How to Maximize the Value of Polymers in Wastewater Treatment Processes

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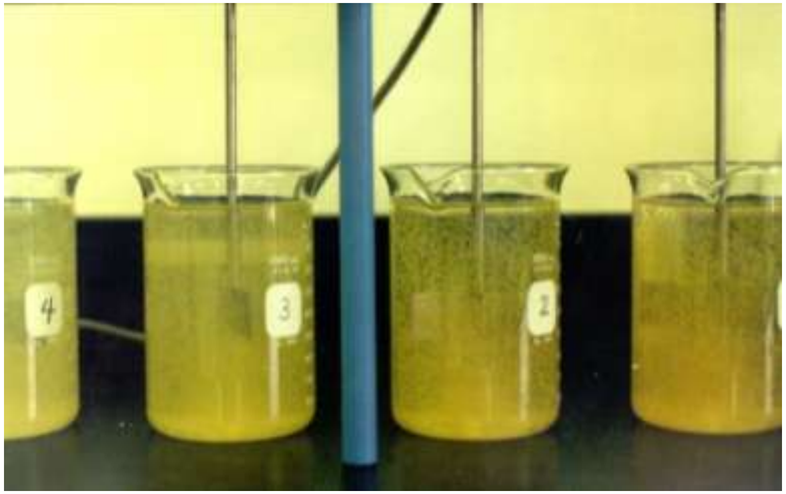
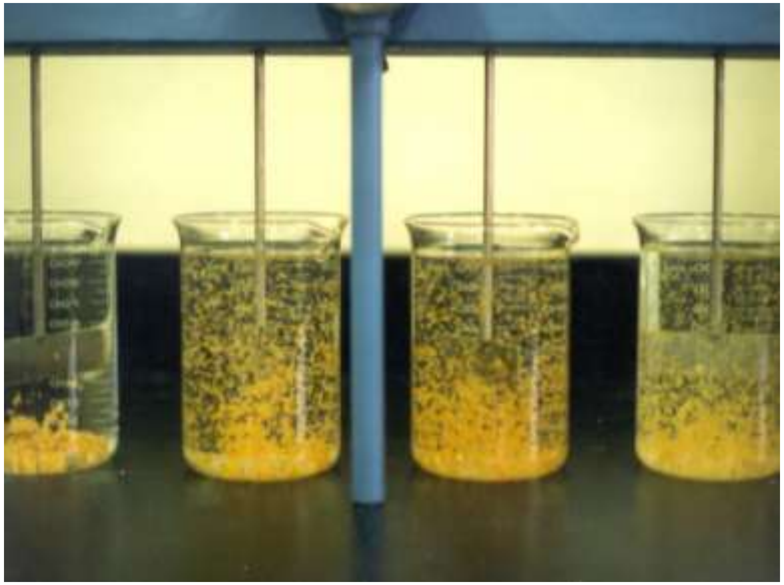
Coagulation and Flocculation





Coagulation

- Double-layer compression (charge neutralization)
- Enmeshment (sweep coagulation)

