

Carbopol[®] Aqua SF-1 Polymer

INCI Name: Acrylates Copolymer

Introduction

Carbopol[®] Aqua SF-1 polymer is a rheology modifier that provides the convenience of a liquid while delivering unique benefits to surfactant-based cleansing products.

Carbopol Aqua SF-1 acrylic emulsion polymer was specifically designed to impart efficient suspending and stabilizing, as well as thickening properties, to formulations containing high levels of surfactants. This is not always possible with typical powdered carbomer products. Another goal in the development of the Carbopol Aqua SF-1 product was the ability to produce very clear formulations containing high levels of surfactants.

Scientists at Lubrizol Advanced Materials were able to incorporate other distinguishing characteristics into the Carbopol Aqua SF-1 polymer. Carbopol Aqua SF-1 polymer works synergistically with surfactants and salts resulting in efficient suspending, stabilizing, and thickening properties. A Lubrizol proprietary process specific to the Carbopol Aqua SF-1 product allows for suspending, stabilization, and thickening of low pH systems. Insoluble and difficult-to-stabilize ingredients such as silicones can be co-emulsified and stabilized. Finally, Carbopol Aqua SF-1 polymer has the remarkable ability to enhance the pearlescent appearance of surfactant formulations.

Carbopol Aqua SF-1 rheology modifier opens the door for new possibilities in surfactant-based formulating and is ideal for the next generation of aqueous personal cleansing products.

Product Overview

Carbopol Aqua SF-1 polymer is a lightly cross-linked acrylic polymer dispersion designed to impart suspending, stabilizing, and thickening properties to a variety of surfactant-based personal cleansing products. It is a low odor liquid, containing 30% active polymer in water that is easily pumped, poured and diluted into aqueous formulations.

Physical Properties

Physical properties of Carbopol Aqua SF-1 polymer are listed in Table 1 and indicate typical values and properties; they are not intended to be used as product specifications. Product specifications are available upon request.

Table 1

<u>As Supplied</u>	
Appearance	milky, white liquid
Odor	mild acrylic
Total Solids (by weight)	30%
Specific Gravity	1.05
pH	3
Viscosity**	10 mPa·s
Residual Ethyl Acrylate (total, ppm)	< 1.0
<u>1% Active Polymer in Water, pH 7.5</u>	
Viscosity***	4,500 mPa·s
Viscosity (0.2 wt% NaCl)***	700 mPa·s
Turbidity	35 NTU
**Brookfield LV at 60 rpm	
***Brookfield RVT at 20 rpm	

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Benefits

◆ Easy-to-Use Liquid Form. . .

Carbopol Aqua SF-1 rheological additive is supplied as a low viscosity liquid that is easily and quickly incorporated.

◆ Suspension and Stabilization. . .

Carbopol Aqua SF-1 polymer was developed to function with surfactants and surfactant blends to provide significant suspending and stabilizing properties to formulations. Insoluble and difficult-to-stabilize ingredients, such as silicones, can be co-emulsified and stabilized. Excellent suspension and stabilization properties are present even in low viscosity formulations.

◆ Thickening and Flow Control. . .

Carbopol Aqua SF-1 polymer thickens shampoo, body wash and other cleansing formulations to their ideal viscosity and provides highly desirable flow characteristics. Carbopol Aqua SF-1 polymer works synergistically with surfactants and salts to provide options for achieving various suspending, stabilizing, and thickening requirements.

◆ Clear Formulations. . .

Carbopol Aqua SF-1 polymer enables the formulation of highly transparent shampoos and body washes at neutral pH.

◆ pH Flexibility. . .

Carbopol Aqua SF-1 polymer is effective in surfactant-based formulations over a wide pH range: from 3.5 to 10 or higher. The polymer also displays a unique ability to provide increasing suspending, stabilizing, and thickening benefits upon acidification after initial neutralization, a process known as "Back-Acid" thickening[†].

◆ Excellent Compatibility. . .

Carbopol Aqua SF-1 polymer is compatible with virtually all commercial nonionic, anionic and amphoteric surfactants as well as a wide array of popular additives and conditioning agents, such as cationic polymers.

◆ Synergistic Thickening with Salt. . .

