

# Understanding Polymer Activation Principles

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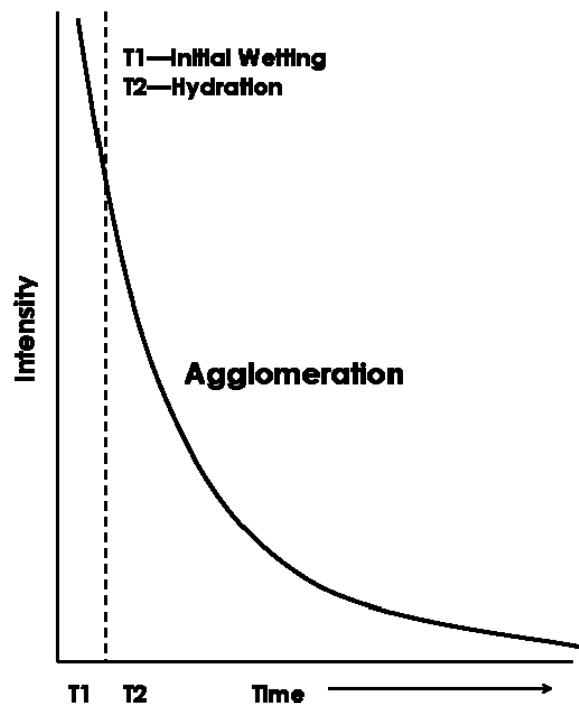
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## Agglomeration

The objective of a polymer preparation system is to fully hydrate or “uncoil” the polymer molecule. This hydration is designed to expose the active sites along the polymer molecule to the substrate they were intended to treat. Maximum exposure to these charge sites will translate to optimized performance of the polymer.

It has been widely accepted that agitation must be applied to the polymer/water mix to effectively disperse polymer particles into the dilution water. This is due to the fact that when polymers begin dissolving, a film of concentrated polymer solution builds up around the polymer particles. This makes them “gluey” and subject to sticking to each other to form aggregates or agglomerations.



These agglomerations are commonly called “fisheyes” or “stringers.” As these agglomerations occur they tend to entrap undissolved polymer at the core of the agglomeration. They can range from microscopic to golf ball size and even bigger. It should be obvious that feed systems which deliver fisheyes to the point of use are wasting significant amounts of polymer since geometry tells us that the amount of polymer trapped within the volume of a sphere is far greater than that making up only the surface area. If inadequate or improper energy is applied to the polymer/dilution water interface at the “moment of initial wetting,” agglomerations will form. The tendency to form agglomerations is shown above.

The owners and operators of batch tank systems are all too familiar with agglomerations since batch systems do not apply the proper type or amount of energy required to completely disperse the polymer particles into the dilution water. So, over the years, operators have attempted to compensate for this drawback by extending the mixing time.

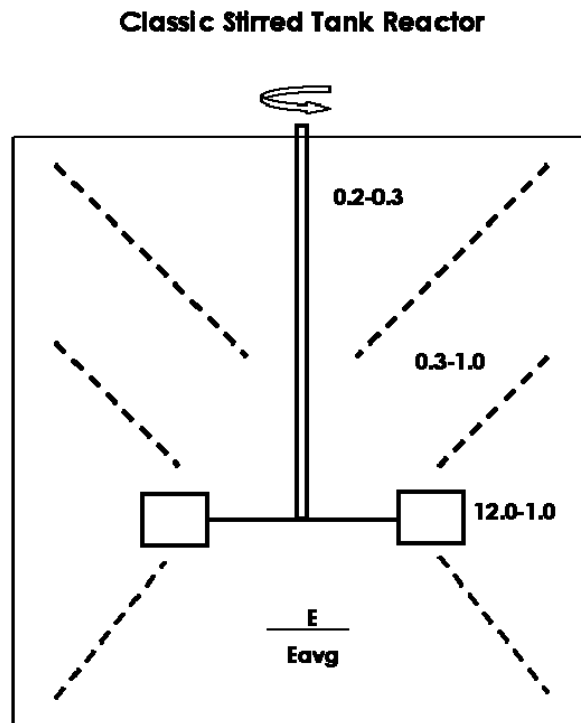
This is the foundation for the sanctity of the aging process. Unfortunately this compensation actually diminishes the cost-effectiveness of any polymer program. This is due to the exposure and re-exposure of semi-hydrated and fully hydrated polymer molecules to inappropriate levels of high shear energy during this extended time mixing. To fully appreciate the impact of this process we must now examine the issue of fragility.

