging/maturing

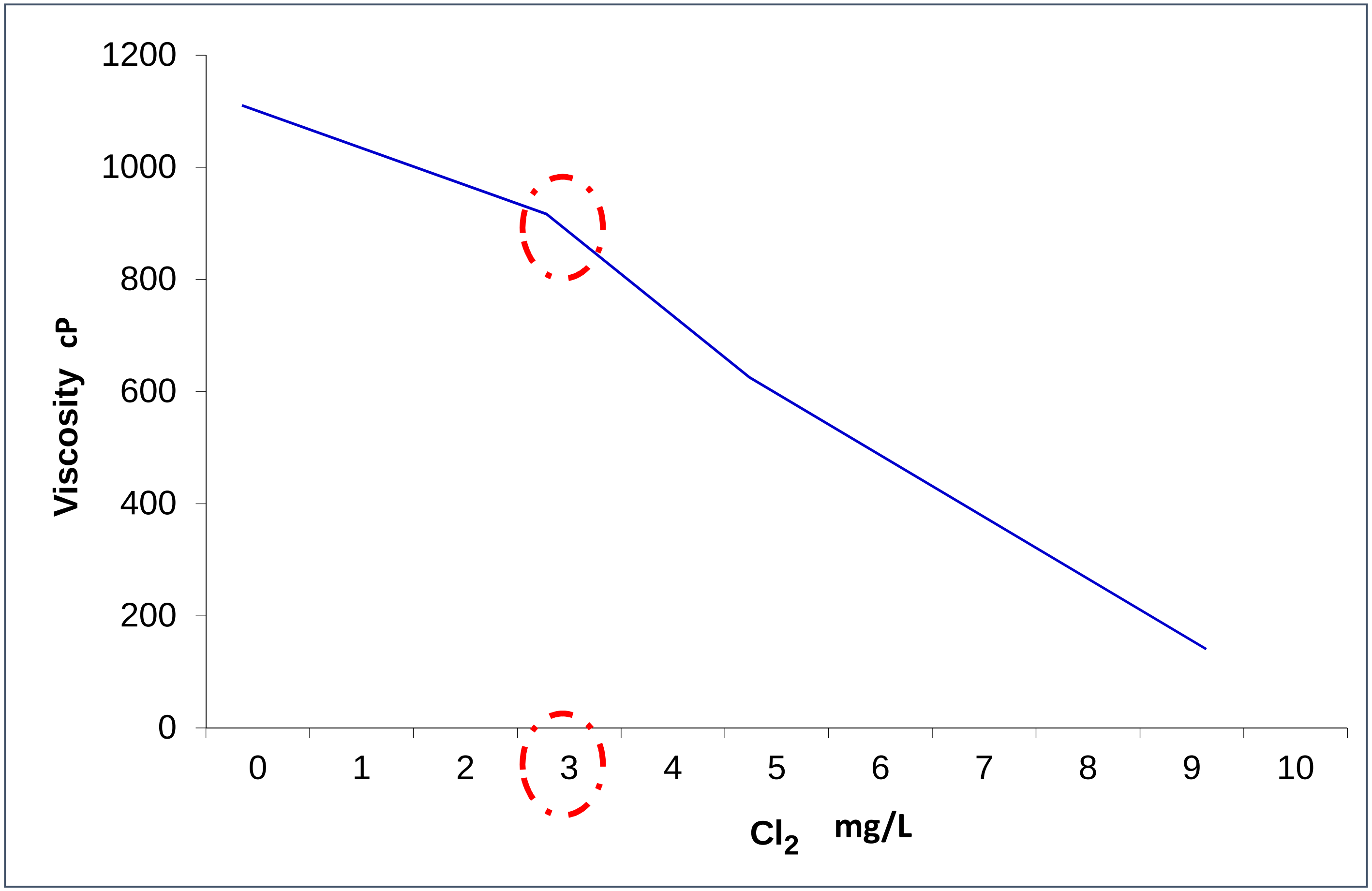
Temperature*: higher temperature, better polymer activation
- Water below 40 ºF may need water heater
- Water over 100 ºF may damage polymer chains

Suspended Solids/ Turbidity:
- In-line strainer recommended
- Caution in using recycled water for polymer mixing

*David Oerke, 20% less polymer with warm water, 40% more polymer with 140F sludge, Residuals and Biosolids (2014)

Effect of Dilution Water **Chlorine Content**

When reclaimed water used for polymer mixing, chlorine < 3 mg/L



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Polymer Activation (Mixing, Dissolution)

(I) Initial Wetting (Inversion)

Sticky layer formed

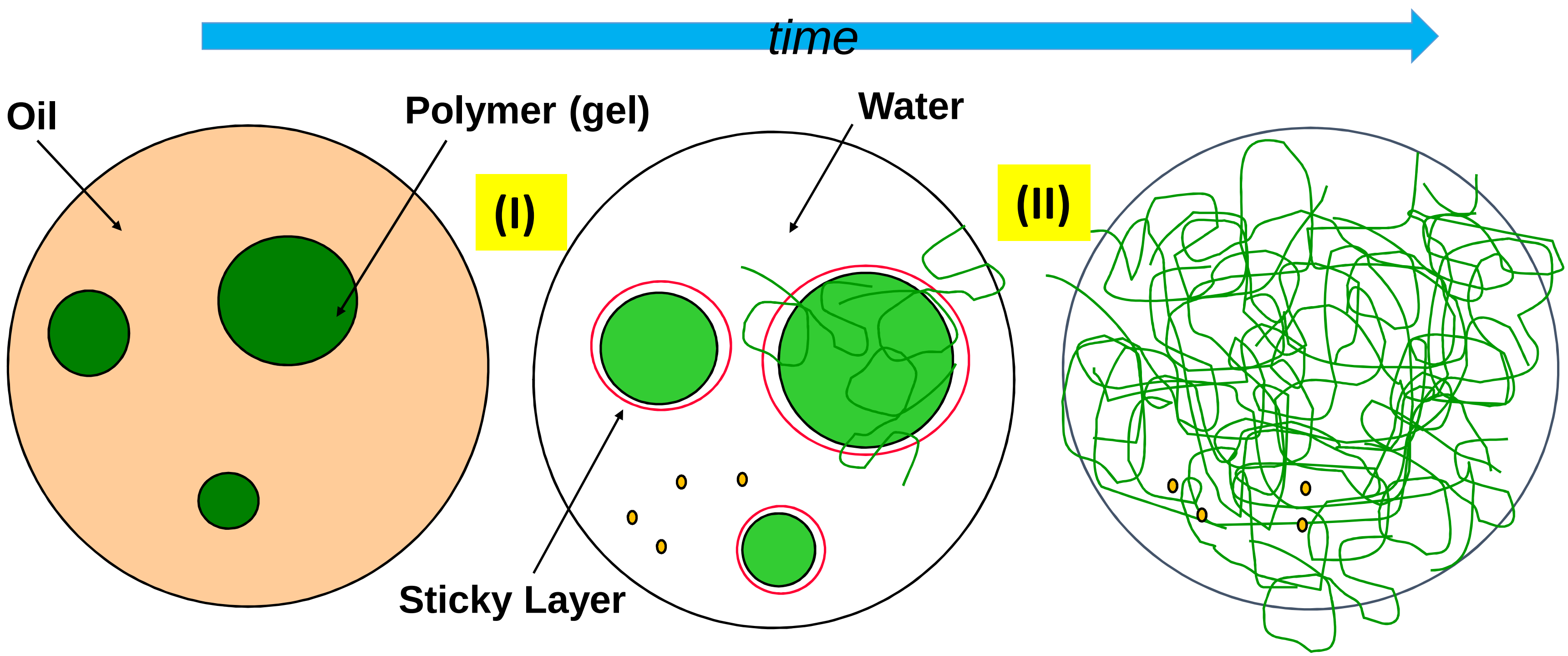
High-energy mixing -> No fisheyes

Most Critical Stage

(II) Dissolution

Reptation* or Uncoiling

Low-energy mixing -> No damage to polymer



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

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Two-Stage Mixing (in mix chamber)

higher energy mixing → low energy mixing

SNF POLYDYNE

CLARIFLOC® WE-1181 POLYMER

TYPICAL PROPERTIES

Physical Form	Clear to Milky White Liquid
Cationicity	60%
Active Polyacrylamide Min.	45.0 %
Freezing Point	7 F. (-14 C.)
Flash Point	>200 F. (>93 C.)
Density	TBD

PREPARATION AND FEEDING

CLARIFLOC WE-1181 is a single component emulsion polymer that must be pre-diluted in water before use. In most cases, this product should not be applied neat. One method for dilution is adding the neat polymer into the vortex of a mixed tank at a concentration between 0.25-1.0% polymer (0.5% is optimum) by weight. The polymer can also be injected through a number of commercially available systems that provide in-line mechanical mixing. The best feed systems use initial high energy mixing (>1000 rpm) for a short time (<30 sec) to achieve good dispersion followed by low energy mixing (<400 rpm) for a longer time (10-30 min). Polymer solutions should be aged for 15-60 minutes for best results. Solution shelf life is 8-16 hours.