Carbopol Aqua SF-1 polymer works synergistically with low levels of salt (~ 0.5 wt% sodium chloride) to increase suspension and viscosity when the polymer is formulated with surfactants.

◆ Enhanced Pearlization. . .

Carbopol Aqua SF-1 polymer has the remarkable ability to enhance the visual impact of mica and other pearling additives used in surfactant-based systems. The stability of the visual impact is also dramatically improved.

Product Chemistry

Carbopol Aqua SF-1 polymer is an alkali-swellable acrylic emulsion polymer. As supplied, the majority of the polymer's carboxyl functionality is in the protonated form; the polymer molecules are coiled and impart relatively little suspension and viscosity to the liquid. Upon neutralization, the molecules ionize, expand due to charge repulsion of the anionic carboxylate and provide suspending and thickening properties to the aqueous system in which they reside. This mechanism is known as "hydrodynamic" thickening. In hydrodynamic thickening theory, it is the physical packing of polymer molecules (and possibly other formula ingredients) that is responsible for the development of suspending ability and viscosity. This "space-filling" mechanism is distinctly different from the associative thickening mechanism attributed to hydrophobically-modified polymeric rheology modifiers.

Suggested Applications

The synergistic suspending, stabilizing, and thickening that Carbopol Aqua SF-1 polymer exhibits with surfactants makes it very well suited for aqueous personal cleansing products. Applications for Carbopol Aqua SF-1 rheology modifier include:

- 2-in-1 Conditioning Shampoos
- Antidandruff Shampoos
- Baby Shampoos
- Conditioning Body Washes
- Bath Gels
- Facial Cleansers
- Pearled Cleansing Products
- Low pH Applications

[†]Back-Acid Thickening is a Lubrizol Advanced Materials, Inc. proprietary process covered globally by one or more patents and pending applications.

Performance Properties

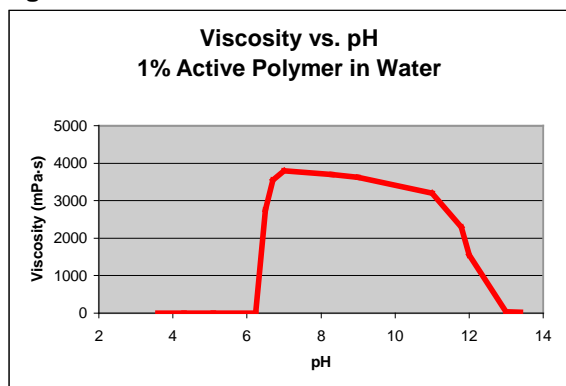
Carbopol Aqua SF-1 polymer was designed to be used in surfactant-containing systems. It is in the presence of surfactants that the polymer displays its most valuable performance attributes:

- Synergistic suspending, stabilizing, and thickening with surfactants and salts
- Low pH suspending, stabilizing, and thickening
- High clarity
- Enhancement of pearlization

Basic Polymer Properties in Water

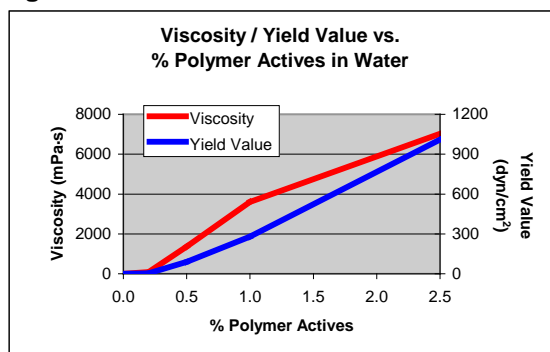
With that in mind, Figures 1 and 2 show basic polymer properties in water. Figure 1 illustrates how Carbopol Aqua SF-1 polymer begins to thicken an aqueous system at pH 6.2. Therefore, it is usually necessary to adjust the formulation pH above 6.5 to obtain initial rheological properties.

Figure 1



Brookfield RVT at 20 rpm. Neutralizer NaOH.

Figure 2



Brookfield RVT at 20 rpm. pH 7.0.

As the polymer in water is neutralized, the system changes from a milky emulsion to a clear gel.