## Fragility

Classical studies, which measured the agitation intensity distribution in the universally accepted stirred tank reactor (a 6-sided turbine impeller occupying 50% of the diameter of the mixing vessel), show that under ideal laboratory design conditions the highest point of energy (directly at the impeller tip) is at least 60 times greater than the point of lowest energy (farthest away from the impeller tip). In spite of the relative lack of uniformity of energy, for years this model has been identified as the ideal batch tank design by fluid dynamics experts.

When we leave the laboratory and evaluate a typical batch system in use today, we see the turbine impeller replaced by a propeller blade. This modification alone changes the high to lower energy ratio from 60:1 to some value greater than 500:1.

When the propeller occupies anything less than 50% of the diameter of the mixing vessel, this high to lower energy ratio dramatically increases.



**Distribution of mixing intensity within a stirred tank with a turbine type impeller. Numbers shown denote the ratio of local energy dissipation rate to mean energy dissipation rate (Okamoto, 1981)**

In many operating batch tank systems it is common to see the propeller occupying less than 10% of the mixing vessel's diameter. In this case, the high to lower energy ratio increases to a value well beyond 2000:1.

Finally, when we remove the mixer to the corner of the tank (because it's easier to mount in this manner) we create an environment which has a point of high energy which is no less than 3000 times greater than the point of low energy. This lack of uniformity of energy results in the destruction of a significant percentage of polymer molecules.

Maintaining a uniform shear field of energy is vitally important to the polymer activation process. Polymers are easily ruptured by excessive force when, after they have extended, they are re-exposed to this type of high shear environment.

The hydrodynamic force required to break a carbon-carbon bond (the bonds that hold together the monomers to create the polymer chain) is very slight.

Studies by Van de Ven, 1981, reveal that a million polymer molecules can be ruptured by the force of 0.01 N, a force equivalent to 1 gram of free-falling water. This is a significant revelation to many batch system operators. If the force of a raindrop can destroy a million carbon-carbon bonds, one can imagine the impact of continuous exposure and re-exposure to the “hot and cold zones” in a typical batch mix system.

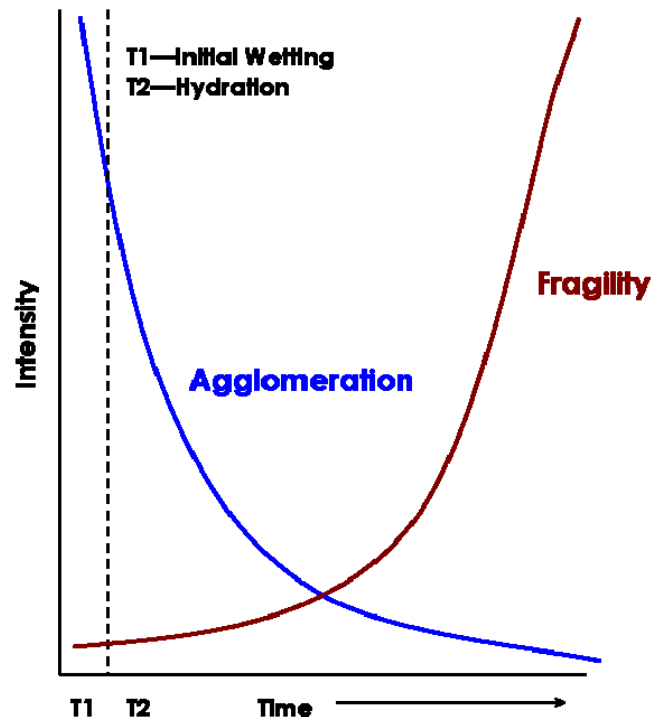
Somewhere in the batch mix tank there may exist the right shear force to activate a given polymer. But in zones of lesser energy, polymers clump together to form fisheyes of all sizes, even microscopic. While this is occurring, in zones of greater energy they are literally chopped to pieces.

This is particularly easy to understand when we consider that the fragility of the polymer molecules increases with the degree of hydration and time. See above.

So far we have identified two key issues which can help explain the “more for less” performance gained with Tempest technology. We have seen that the lack of controlled energy at the moment of initial wetting promotes the formation of wasteful agglomerations.

To compensate for this, operators of conventional mix systems have been forced to allow the polymer solution to mix for extended periods of time in an environment which literally destroys a percentage of the polymer. There is simply no way around this vicious circle when using a conventional polymer preparation system.

To fully appreciate this dilemma we now must examine how the rate of hydration is affected by a polymer feed system design.