SOLENIS™

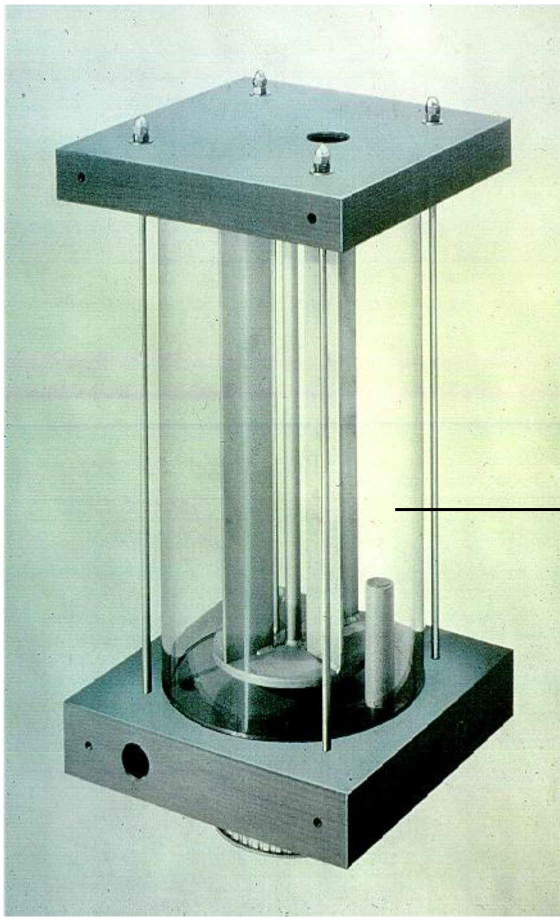
YM-PDS-NA-Praestol Cationic Polymers

There are a number of commercially available automatic feed systems that provide in-line mechanical mixing. The best units of this type feature initial high energy mixing (>1000 rpm) for a short time (<15 sec) to achieve good dispersion of the product into water. This is followed by lower energy mixing (<400 rpm) for a longer period of time (10-20 min) and aging for an additional 10-20 minutes to achieve complete polymer dissolution. Best practice is to use these in-line dilution systems followed by a mixing/aging tank fitted with high/low level probes to refill the tank. The optimum concentration in the mixing/aging tank is 0.5 percent, and in no case should the initial concentration of polymer be less than 0.25 percent for best results.

"Discrete" Two-Stage Mixing - discrete means "separation of high and low energy mixing zones"

One-Stage vs Two-Stage Mixer (Emulsion Polymer)

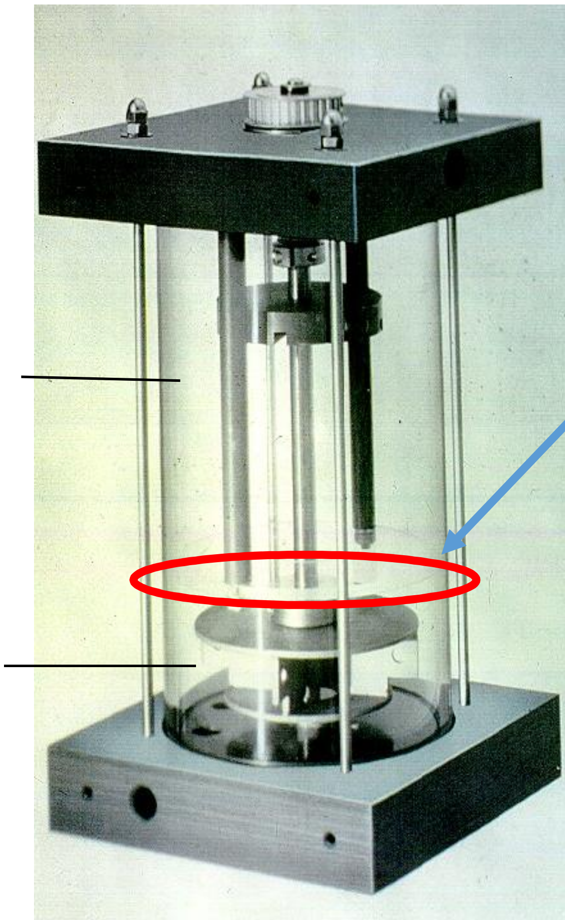
1- stage mixer



1,700

2- stage mixer

1,100



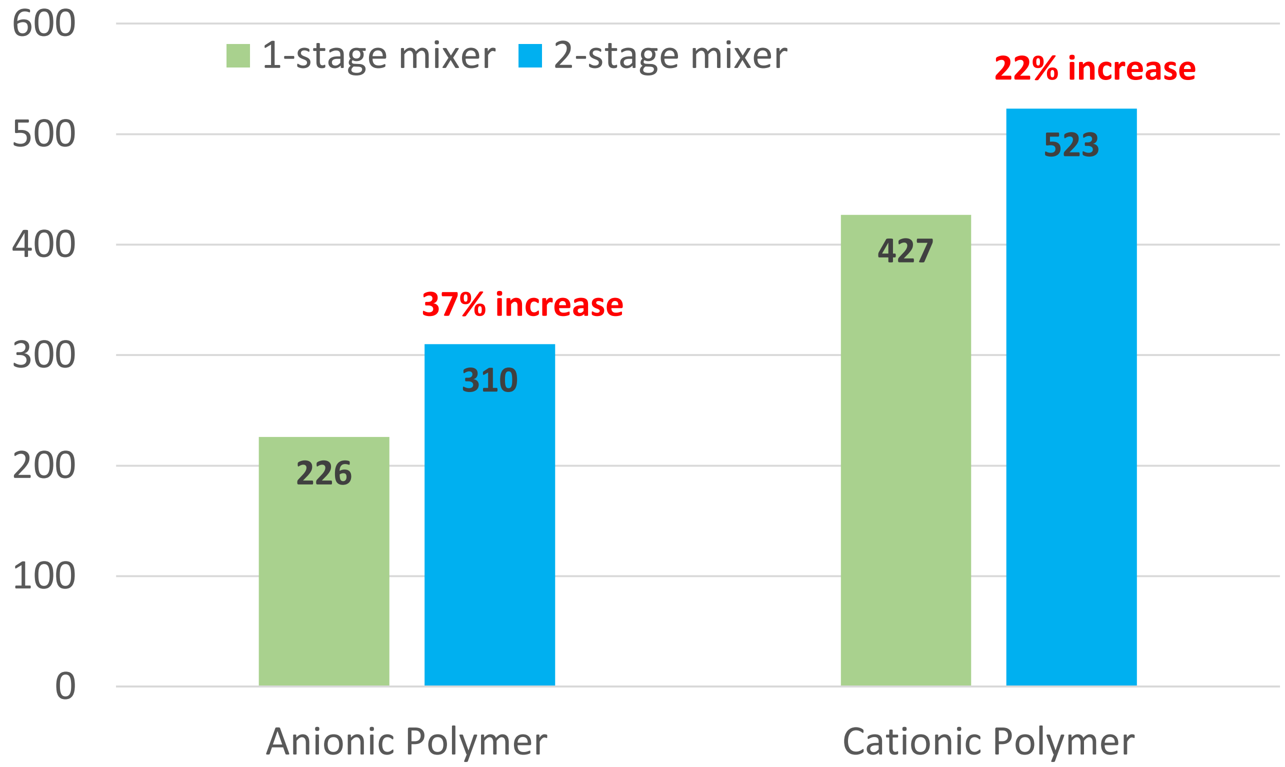
Dividing Baffle

4,000

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

One-Stage Mixing vs. Two-Stage Mixing

Two-stage mixing → significant increase of polymer solution efficiency



Viscosity of 0.5% Emulsion Polymer Solution, cP

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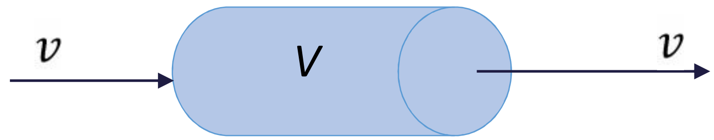
Residence Time (in mix chamber)