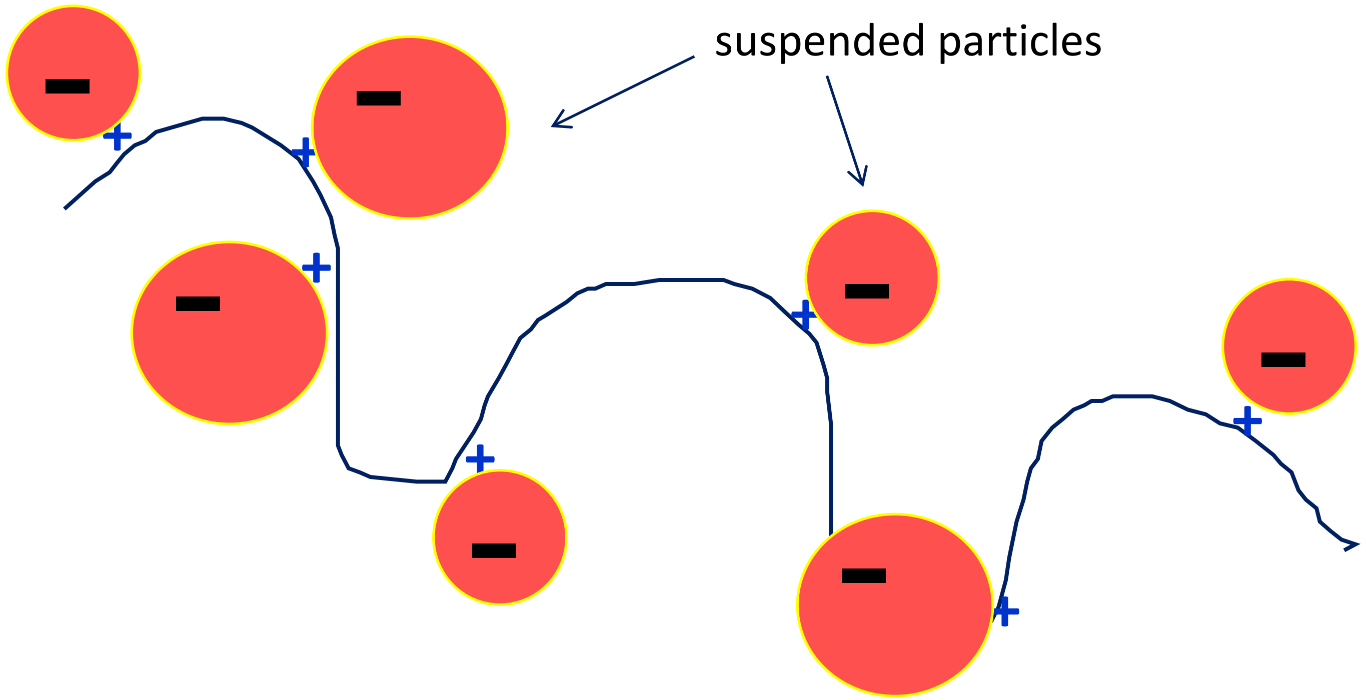
- Clay suspension + Ferric chloride

Flocculation

- Polymer Bridging

- Clay suspension + Ferric chloride + Polymer (0.1 - 1 ppm)

Flocculation - Bridging by Polymer Molecules



Extended cationic polymer molecule attracts negatively-charged suspended particles

Structure of Polymer

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

- **… - CH_2 - CH - [CH_2 - CH]$_n$ - CH_2 - CH- …**

CO CO CO

NH_2 NH_2 NH_2

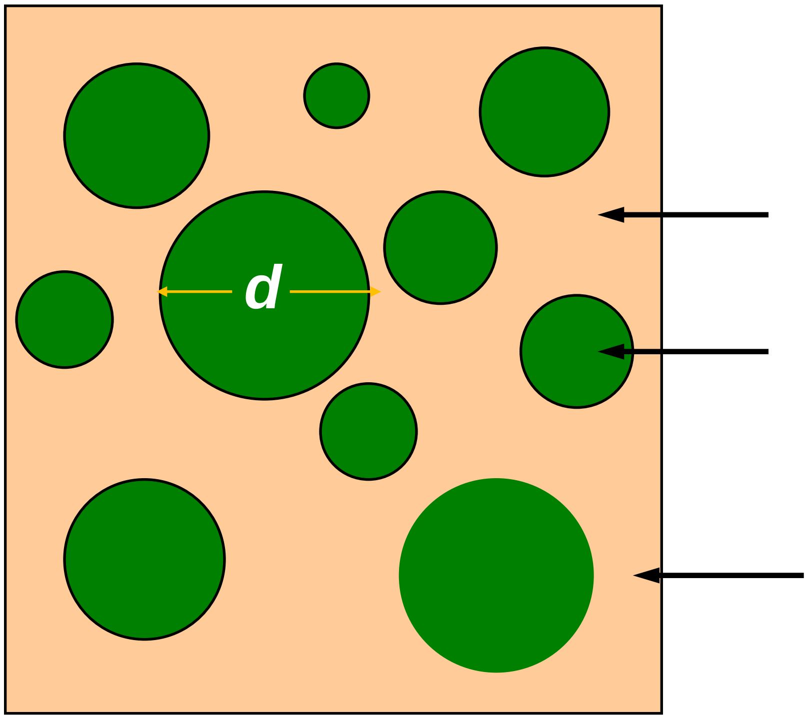
Most polymers in water industry are acrylamide-based.

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

n = 10,000,000 / 71
= 140,850

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

Emulsion Polymer - 40% active



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

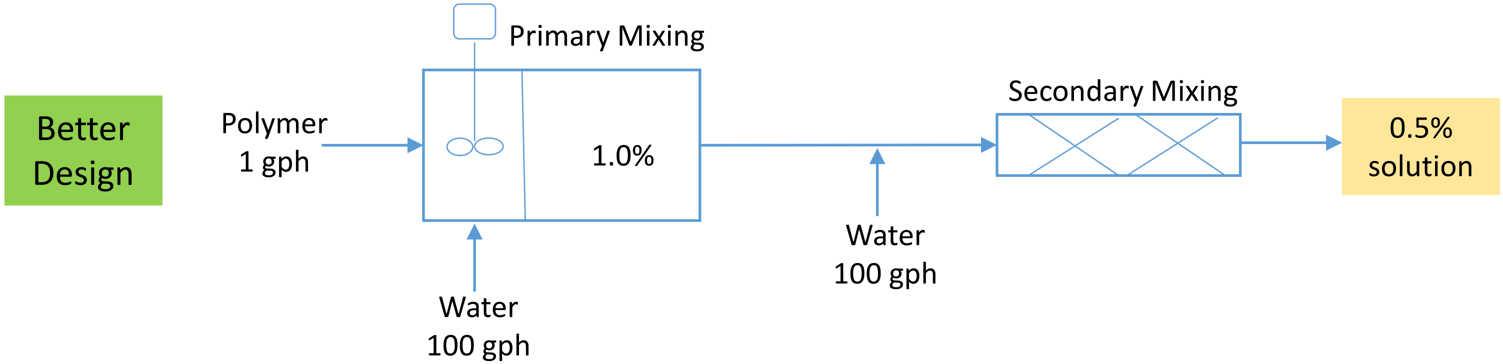
* 0.25% - 0.5% secondary mixing (dilution)

