

Thickening Properties

Effective pH Range

In most liquid systems, Carbopol®* polymers require neutralization to thicken most efficiently. Sodium hydroxide, potassium hydroxide, ammonium hydroxide, and some water-soluble organic amines are excellent neutralizing agents for Carbopol® polymers in aqueous systems.

Figures 1, 2 and 3 show the effective pH range for the traditional Carbopol® polymers neutralized with sodium hydroxide. Generally, analogues of the traditional Carbopol® polymers will have similar results to those shown. Carbopol® Ultrez 10 NF polymer will show higher viscosity ranges than its traditional Carbopol® polymer counterparts. Figures 4 and 5 show the effect of pH on viscosity with triethanolamine as the neutralizing agent. This performance is typical of Carbopol® polymers, neutralized with water-soluble amines, in water systems.

Figure 6 shows the relative thickening efficiencies when sodium hydroxide and triethanolamine were used to neutralize a 0.5% aqueous dispersion of Carbopol® 940 NF polymer.

In all cases the solution viscosity increases as the various Carbopol® polymers are neutralized. A flat plateau is reached for the pH range of 5 to 10 and a loss in efficiency occurs as higher pH is obtained. This is caused by excessive neutralizing ions acting as stray ions do. (See [“Effect of Ions”](#).)

An unneutralized 1% dispersion of Carbopol® 934 NF polymer in water has a viscosity of only 390 cP. When neutralized with sodium hydroxide to a pH of 7.0, the viscosity increases above 50,000 cP.

Figure 7 illustrates the effect of increasing concentration over the range of pH. Note that the flat pH plateau is broader at **higher concentrations** of Carbopol® polymers. While Carbopol® 940 NF is shown as an example, this phenomenon is true for all Carbopol® polymers, Pemulen™* polymeric emulsifiers and Noveon®* polycarbophil.

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Figure 1 – Effect of pH on viscosity of a 0.2% solution of Carbopol® polymer in water

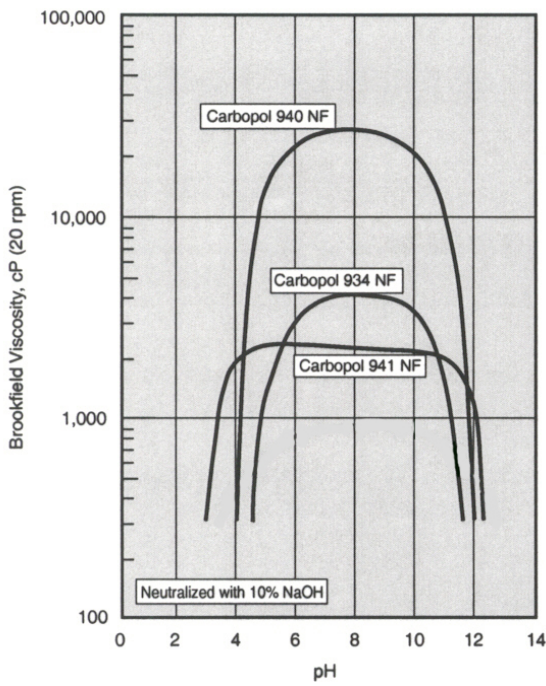


Figure 2 – Effect of pH on viscosity of a 0.5% solution of Carbopol® polymer in water

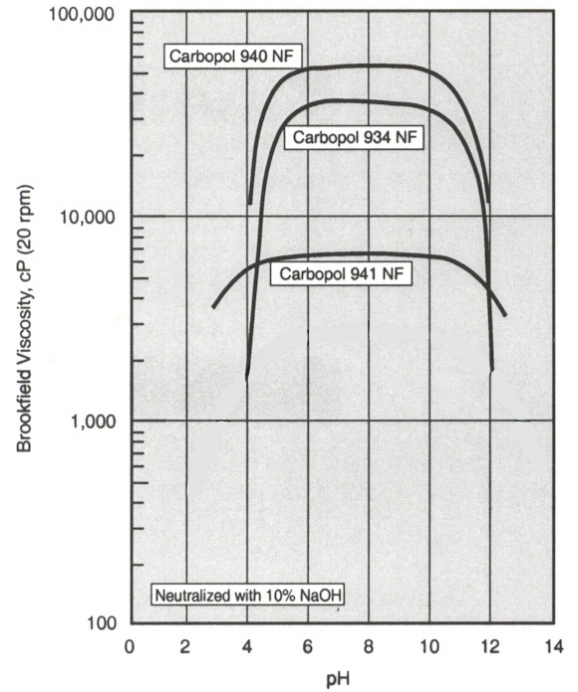


Figure 3 – Effect of pH on viscosity of a 1.0% solution of Carbopol® polymer in water