Sufficient residence time of low-energy mixing zone is required for complete polymer dissolution

$$t = \frac{V}{v}$$



Residence time (t) in flocculating basin: Gt-value

Gt-value = mean shear rate x residence time

Contact time (T) in clear well design: *CT* calc

CT calc = residual chlorine concentration x contact time

Residence time (t) in polymer activation

Second stage of polymer activation – "uncoiling" of long chain polymer molecules requires more time under low energy mixing than high energy first stage mixing

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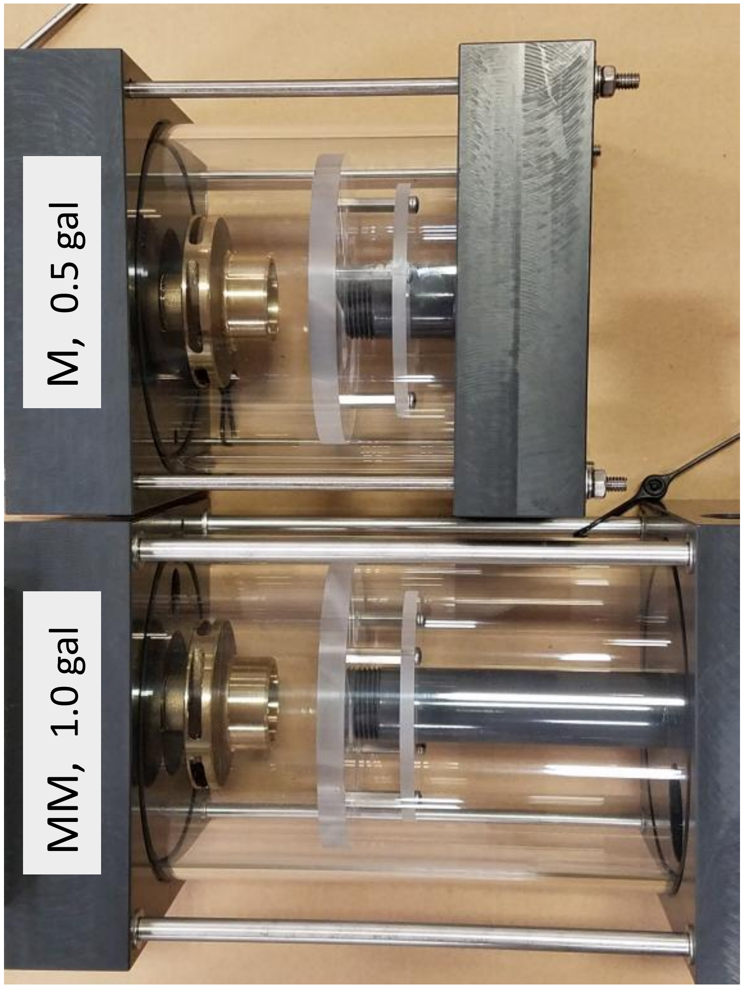
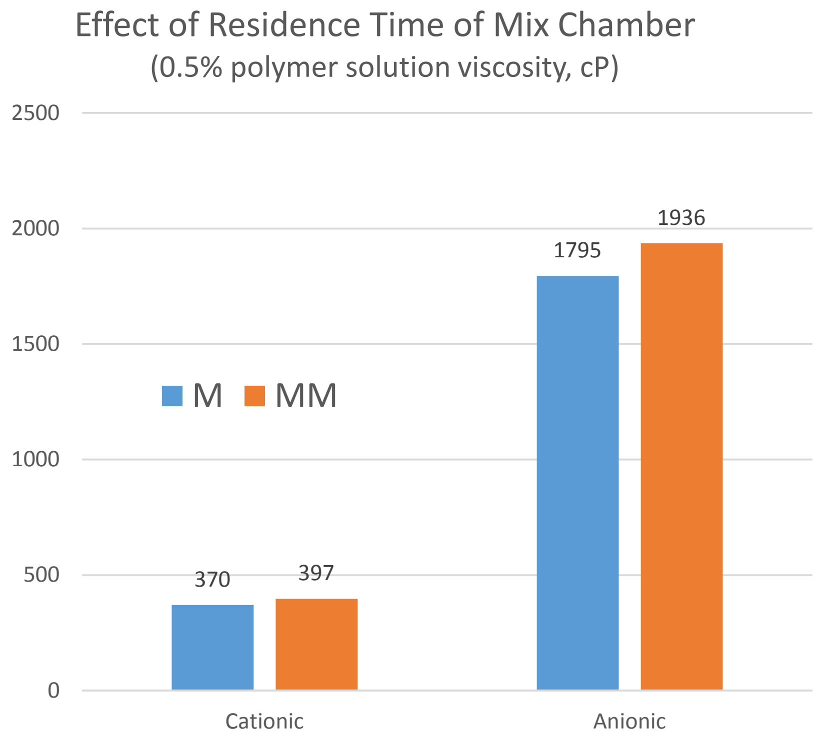
Effect of Residence Time on Polymer Activation



Volume of low-energy zone: V_L

$V_{L,MM} = 3^* V_{L,M}$



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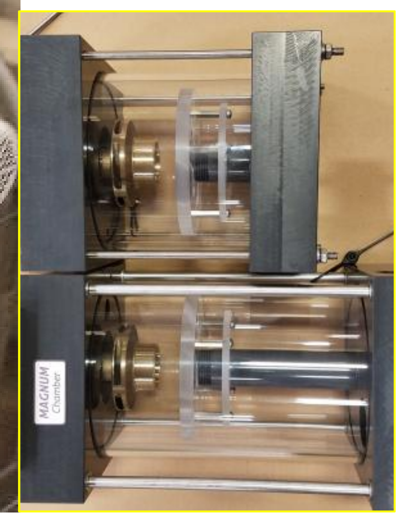
16-mgd Water Plant, PA with two BFP (2-M)



Existing Polymer System
Siemens M1200-D10AA (2011)

New Polymer System
UGSI MM1200-D10AA (2016)

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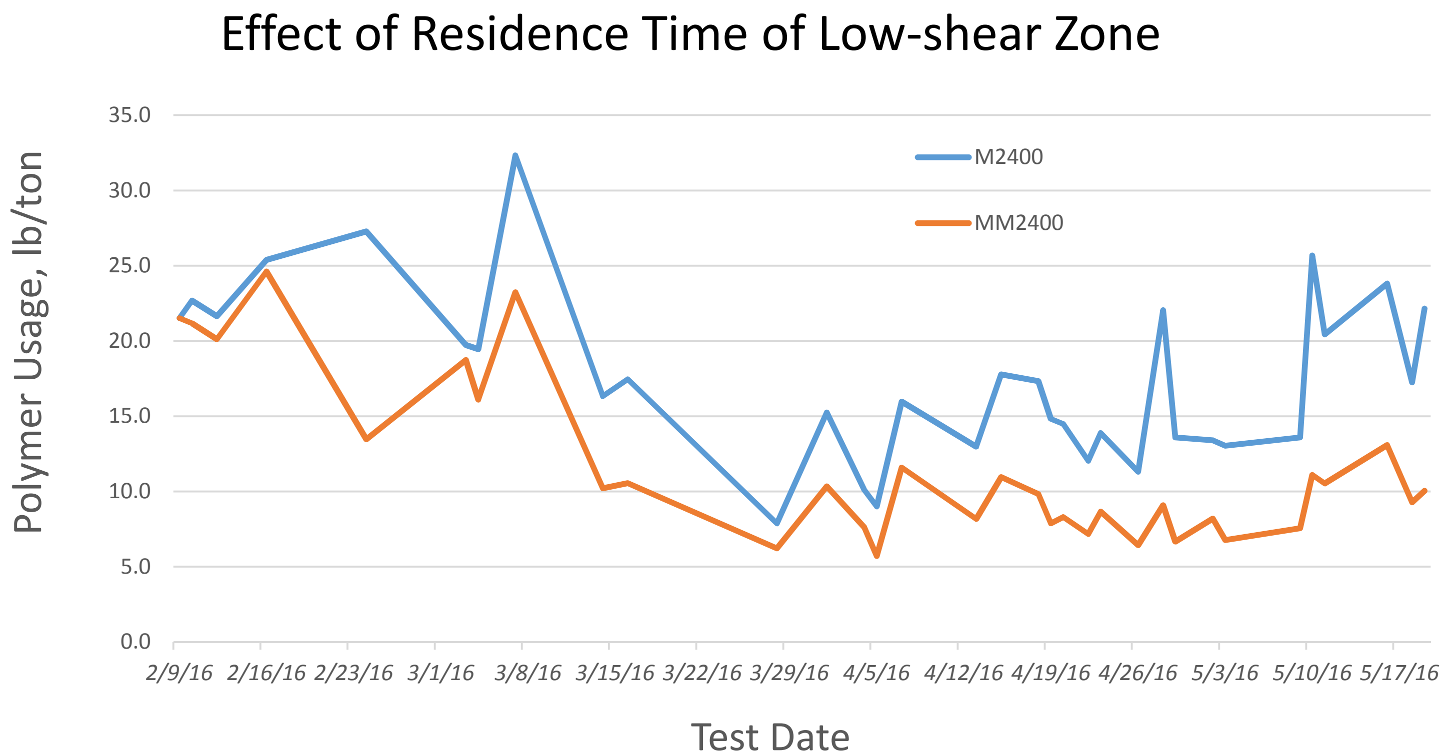
Test Results of Two Mixing Chambers