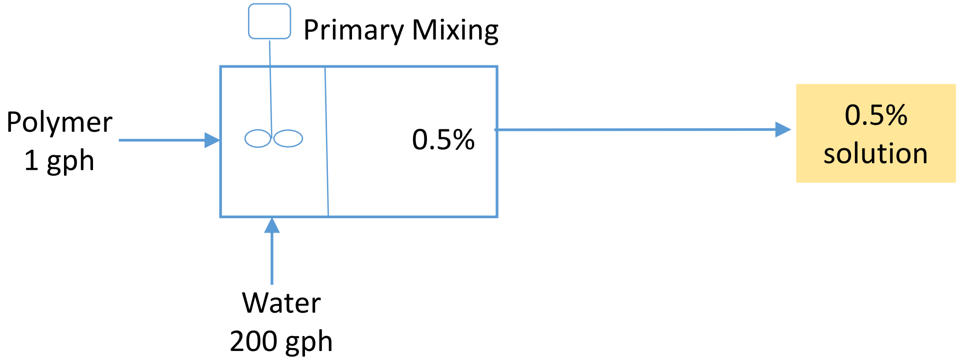
d = 0.1 to 2 µm

* AWWA Standard for Polyacrylamide (ANSI-AWWA B453-96), 10 - 11, 1996

How to Maximize the Value of Inverting Surfactant?

Primary mixing at high % + Secondary mixing at feed %





Storage of Emulsion Polymer

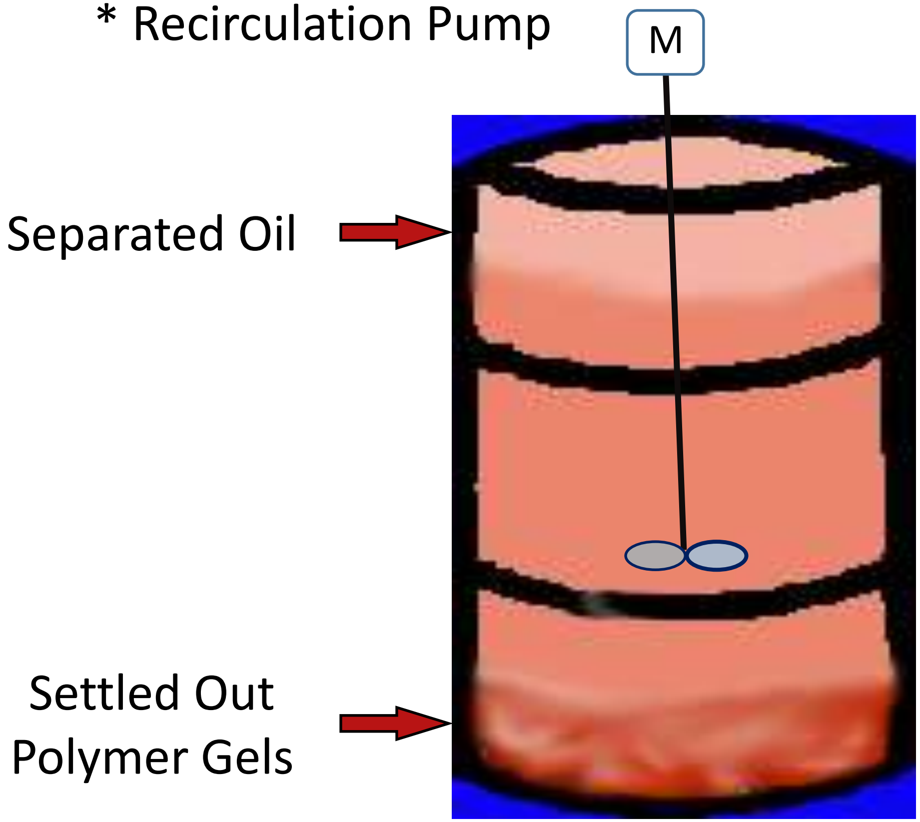
- Separation (stratification)