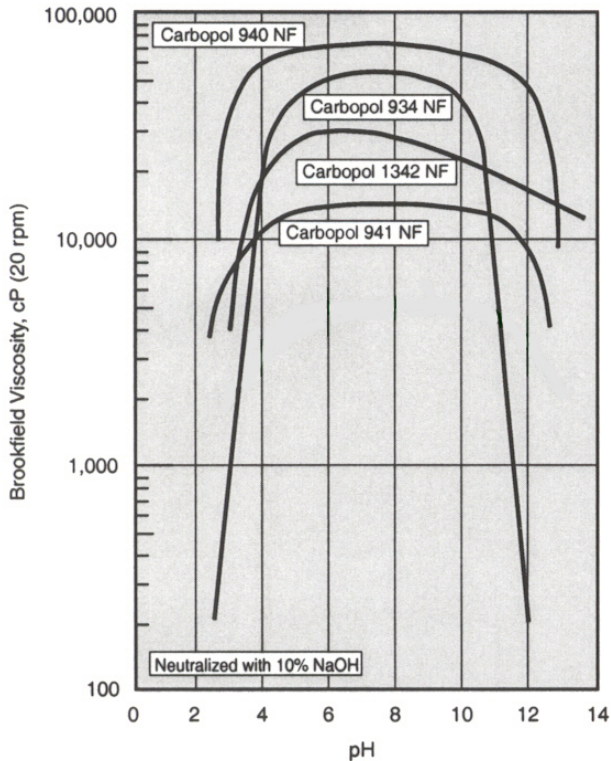


Figure 4 – Effect of pH on viscosity of a 0.2% solution of Carbopol® polymer in water neutralized with 50% triethanolamine (TEA)

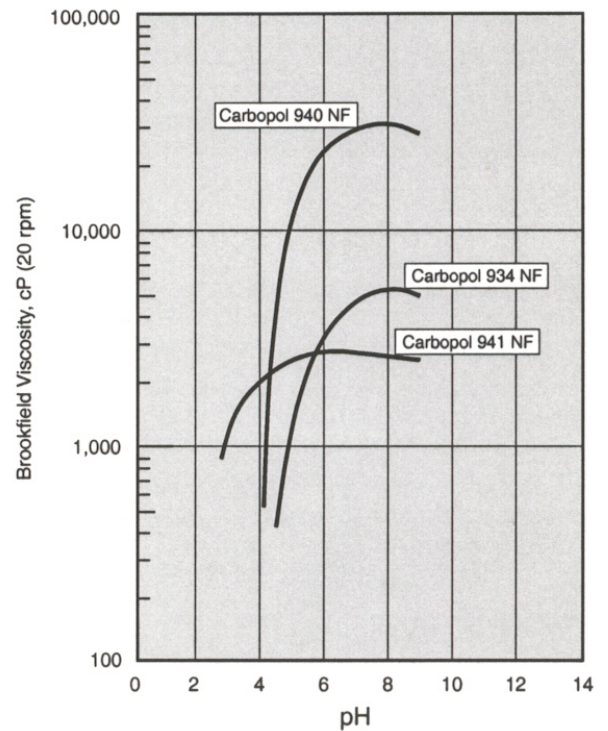


Figure 5 – Effect of pH on Brookfield viscosity of a 0.5% solution of Carbopol® polymer in water neutralized with 50% triethanolamine (TEA)