- Side-by-Side Trial from Feb to May 2016
- ***Polymer savings 30% - 35%***
- ***Sludge throughput increased by 10%***

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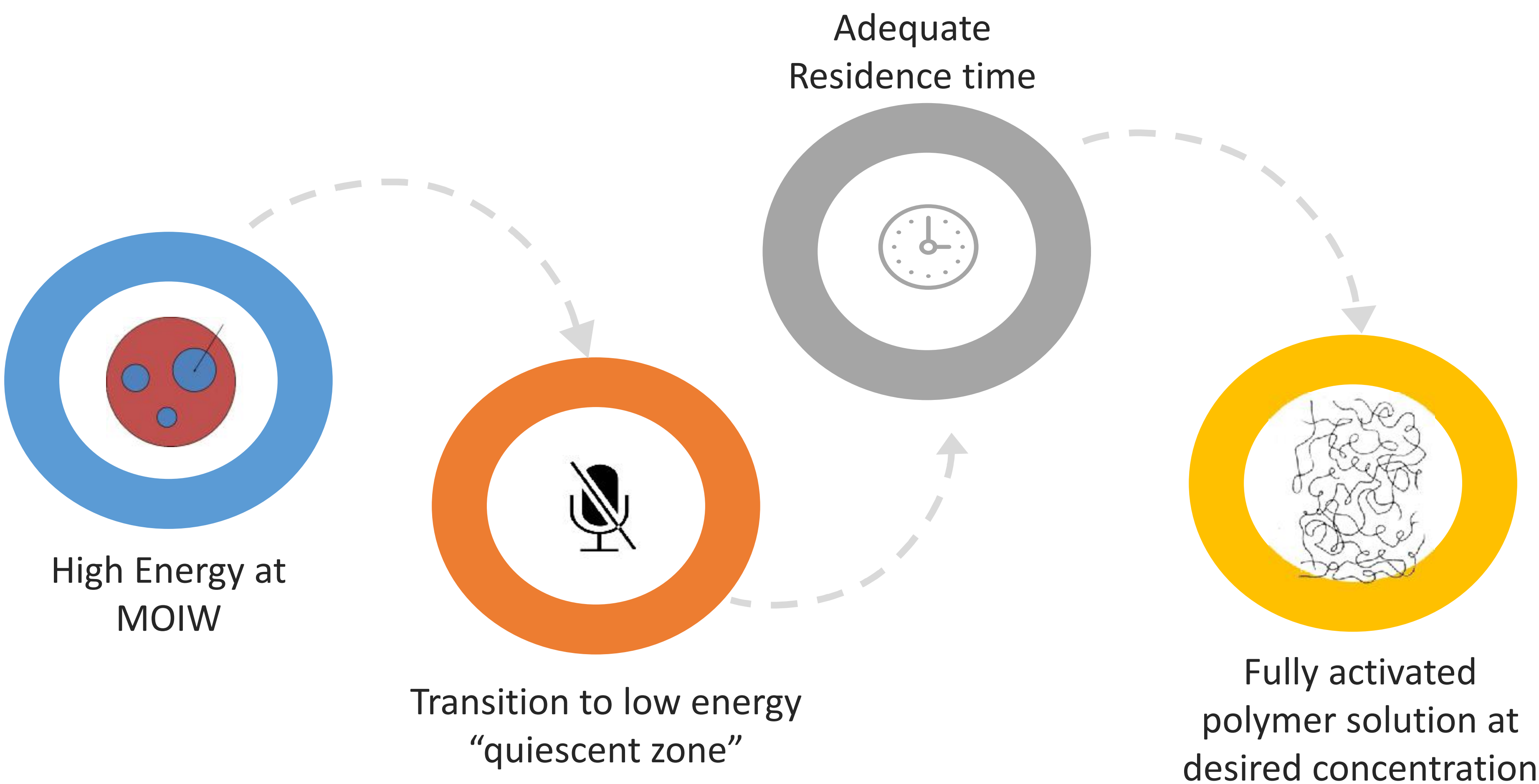
Polymer science dictates the most effective way of activating polymers- Your activation equipment should follow:



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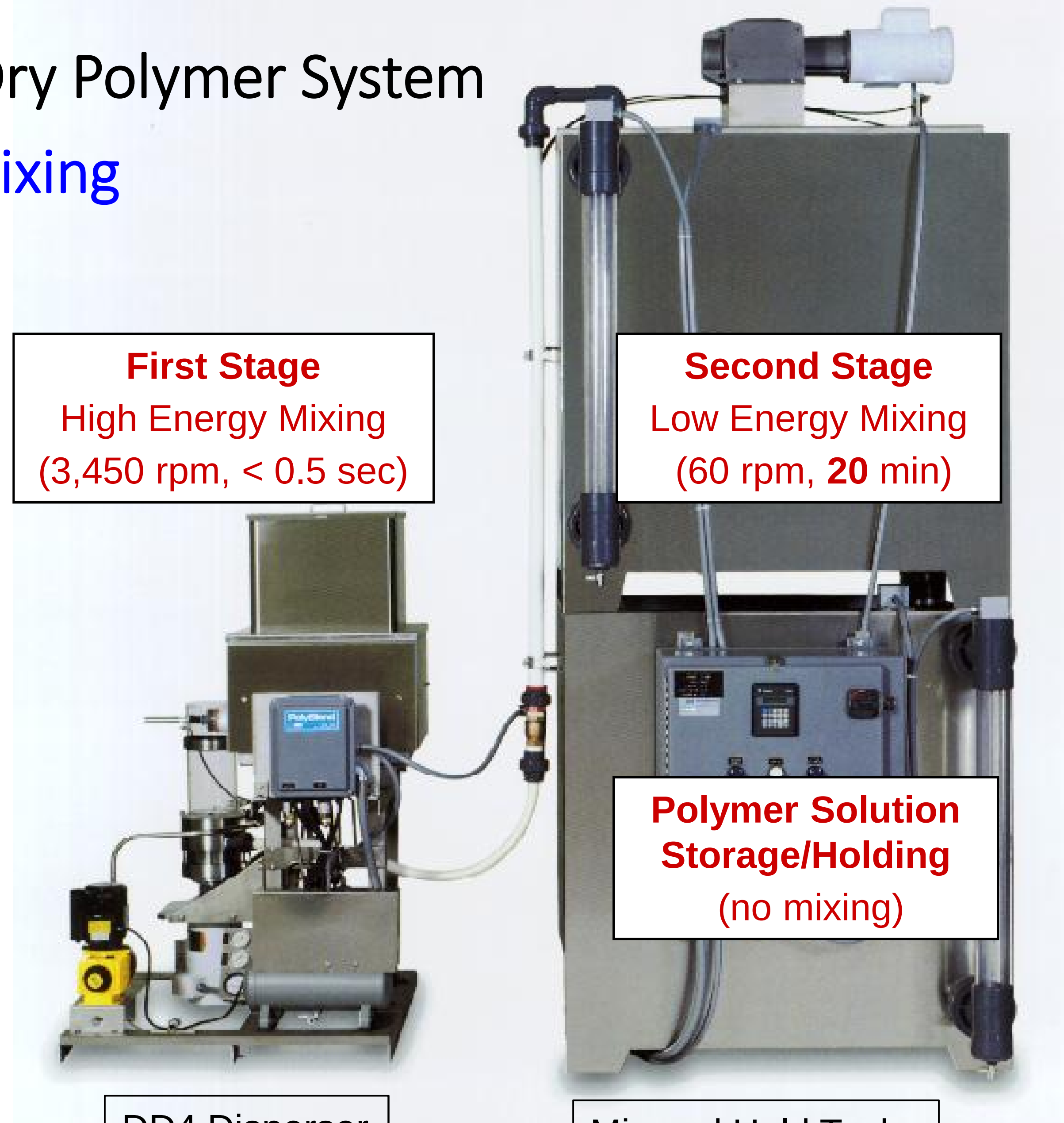
PolyBlend® Dry Polymer System