  * Drum (Tote) Mixer

  * Recirculation Pump

- Moisture Intrusion

  * Drum (Tank) Dryer



Recommended Dilution Water Quality

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

- Maintain less than 3 ppm

Temperature*: higher temperature, better polymer activation

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

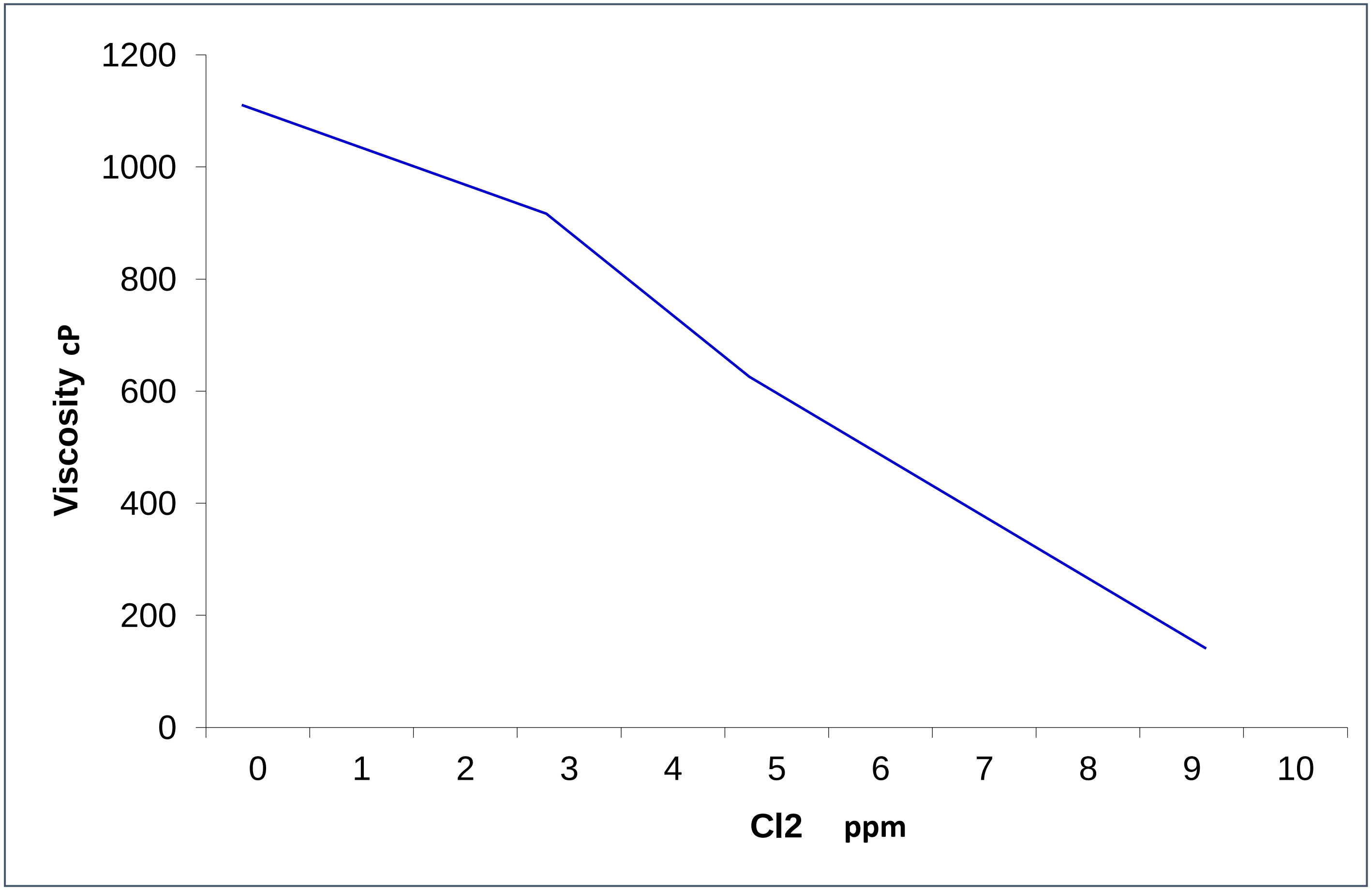
Suspended solids: strainer recommended if > 10 ppm

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^{o}F sludge

Effect of Chlorine (Oxidizing Chemical)

Oxidizing chemicals break down polymer chains



Polymer Activation (Dissolution)

