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Technical Topics

How Polymers Work

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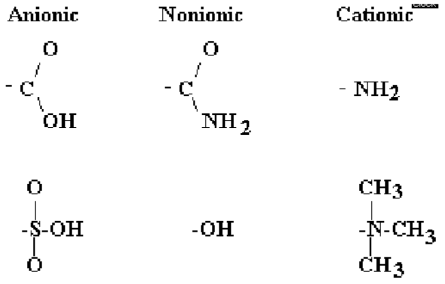
The development of synthetic polymeric technology has facilitated a dramatic improvement in the ability to control scale and fouling in cooling water systems. By varying raw materials and manufacturing techniques, materials with different molecular weights and reactive sites can be produced to meet specific deposit control objectives. A wide variety of polymers are used and can be made to function as flocculants, as dispersants, and as scale inhibitors.

The term polymer is a very general term describing materials of very different properties. A polymer is a large molecule consisting of a number of repeating units or structures. Polymers can be further characterized by electrical charge and molecular weight. Polymers may be cationic (positive), anionic (negative), or non-ionic (neutral). Examples of functional groups with these characteristics are shown below.



Functionality

The charge and the functional group of a polymer affect its reactivity. Molecular weight greatly changes the properties of a polymer. Molecular weight can range from 1,000 to several million and indicates the length of the polymer chain or the size of the polymer. By using different functional groups, charge density, and different molecular weights, the properties of the polymer can be modified as desired.

Polymers used for flocculation have high molecular weights, usually between 1,000,000 and 10,000,000. This large size of the polymer chain promotes bridging between particles to form a low density but large floc. Agglomeration of particles can be greatly improved by using polymer charge to neutralize the charges present on the original particles. For example, most natural suspended matter such as mud and silt tends to have a negative particle charge. The like charges on the particles cause them to repel each other which tend to keep the particles dispersed. By using a cationic polymer, the negative charges on the particles can be neutralized allowing the particles to group together. Care must be taken to avoid having the cationic polymer reverse the charge on particles causing them to disperse. Combining the effects of charge neutralization and bridging can develop large floc particles and this effect is used to good advantages in clarification and waste treatment where low turbulence permits the settling of the floc.

The flocculating phenomenon can also be used as deposit control in cooling water systems. The floc particle formed has a much larger surface area and is much less dense than the individual particles. By using flocculating polymers, light, fluffy flocs are formed which can be carried through the cooling system by the water velocity much as a kite is blown by the wind. In this way, mud and silt can be prevented from forming troublesome deposits. Care must be taken to insure consistent good water velocities in the cooling system or the floc will tend to settle in low flow areas just as it does in a clarifier. The use of flocculating polymers for deposit control is most appropriate in once-through systems or when side filtration is used.

Polymers can also be used for dispersing particles so they do not tend to settle. For dispersancy, low molecular weights, usually 1,000-20,000 are most effective. Both anionic and non-ionic polymers are effective dispersants. Anionic polymers are effective because they will increase the negative charges of particles causing the particles to repel each other and more easily kept in suspension so they can be removed by normal bleedoff. Low molecular weight is used to prevent bridging from occurring.

Non-ionic surface active polymers are also effective in deposit control. These polymers act much like detergents by breaking down surface tension allowing the water to break up particles into a fine suspension which do not tend to adhere or settle already. Just as the detergents we use in everyday life, nonionic surface active polymers are effective in cleaning, removing or dispersing mud, silts and oils and will help to break up microbiological slime. Since their surface active nature tends to promote foaming, the normal detergents used in washing clothes would produce excessive foaming. A properly selected polymer will have the necessary surface activity to function without causing excessive foam within the system.

The scale control properties of some polymers have added a whole new dimension to our ability to control scaling in cooling water systems. The most commonly used polymers for scale control are anionic, low molecular weight and usually use the carboxyl (-COOH) functional group. The specific properties or scale control abilities are a function of the functional group, the organic molecule structure, the charge density and the orientation of the functional groups. Depending on these factors, polymers can be effective in controlling calcium carbonate, calcium sulfate, calcium phosphate, other hardness precipitates or metallic compounds.

Polymers can distort the crystal growth of the scale by disrupting the crystalline lattice which causes the hard dense adherent nature of scales. With the inclusion of a relatively large, irregularly shaped polymer in the crystalline lattice, scale does not develop or adhere to surfaces where it could cause heat transfer problems.

The polymer prevents normal scale development and disperses the more amorphorus material which may form. The effectiveness of polymers in scale control has changed the nature of many cooling water treatment programs by allowing high cycles and/or high pH conditions to be used.

Theoretically, there are many types of polymers. As mentioned before, polymers have only three different functional groups:

Weak Acid (Carboxylates**)**

Strong Acid (Sulfonates)

Nonionics

Carboxylate functional groups (common to polyacrylates) are critical to adsorption of the polymer on the crystal as it forms. The carboxylate helps it "stick" to the surface and form a complex between the calcium or magnesium ion and the carboxyl groups. This stabilizes the suspension and prevents the crystalline formation. The presence of the polymer in the crystal lattice also causes distortion.

Sulfonate functional groups do not attach very strongly but are excellent at enhancing the negative charge of crystal formations so repulsion occurs. This process is a dynamic equilibrium of constant adsorption and desorption of the polymer on charged particles.

A nonionic functional group may be considered to compare to a string of pearls. If the polymer curls up, the active sites get too close and the polymer cannot do its job. The properties of a nonionic functional group cause it to stay uncurled therefore allowing it to cover more surface area.