Two-Stage Mixing



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First-Stage of Dry Polymer Mixing:

High Energy Initial Wetting

Very High-Energy Mixing for Short Time

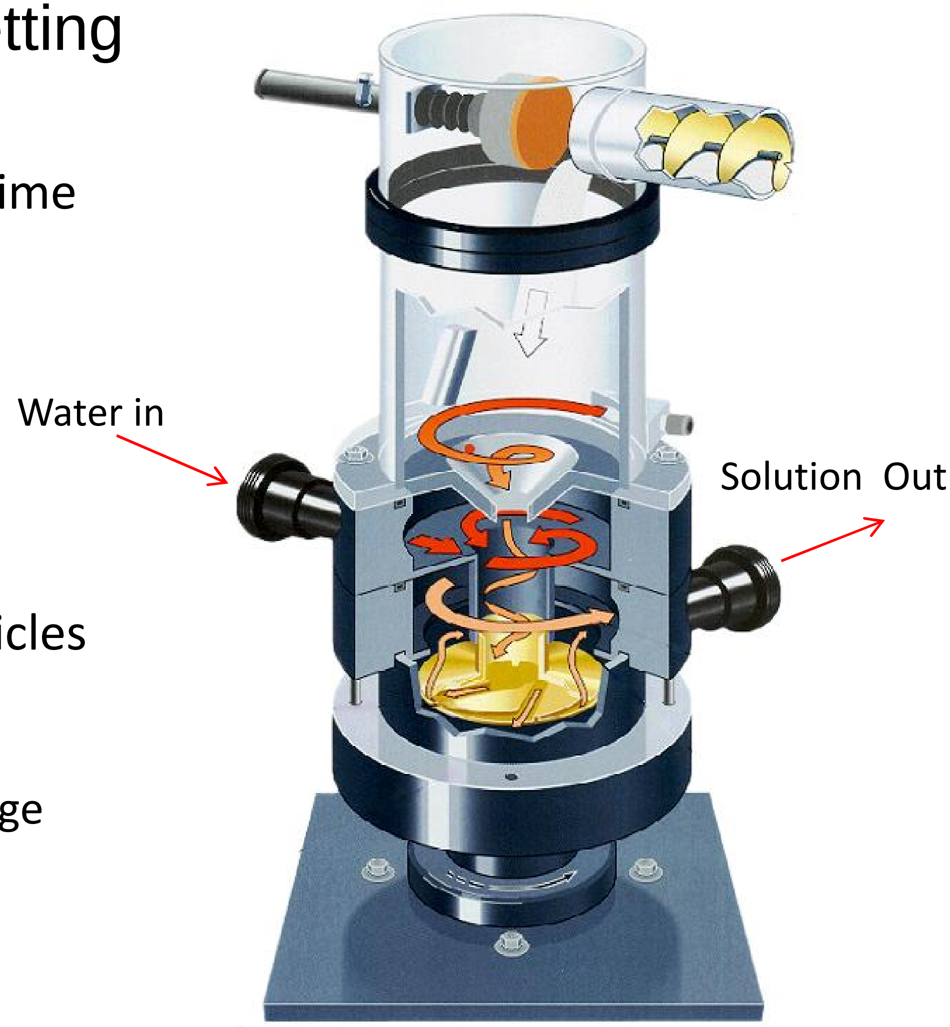
$G = 15{,}000\ sec^{-1}$

3,450 rpm for < 0.5 sec

Disperses Individual Polymer Particles

* No Fisheye Formation

* Shorter Mixing Time in Next Stage



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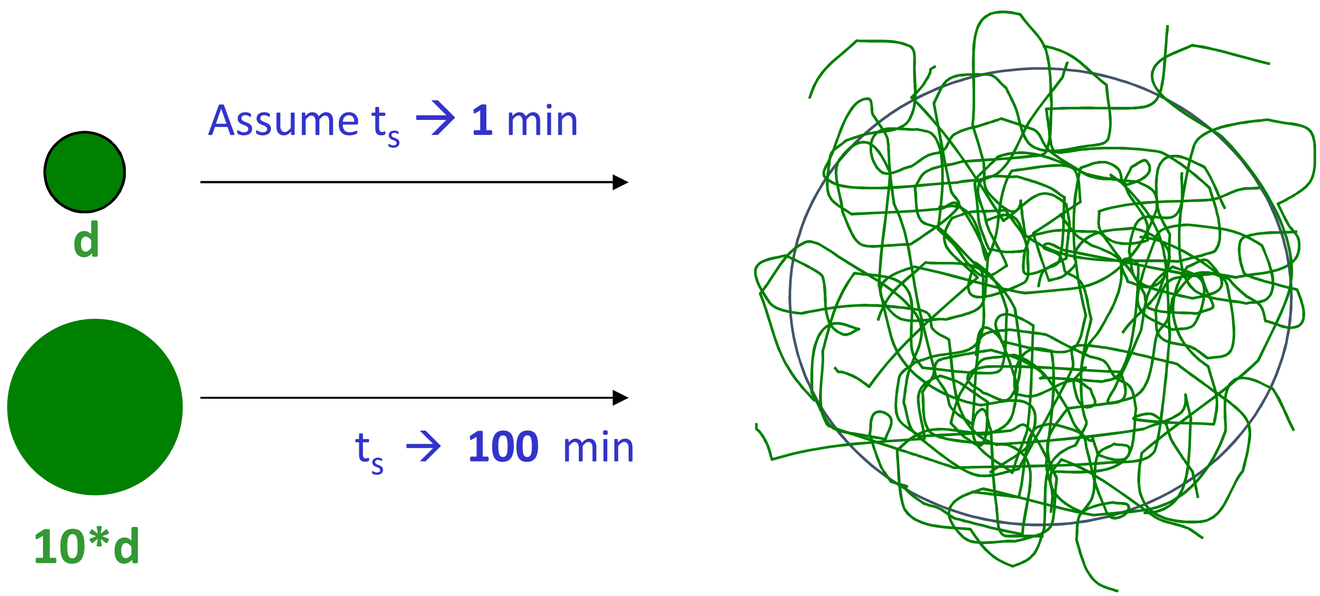
Why Initial High-Energy Mixing is So Critical?