1. Initial Wetting (Inversion)

Sticky layer formed

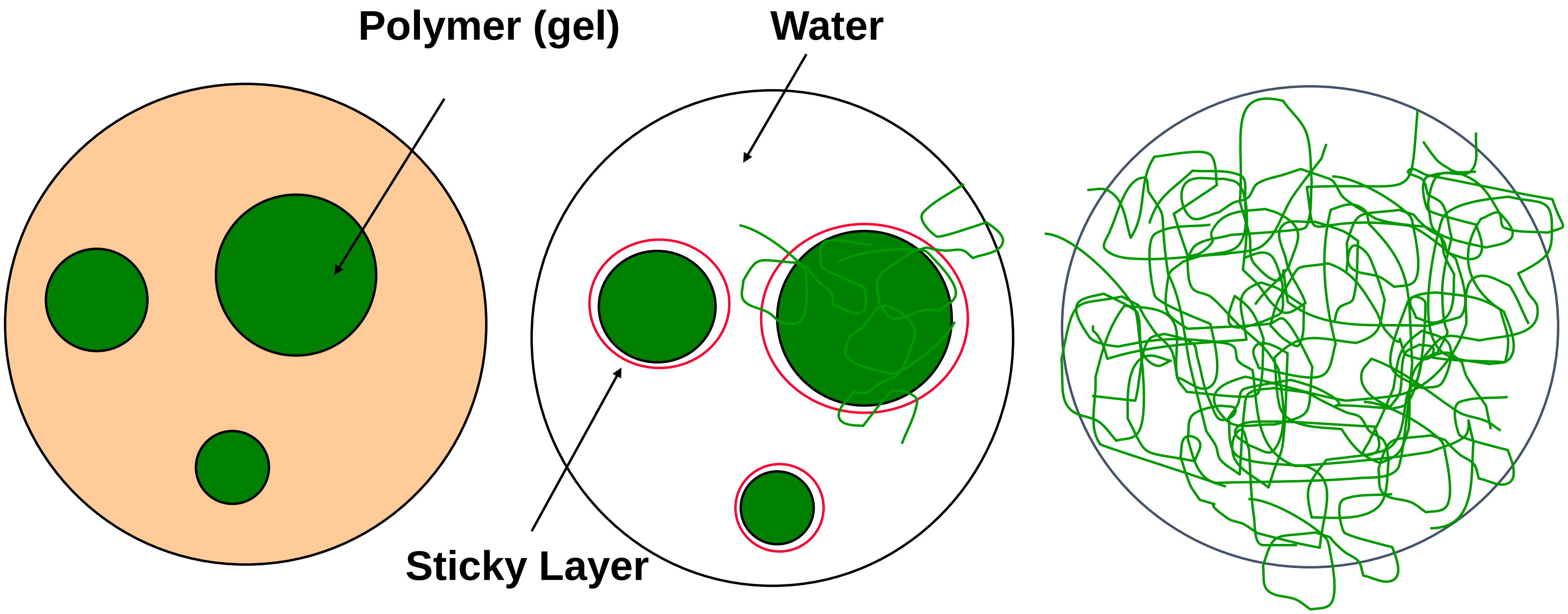
High-energy Mixing Required

2. Dissolution

"Reptation" by *de Gennes (1971)**

Low-energy Mixing Required

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



Mixing Effect on Polymer Activation

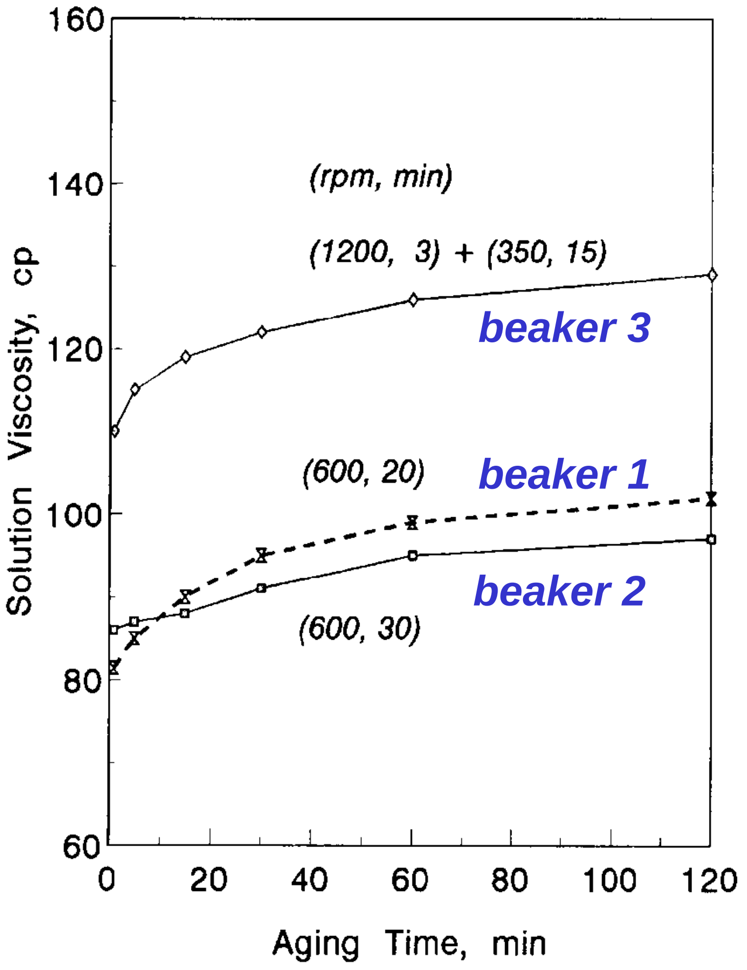
Viscosity of polymer solution
(prepared in 600 mL beakers)

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

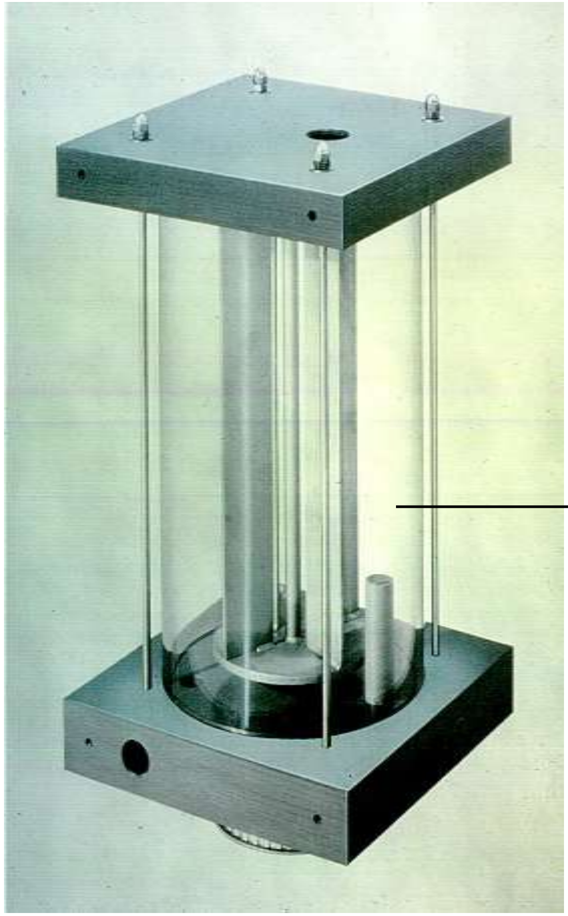
<u>Two-stage mixing </u>resulted in polymer solution of much better quality