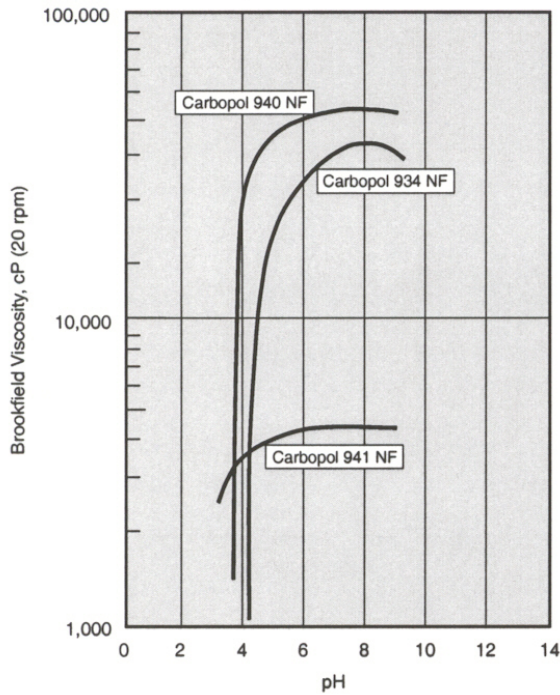


Figure 6– Effect of pH on Brookfield viscosity of a 0.5% solution of Carbopol® 940 NF polymer

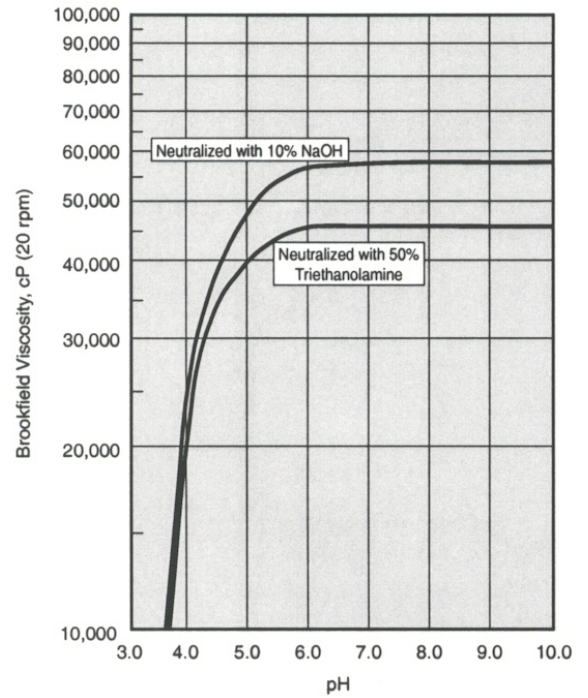
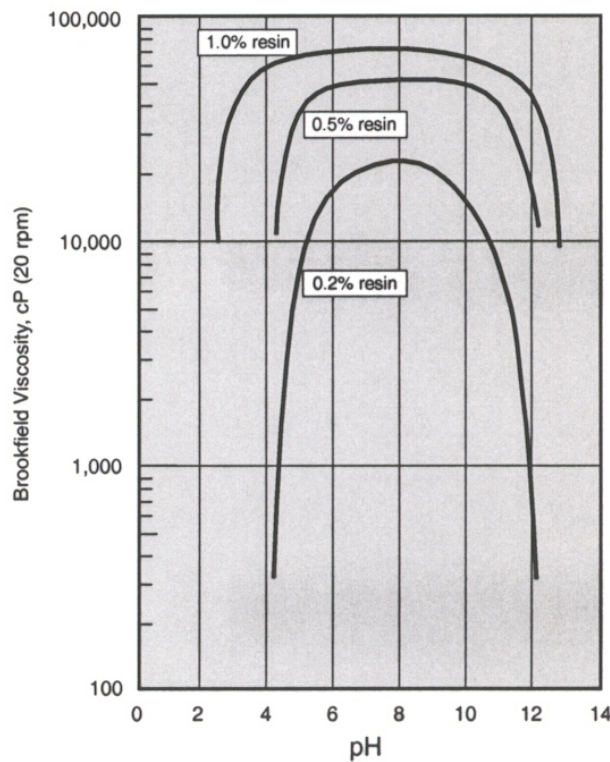


Figure 7– Effect of concentration on pH profile of Carbopol® 940 NF polymer in water neutralized with 10% NaOH



Thickening Efficiency

Carbopol® polymers are extremely efficient thickeners. A 1% neutralized mucilage of Carbopol® polymer forms a stiff gel. Figure 8 illustrates the effect of concentration on the viscosity of various Carbopol® polymers, both unneutralized or neutralized.