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



Initial high-energy mixing → No fisheye formation → Significantly short mixing time

* 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, ***70%*** of tank diameter

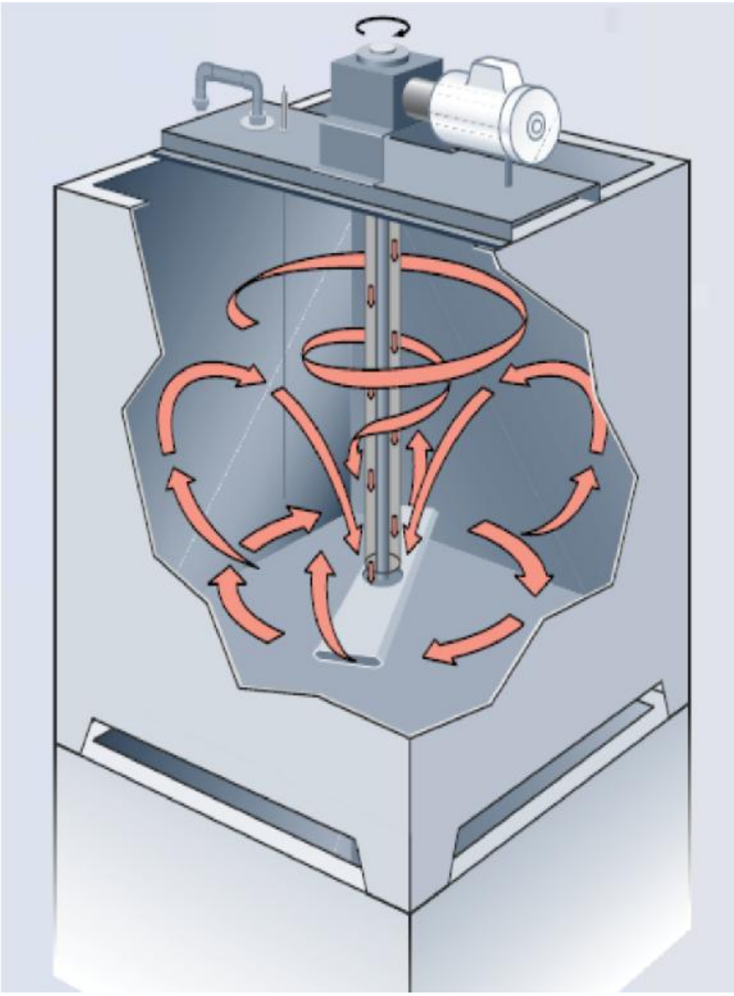
- Uniform Mixing Energy

Low RPM, 60 rpm

- Low-intensity Mixing
- Minimize Damage to Polymer Chain

Shorter Mixing Time – Due to high energy DD4

- 20 - 30 min for Cationic Polymer
- 30 - 40 min for Anionic Polymer
- Minimize Damage to Polymer Chain



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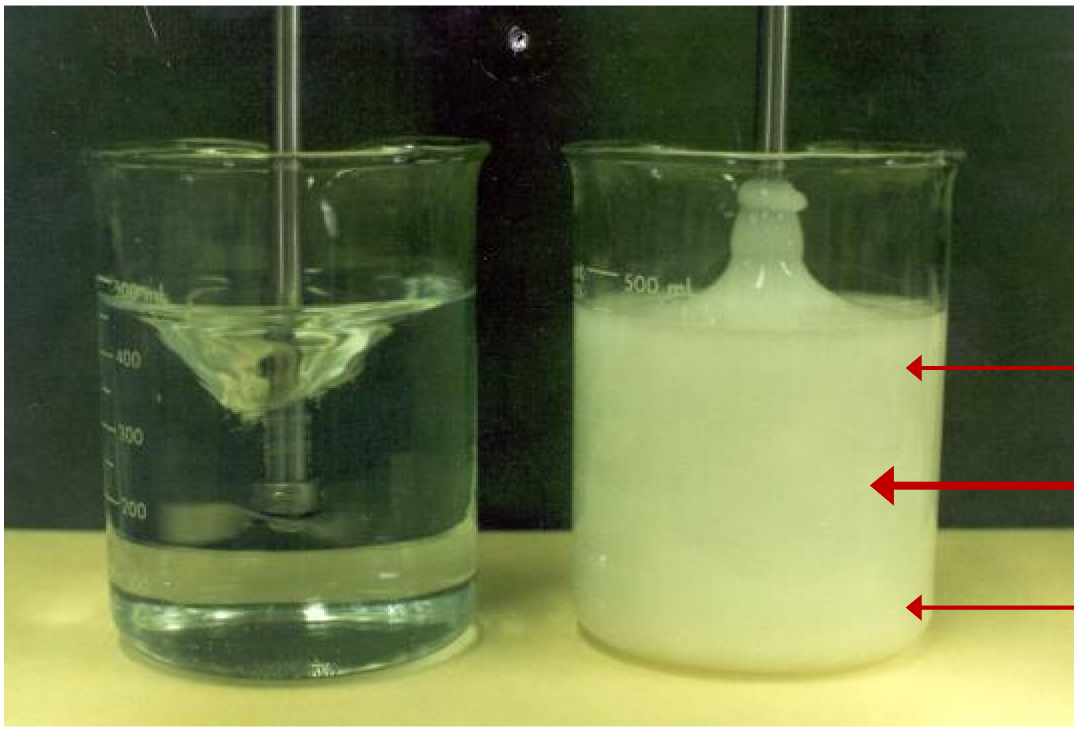
Weissenberg Effect in Polymer Mixing

* Polymer solution exceeding "critical concentration" climbs up mixing shaft
* Extremely non-uniform mixing
* Critical factor for "conventional" polymer mix tank → max 0.2% limit for HMW polymer



extremely low mixing

very high mixing

extremely low mixing

Water
(Newtonian)

Polymer Solution
(Non-Newtonian, Pseudoplastic)

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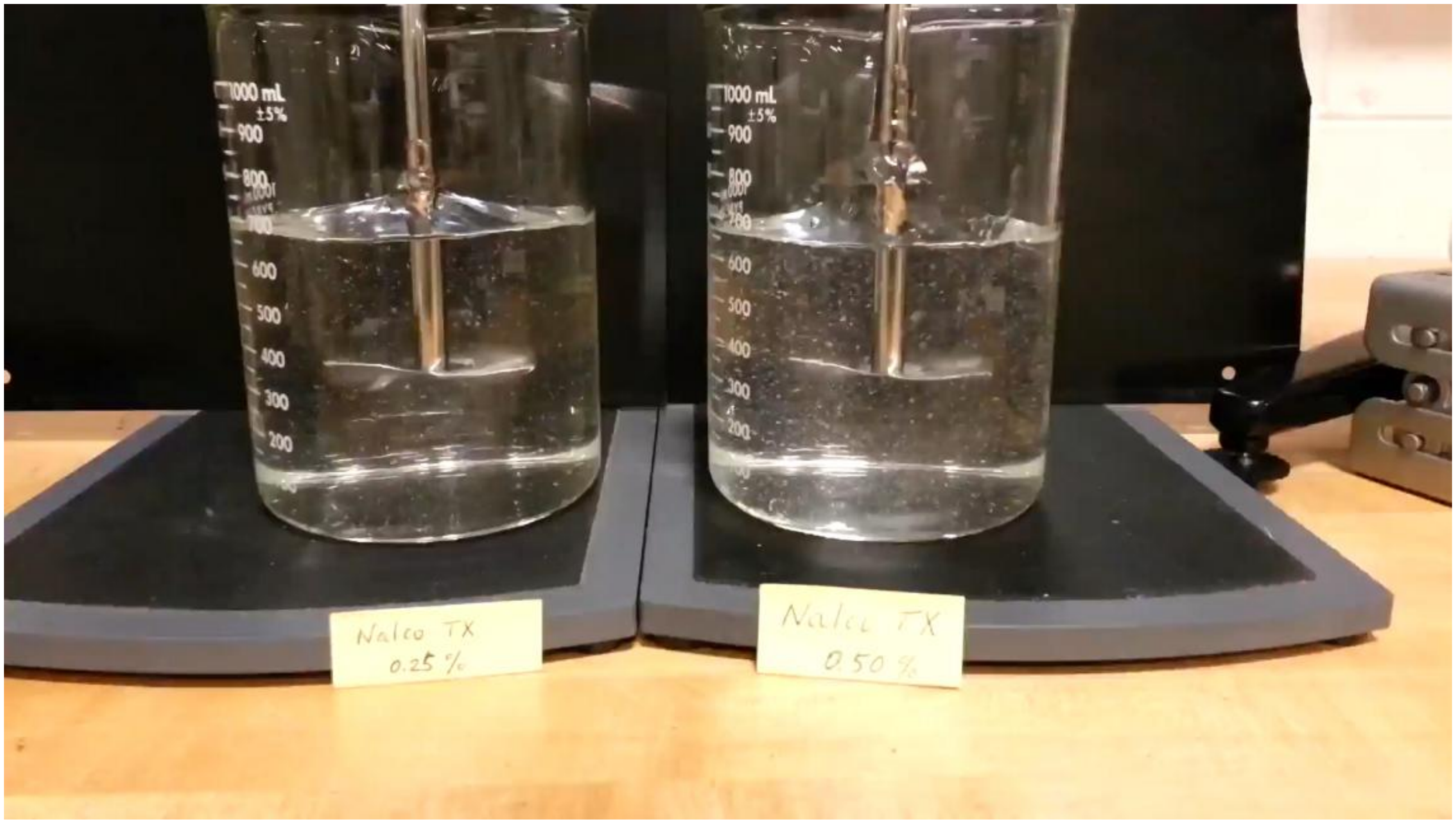
Notice polymer solution is "climbing" up the mixer shaft