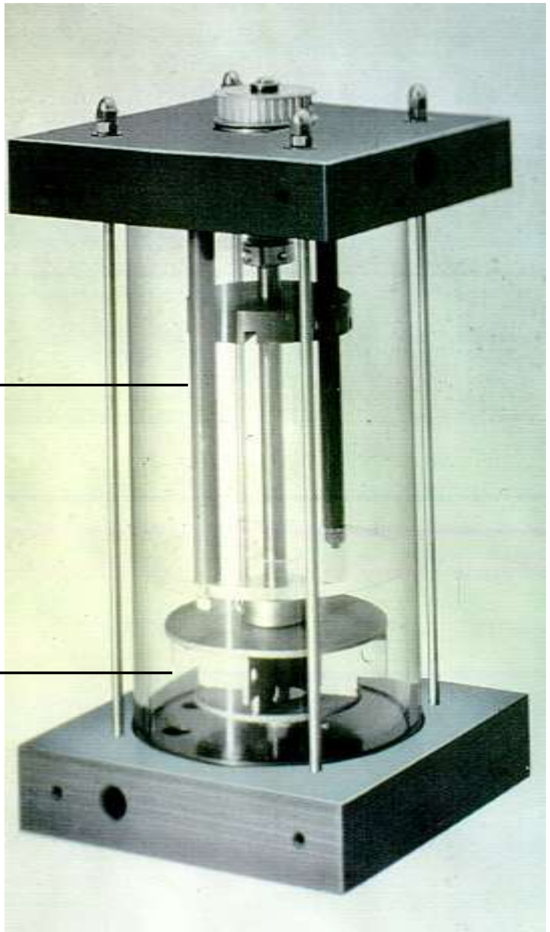
* High energy first: prevent fisheye formation

* Low energy followed: minimize polymer damage



Development of Two-stage Mixer





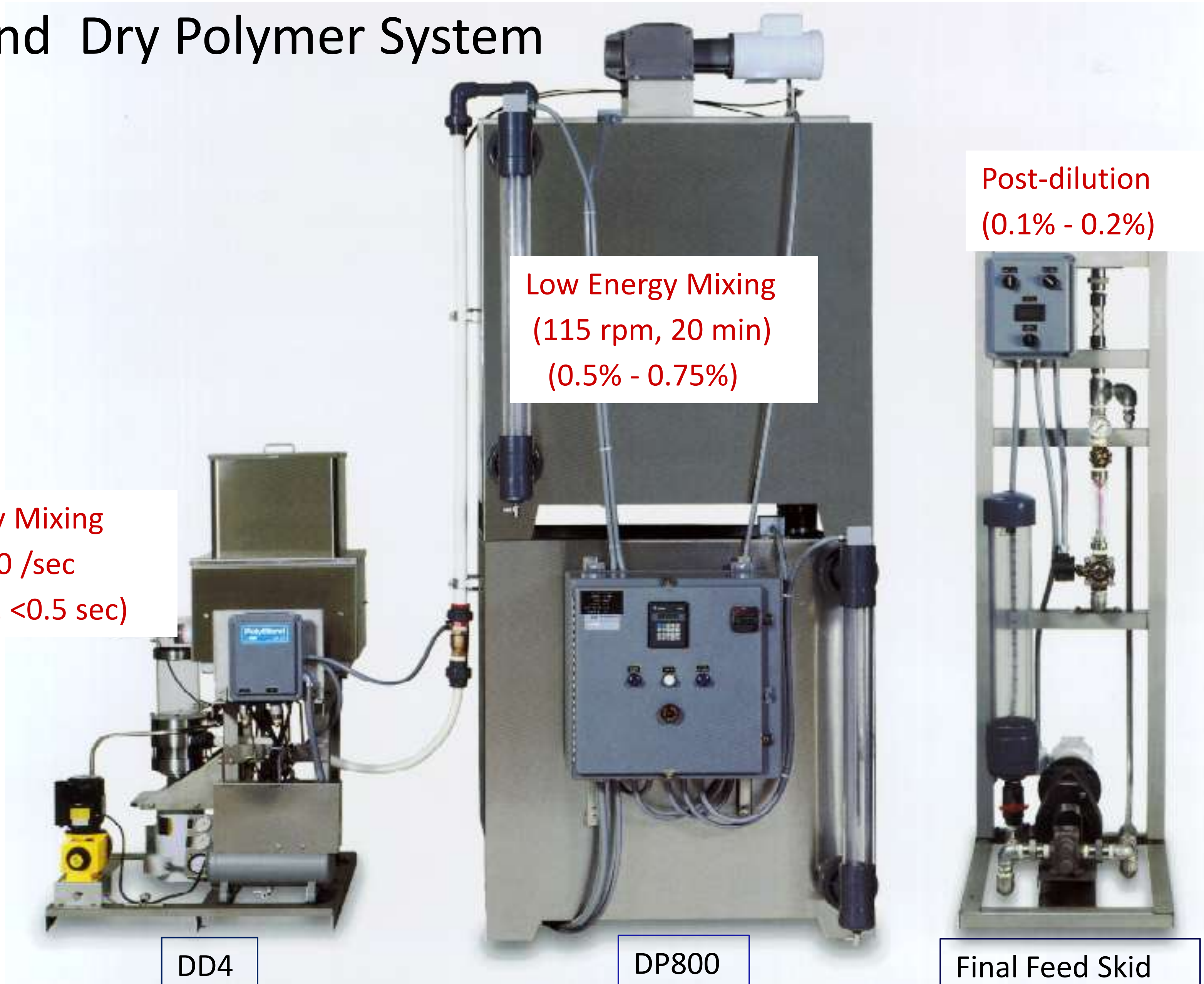
G-value, mean shear rate (sec^{-1})