Carbopol® 941 NF polymer and its analogues are more efficient than Carbopol® 934 NF or 940 NF polymers and their analogues at concentrations below 0.1%. This means Carbopol® 941 NF polymer and its analogues are ideal for thin formulations which require maximum stability and minimal viscosity. (See Figure 9.)

Figure 8 – Thickening efficiency of Carbopol® polymers at high concentrations in water, unneutralized and at pH 7

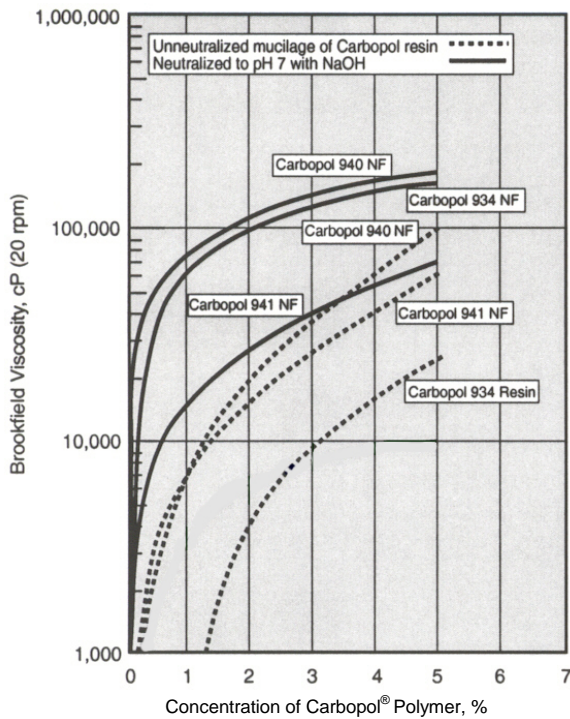
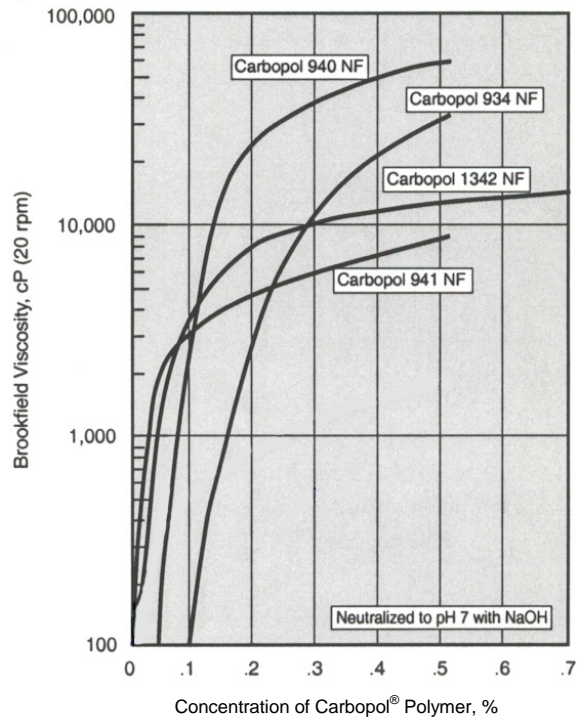


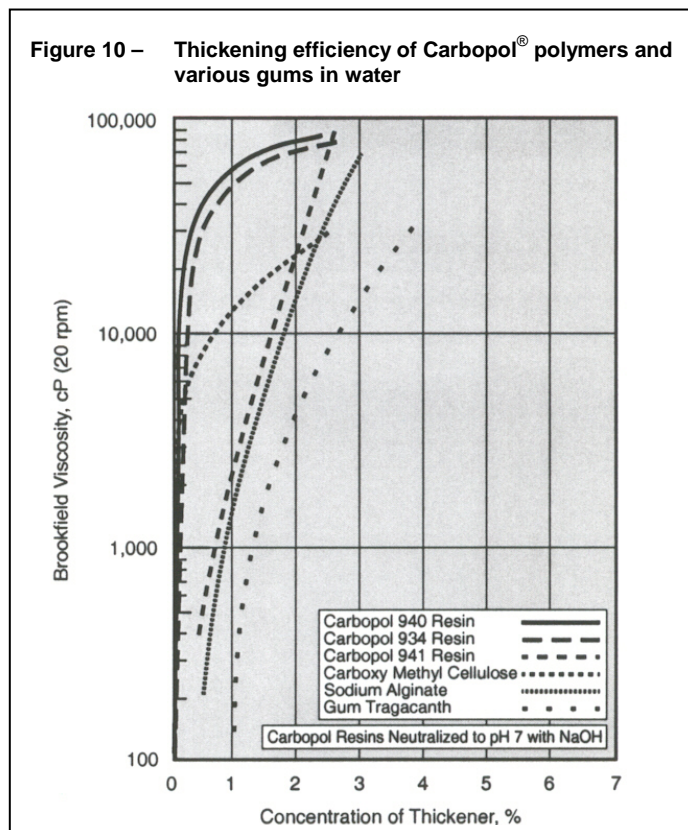
Figure 9 – Thickening efficiency of Carbopol® polymers at low concentrations in water