(30 min after mixing (Nalco TX13182): 0.25%, 0.50%)



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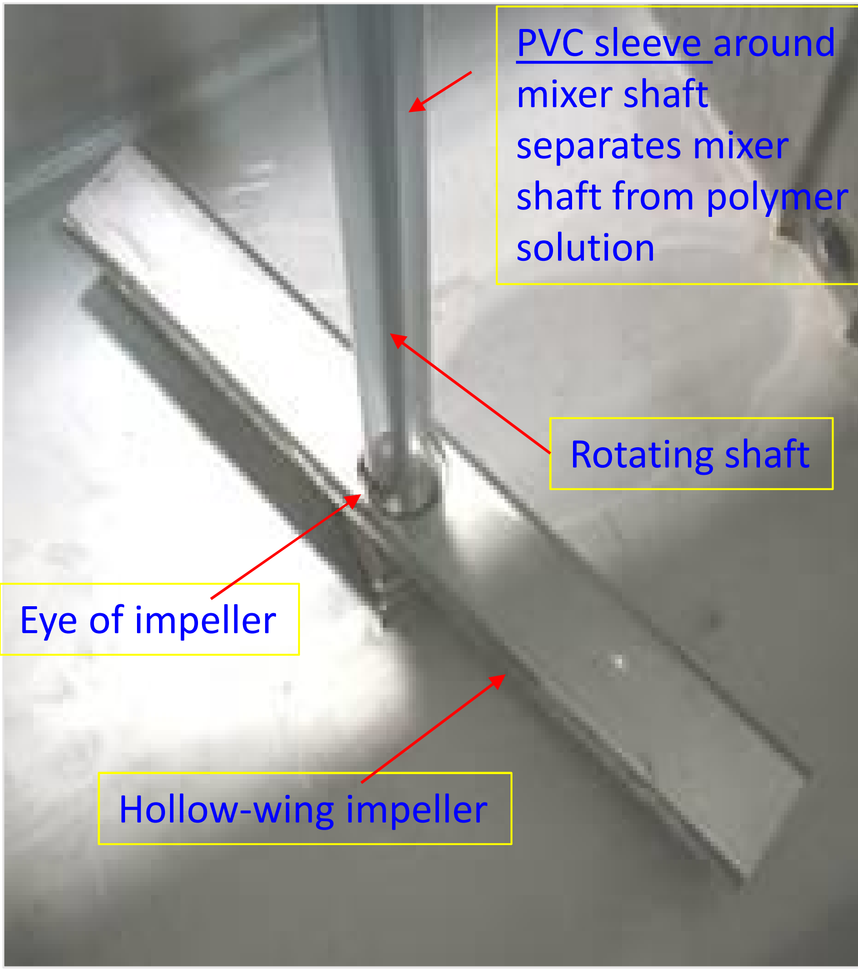
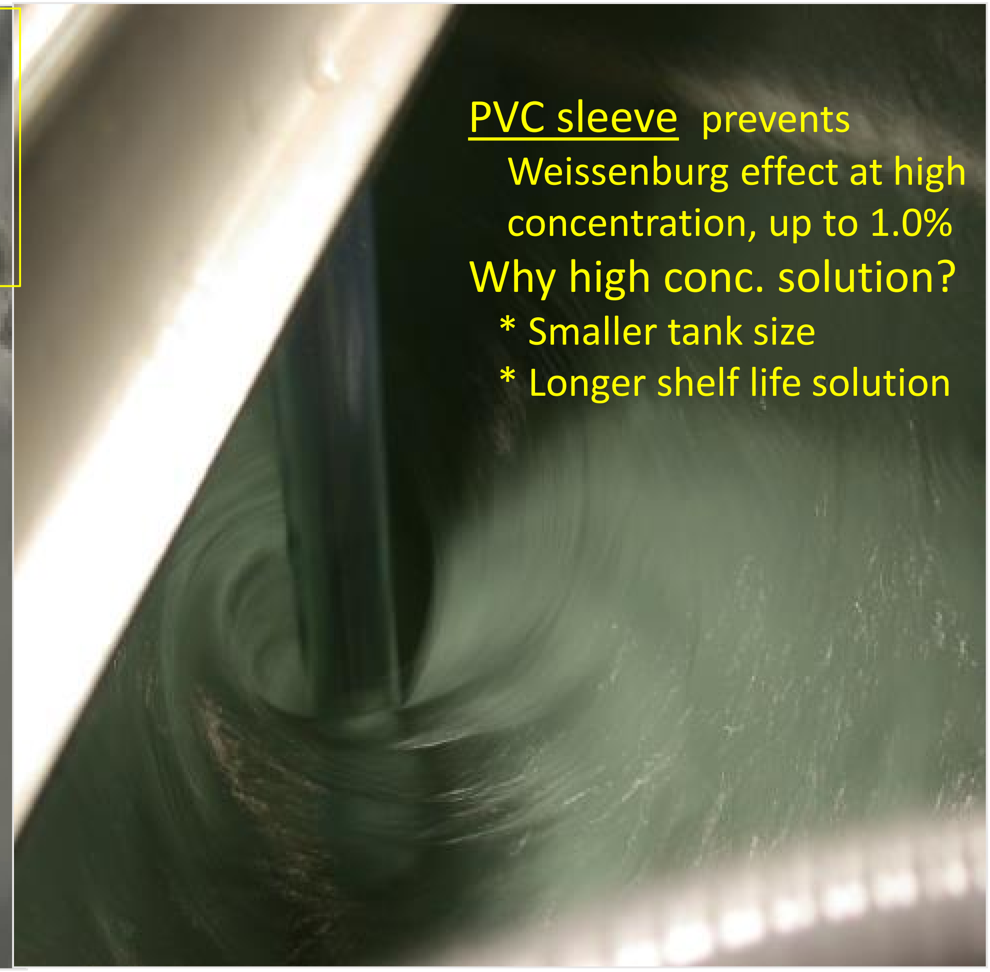
Polymer Mixing Tank With No Weissenberg Effect



Impeller / tank diameter > 0.7



Cationic Polymer Solution @ 0.75%

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Case Study: Dry Polymer Mixing System
Fairfield-Suisun Sewer District, CA

- Solano County, CA, 40 miles North San Francisco
- Design capacity: 24 MGD tertiary treatment/ UV
- Population served: 135,000
- Polymer use for dewatering (screw press) and thickening (GBT)

FKC screw press runs at average 70 gpm of sludge (2% solids content)

Problems with existing polymer system

- Struggled to make proper polymer solution
- Polymer performance inconsistent
- Frequent maintenance issues

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Pilot Testing with Two Polymer Mix Equipment

Existing Polymer System

- Initial wetting: air blower –> wetting head
- Mixing: two (2) 4,600 gal mix/age tanks
- 1 hour mixing and 4 - 8 hour aging time

UGSI PolyBlend Dry Polymer Demo System

- Initial wetting: high-energy mechanical mixing
- Mixing: two (2) 360 gal mix tanks
- 20 minute mixing, 10+ minute transfer time