Mixing Effect on Polymer Activation

Two-stage mixing → significant increase in polymer solution viscosity

Polymer	Mixing unit	Conc. %	Viscosity cP
Anionic	1-stage 2-stage	0.50	226 310 **(27%↑)**
Cationic	1-stage 2-stage	0.50	427 523 **(18%↑)**
Nonionic	1-stage 2-stage	0.50	156 178 **(12%↑)**

PolyBlend Dry Polymer System



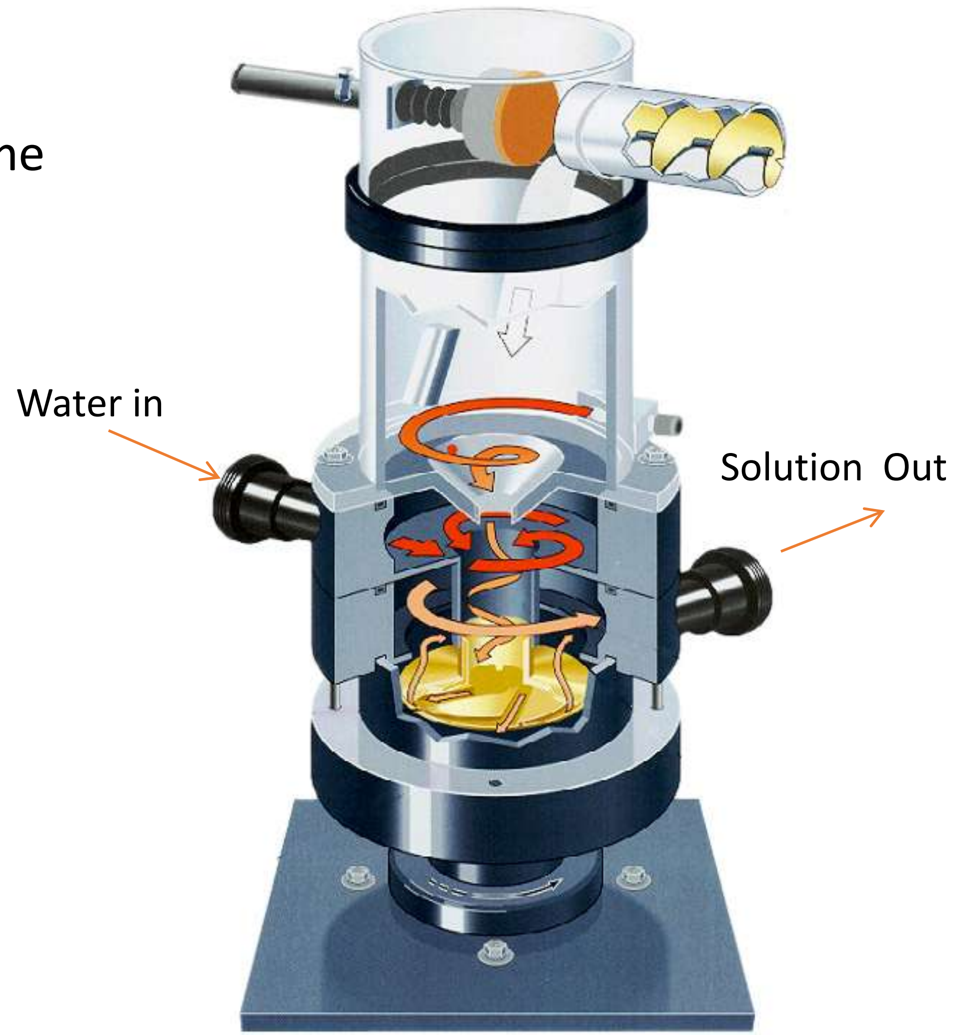
Dry Disperser (DD4) for Initial Wetting

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

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 - 115 rpm

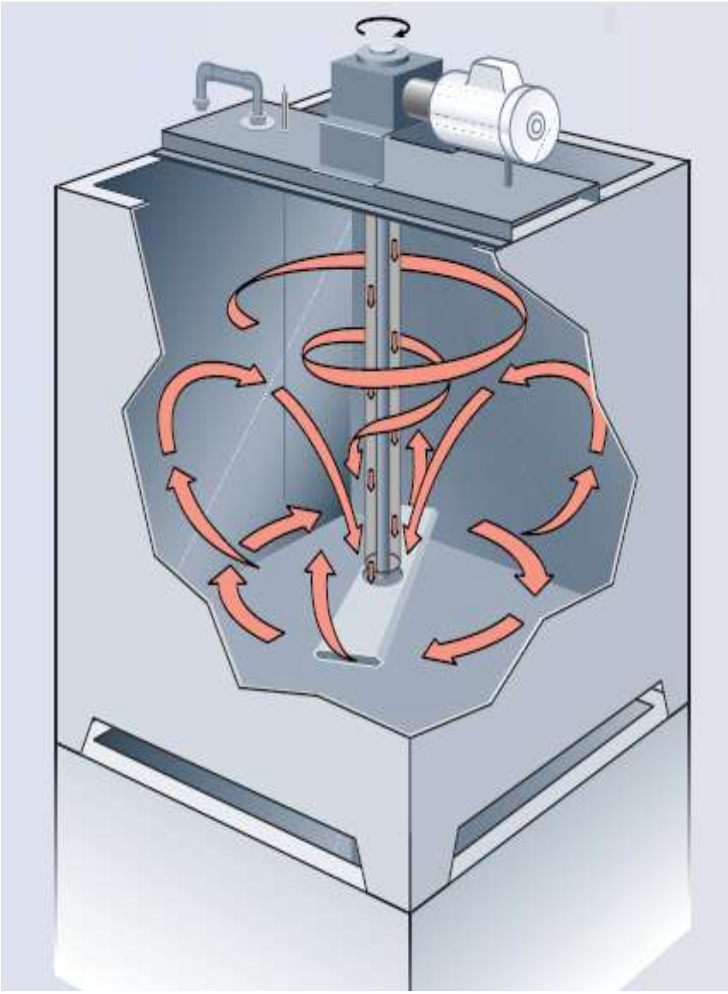
- Low-intensity Mixing
- Minimize Damage to Polymer Chain

Square Tank Design

- No Wessenberg Effect
- No Baffles Needed, No Dead Zone

Shorter Mixing Time – Due to DD4

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



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

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 dry polymer system

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