Different neutralizing agents and other Carbopol® polymers give similar results. Table 1 shows the effect of sodium hydroxide and triethanolamine on the viscosity of 0.5% dispersions of Carbopol® 940 NF polymer.

pH	10% Sodium Hydroxide	50% Triethanolamine
4.0	23,500	19,000
4.5	38,500	34,000
5.0	48,500	40,250
5.5	54,000	44,000
6.0	56,800	46,000
6.5	57,800	46,500
7.0	57,900	46,500
7.5	58,000	46,500
8.0	58,000	46,500
8.5	58,000	46,300
9.0	58,000	46,200
9.5	58,000	46,000
10.0	58,000	46,000

Carbopol® polymers are significantly more efficient than natural and semi-synthetic thickeners. Figure 10 illustrates the thickening efficiency of Carbopol® polymers in contrast to natural gums and a modified cellulosic.



Effect of Ions

Carbopol[®] polymers are compatible with many ingredients used in either water or solvent systems. Soluble salts decrease the efficiency of mucilages of Carbopol[®] polymers as shown in Figure 11. All monovalent salts affect Carbopol[®] polymers similarly. Note that Carbopol[®] 1342 NF polymer exhibits the most resistance to loss of viscosity in the presence of salts. Di- and trivalent cations cause a more drastic loss in efficiency. (See Figure 12.) Ion sensitivity is greater in aqueous systems than in emulsions. Figure 13 shows that loss of viscosity is much lower in oil/water emulsions. In many cases, systems containing multivalent metal ions can be thickened with Carbopol[®] polymers if the pH is adjusted to 8.0 or above before the divalent ingredients are added. A hydrophobic coating around the ionic ingredient can, in many cases, reduce or eliminate the crosslinking potential.

The effect of dissolved salts on mucilages of Carbopol[®] polymers should be considered when packaging. Glass, plastic or polymer-lined containers are recommended for products which contain Carbopol[®] polymers, Pemulen[™] polymeric emulsifiers or Noveon[®] polycarbophil. In general, use only aluminum tubes when a product formulation has a pH of approximately 6.5 or less. With other metallic materials, a pH of approximately 7.7 or greater is preferred.

Figure 11 – Effect of sodium chloride on 1% mucilages of Carbopol[®] polymers at neutral pH