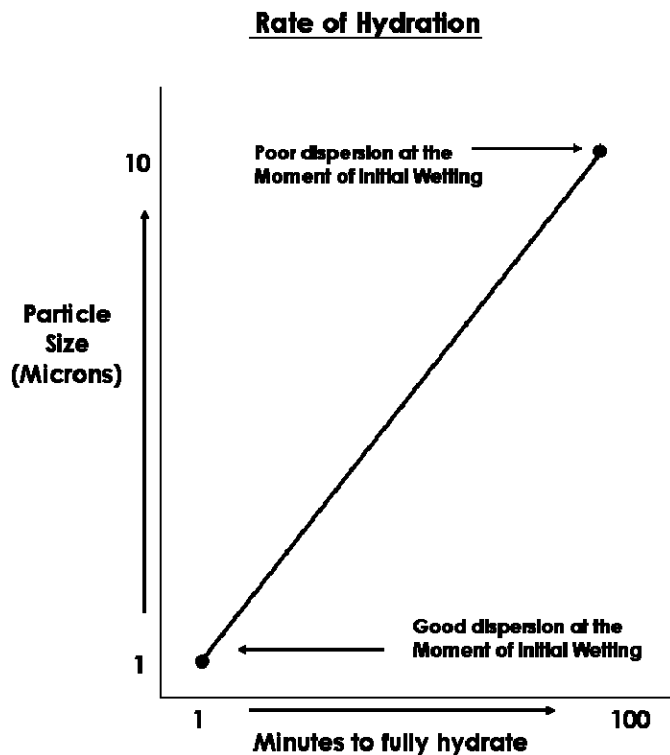
## Rate of Hydration

The time that the polymer solution needs to be exposed to this mixing process is directly related to the ability of the system to prevent agglomerations. The rate of hydration (how fast the polymer solution can be readied for delivery to the point of application) is hinged upon the polymer particle size. As particle size increases, the required aging time increases. In fact there is a direct relationship between aging time and particle size that is well documented. Aging time increases by the square of the radius of particle size.

It is well known that a particle size of 1  $\mu\text{m}$  which undergoes the hydration or “uncoiling” process will swell 6 to 7 times in radius and take on roughly 300 times its volume in water. Suppose, for example, that this process will take approximately 60 seconds.

Without adequate hydrodynamic shear at the moment of initial wetting, agglomerations will increase the particle radius many times. It is common to see particle radii of 10  $\mu\text{m}$  or more in conventional systems.

Based on the relationship of particle size versus the rate of hydration, an agglomeration of 10  $\mu\text{m}$  will take 100 minutes to fully hydrate! We can see now why aging was sacred.



The key to minimizing polymer damage and optimizing the polymer program effectiveness is the prevention of agglomerations which occur at the first milliseconds of initial wetting. This must be done with a high, hydrodynamic shear energy which disperses the polymer into small particles.

These small particles hydrate much more rapidly than those which are allowed to form agglomerations. Adequate dispersion energy greatly truncates the time that the polymer solution needs to be mixed. Herein lays the explanation of why Tempest technology typically reduces polymer usage. The Tempest design prevents agglomerations, promotes rapid full hydration and minimizes the destruction of polymer molecules.

## Charge Site Exposure

The polymer performance observed with Tempest system testing relates to the ability to fulfill the objective of maximum charge site exposure.

The activation of a polymer molecule results in the exposure of charge sites on the polymer chain and an increase in viscosity of the polymer solution. Therefore, as the degree of activation increases so does the overall charge viscosity of the solution. The amount of polymer activation can be quantified by surface charge or rheological type measurements. Tempest systems result in a charge site exposure rate which cannot be equaled by a conventional preparation system.

A review of the graph to the right illustrates the fact that conventional systems cannot achieve the level of charge site exposure that is achieved with the Tempest system design even if the aging process is hyper extended. This is due to the fact that micro agglomerations are allowed to form during the initial stages of dilution.

Once again, this relates to the magnitude and type of energies employed at the moment of initial wetting. In spite of the extended aging and mixing time, a percentage of polymer remains inactivated. Conversely, the superior dispersion capabilities of the Tempest prevent even micro agglomerations. This promotes maximum charge site exposure and greatly reduces the mixing time required for full hydration. This capability translates to improved polymer performance in virtually any polymer application.

## Summary

Cost-effective performance of a polymer program is tremendously influenced by the activation mechanics described above. The Tempest and DP Series were designed with a full understanding of these principles. The combination of research, application expertise and quality engineering has come together in this design.

We have seen that proper amounts of controlled dispersion energy at the moment of initial wetting prevent agglomerations. This in turn eliminates the need to expose the polymer to extended time aging and the polymer destruction associated with that process. Thus, waste is minimized and overall polymer consumption is reduced.

Further, the prevention of agglomeration promotes the full hydration of all the polymer. This in turn maximizes charge site exposure, which in turn improves polymer performance. We can now understand the basis of the “more for less” phenomenon of Tempest systems.