Fairfield-Suisan SD – Pilot Test Results

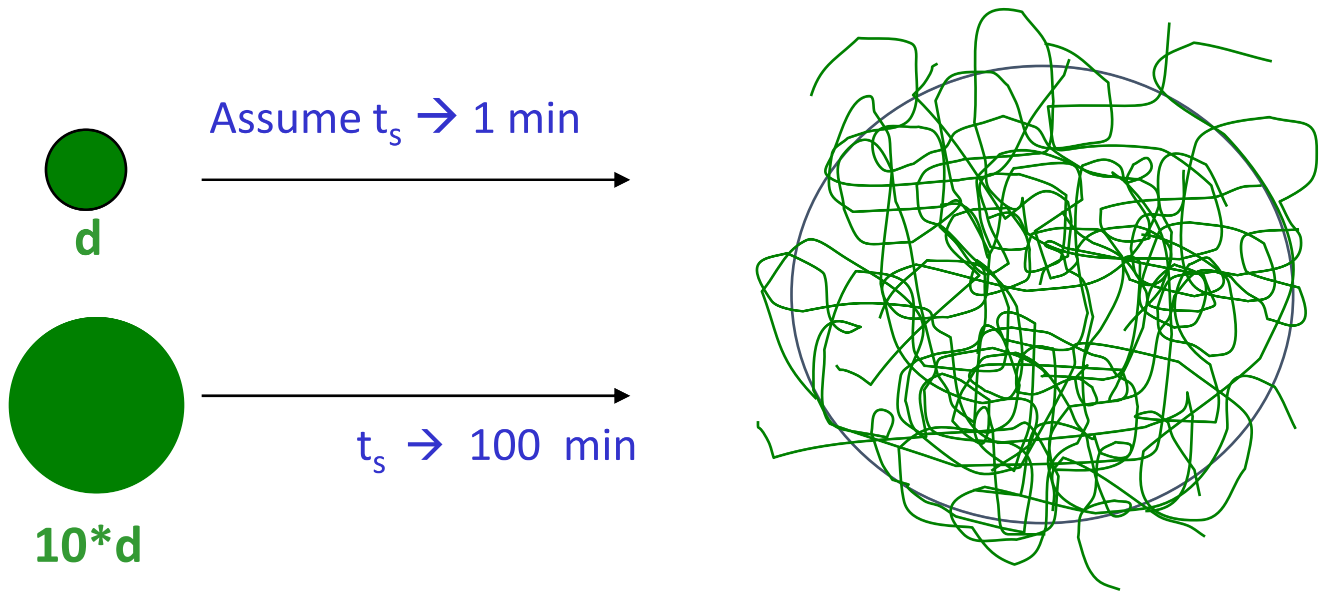
- **Dewatering by Screw Press** (3/21 – 4/21)
- Less polymer consumption
  - 1200 lb super sack lasted from 3.4 to 4.4 days
  - Daily usage from 359 lbs to 278 lbs (23% less)
  - $4,300/month polymer savings
- Better cake solids
  - 14% ~ 16% to average 16.4%

- **Thickening by GBT** (4/24 - 5/23)
- Less polymer consumption
  - Daily usage from 40 lbs to 17.5 lbs (56% less)


DP800/DD4 demo trailer at Fairfield

How could we achieve this?
initial high-energy mixing is a critical factor

Polymer swelling time, t_s ~ (diameter)^2 ***Tanaka (1979)****



Initial high energy mixing (DD4) → No fisheye formation →
Significantly shorter mixing time → Minimum damage to polymer structure →
Better quality polymer solution → Polymer savings

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

Thank You

Please contact Yong Kim with any questions

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Questions & Answers