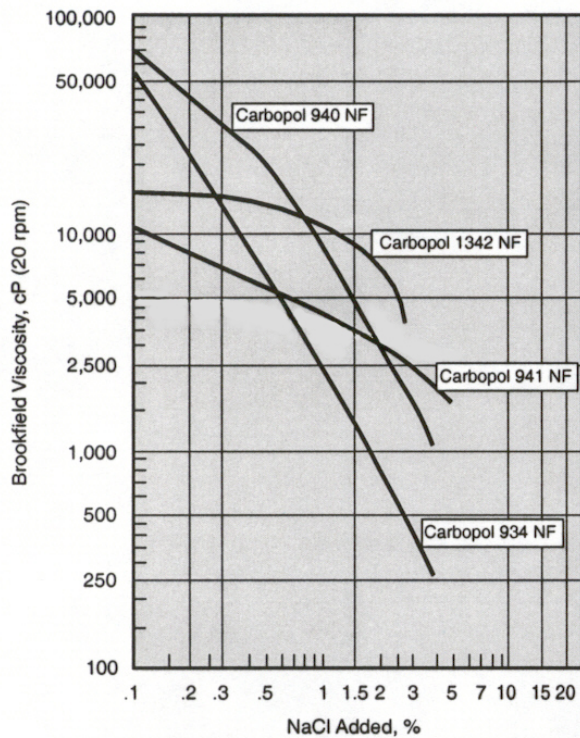
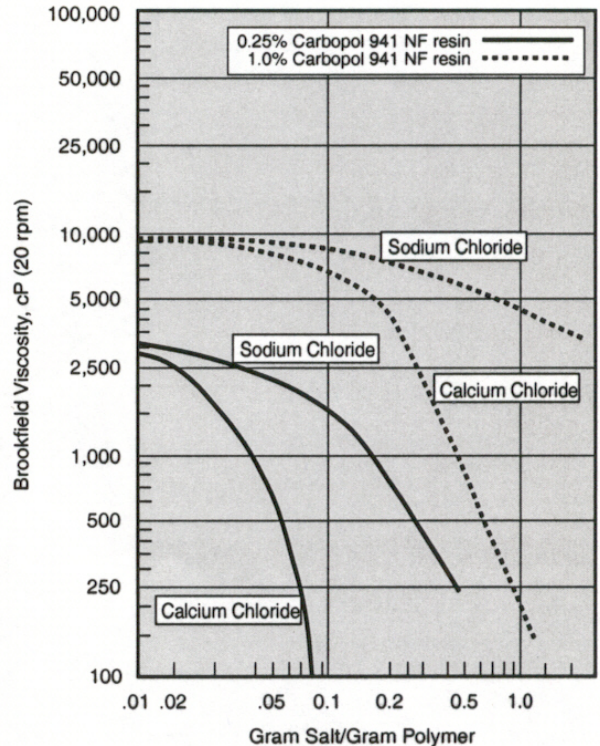
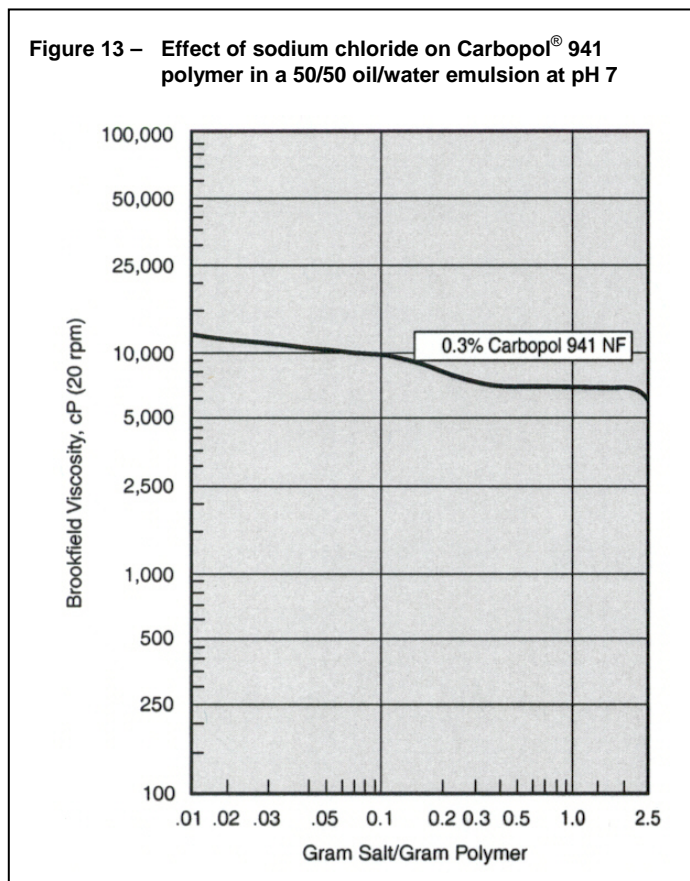


Figure 12 – Effect of salt on Carbopol[®] 941 NF polymer in water at pH 7





Cationic Ingredients

Because Carbopol® polymers are anionic, they are not expected to be compatible with cationic ingredients. However, in general, if the cationic ingredients are of moderate to high molecular weight and exhibit steric hindrance, they will not interfere with the efficiency of Carbopol® polymers. This has been demonstrated in such systems as quaternized vinylpyrrolidones, cationic starch and others. Use of amphoteric surfactant/retarder such as alkylamine polyglycoether sulfate can result in compatibility with some cationic ingredients.