Newly Installed Dry Polymer System

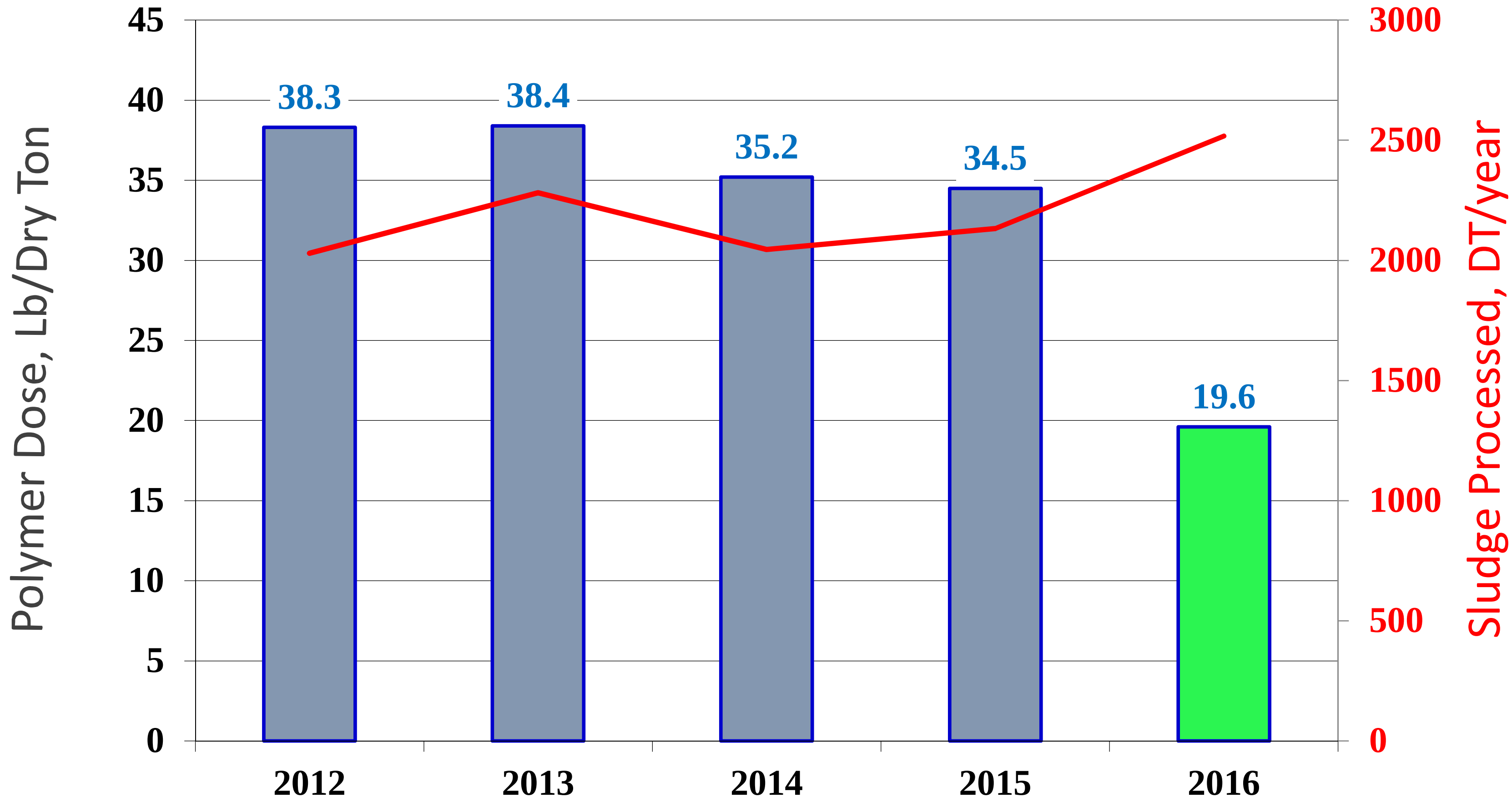
Existing impeller

Old: Two 4,600 gal mixing/aging tanks
* 60 min mixing, 2-4 hour aging

New: Two 1,000 gal mixing tanks
* 30 min mixing, 15 min holding

Hollow wing impeller

FSSD Installed New PolyBlend® DP2000
Performance Data in 2016



FSSD saved <u>42%</u> on Screw Press Polymer in 2016 despite an increase in solids throughput by <u>18%</u>

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AGING "accelerated maturing" *by initial high-energy wetting*

Very High-Intensity Mixing for Short Time

$G = 15{,}000\ sec^{-1}$ @ 3,450 rpm

Residence time < 0.5 sec

Disperses Individual Polymer Particles

* No Fisheye Formation

* Complete dissolution in 20 - 30 min mixing

* Aging – reduced or eliminated

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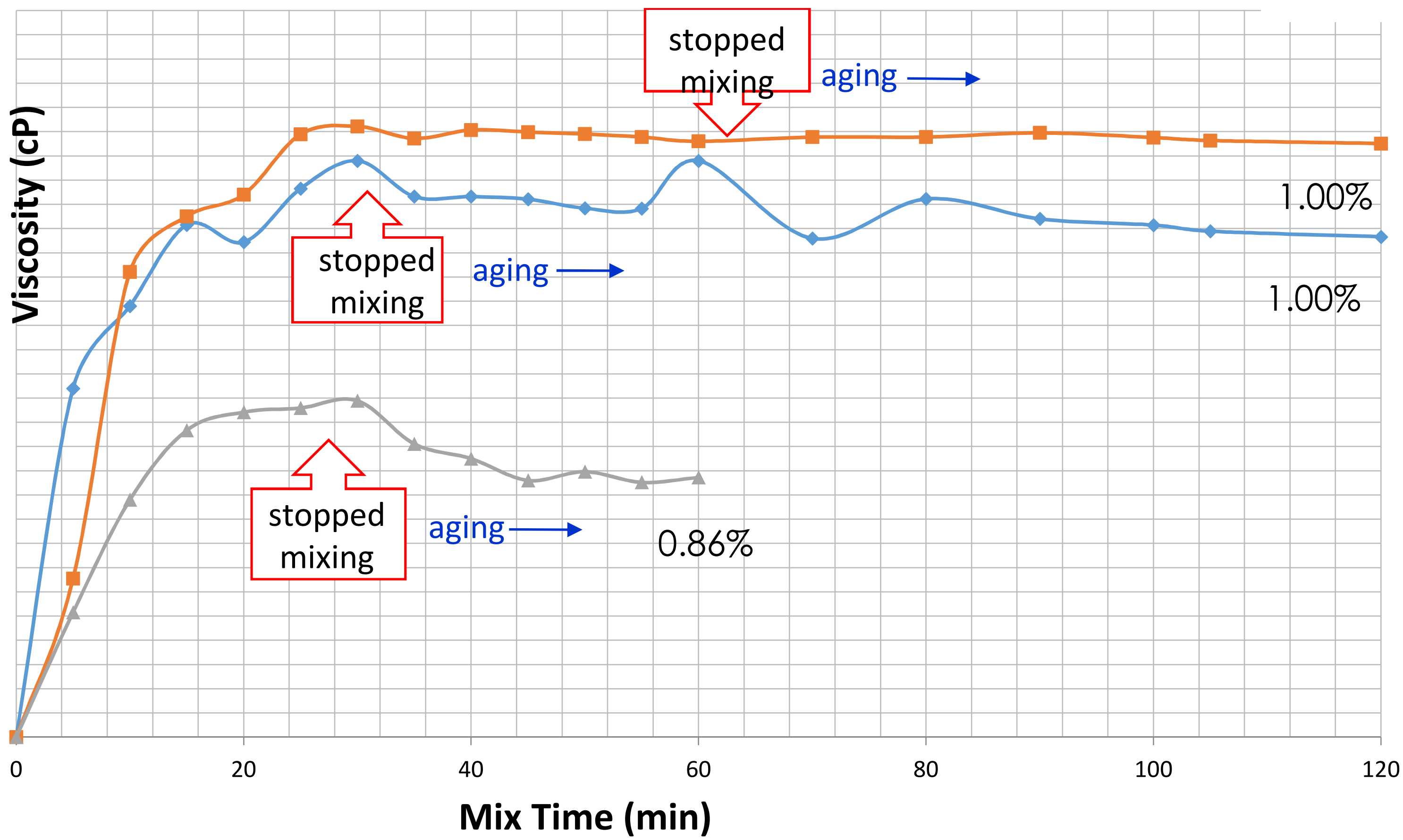
How Much Aging is Required for Dry Polymer?

Minimum aging required for well-designed equipment



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

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Aging – heavily depends on Polymer, Mixing, Water

Aging may help:

* Very high molecular-weight, low charge (nonionic) polymers, or
* Low energy mixing at initial wetting stage

Aging does not help:

* Medium high molecular-weight, high charge polymers, or
* Very high energy mixing at initial wetting stage

Aging may hurt:

* Reclaimed water for polymer mixing, or
* Low concentration of polymer solution

Aging must be reconsidered when reclaimed water is used

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Thank You
Any Questions?

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