Mechanical Stability

As previously mentioned, dispersions of Carbopol® polymers show sensitivity to prolonged and/or very high-shear mixing. Figure 14 shows the effects of shear on unneutralized solutions of Carbopol® polymers. The resulting viscosities were obtained by neutralizing the above samples with sodium hydroxide to neutral pH. Carbopol® 934 NF polymer is the most shear resistant. Unneutralized, Carbopol® polymers are less susceptible to shear breakdown.

As shown in Figure 15, Carbopol® 980 NF is less susceptible to shear than Carbopol® 940 NF. In general, this is true for the cosolvent polymerized analogues compared to the traditional Carbopol® polymers.

Figure 14 – Shear sensitivity of unneutralized 0.5% dispersions of Carbopol® polymers (viscosity determined after neutralizing with NaOH)

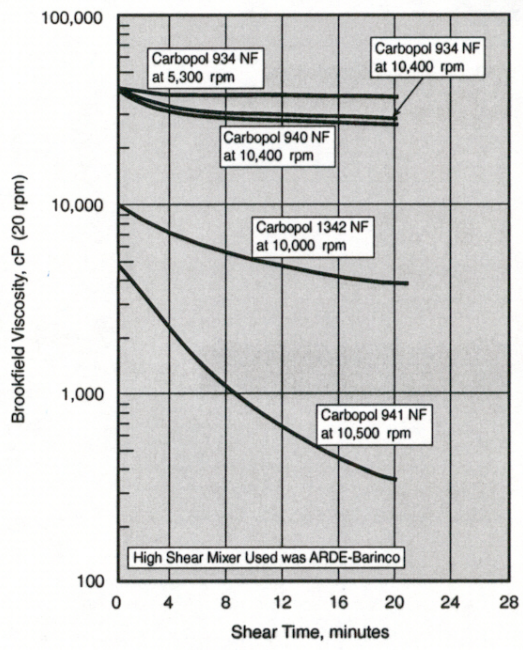
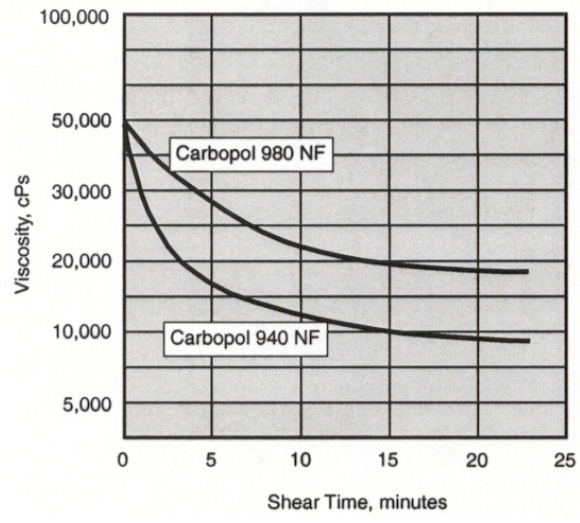


Figure 15 – Carbopol® 980 NF polymer is less susceptible to shear than Carbopol® 940 NF polymer



Temperature Stability

Dispersions of Carbopol®, Pemulen™ and Noveon® AA-1 polymers are not subject to hydrolysis or oxidation under normal conditions. Furthermore, mucilages and emulsions containing the polymers are stable under freeze-thaw conditions, but there is a slight drop in viscosity when exposed to high temperatures. Mucilages containing Carbopol® 934 NF polymer, Carbopol® 941 NF and 940 NF polymers are unaffected after extended aging at 70°C (158°F), and Pemulen™-based emulsions are stable for years at 50°C. The viscosity of gels based on Carbopol® 1342 NF polymer will drop slightly as the temperature increases from 0°C to 80°C (32°F to 176°F). This trend reverses as the temperature decreases. Figure 16 illustrates the relative viscosity drop versus exposure temperature for various similar materials.

Figure 16 – Effect of temperature on viscosity of water solutions of Carbopol® polymers