In Figure 2, viscosity and yield value are plotted against various Carbopol Aqua SF-1 polymer % active levels. The system represented has a pH of 7.0 and contains no surfactants. The data shows that Carbopol Aqua SF-1 polymer has high suspending and stabilizing capabilities even at low viscosity.

Polymer Properties in Surfactant Systems

It is very important to note that the performance of Carbopol Aqua SF-1 polymer differs a great deal when comparing the base aqueous gel properties to the properties observed in surfactant formulations.

The suspending and stabilizing properties, as well as thickening capabilities, of formulas utilizing Carbopol Aqua SF-1 rheology modifier are dependent on the surfactant type and level, salt content, pH and polymer concentration. A variety of ingredients typically used in shampoo, body wash and other surfactant-based cleansing products may be used with Carbopol Aqua SF-1 polymer. Various ingredients can have additive or synergistic effects on suspension and viscosity when formulated with Carbopol Aqua SF-1 polymer. A few general guidelines are shown in Figure 3.

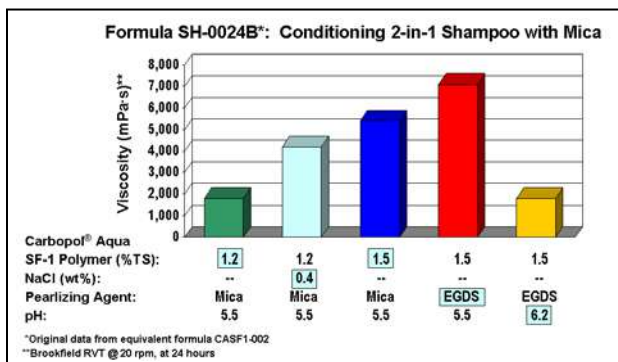
Figure 3

Factor	When Factor Is . . .	Suspending and Viscosity Properties . . .
Polymer Concentration	INCREASED	INCREASE
Surfactant Concentration	INCREASED	INCREASE
Low pH ("Back-Acid" Thickening Technique [†])	UTILIZED	INCREASE
Salt	ADDED	INCREASE
Other Ingredients (EGDS)	ADDED	VARY

Figure 4 displays the effect of materials in combination on viscosity in a pearlized conditioning shampoo. Variables include polymer concentration, sodium chloride, type of pearlizing agent and pH. In this diagram, all five formulations contain the same surfactant system composed of sodium laureth sulfate, cocamido-propyl hydroxysultaine, and disodium laureth sulfosuccinate for a total active surfactant level of 17.4 wt%.

[†]Back-Acid Thickening is a Lubrizol Advanced Materials, Inc. proprietary process covered by one or more patents and pending applications.

Figure 4
FACTORS INFLUENCING VISCOSITY



Performance properties of Carbopol Aqua SF-1 polymer as they relate to the benefits provided are discussed the following sections:

- I. Suspension & Thickening
- II. Effect of Salt
- III. pH: "Back-Acid" Thickening†
- IV. Clarity
- V. Pearlescence
- VI. Co-Emulsification and Stabilization
- VII. Shear

I. Suspension & Thickening

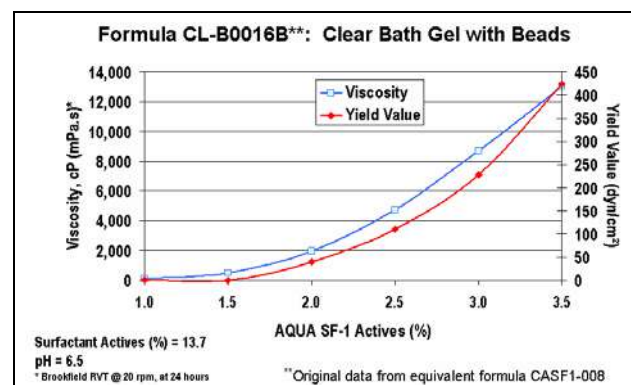
The suspending ability of Carbopol Aqua SF-1 polymer is very significant in surfactant-based formulations. Many types of insoluble ingredients are easily suspended and stabilized including:

- Gelatin-based and other beads and capsules
- Polyethylene
- Pumice
- Loofah
- Walnut shell

While yield value is a way to measure suspending properties, analytical tests measuring Carbopol Aqua SF-1 polymer yield values are generally lower than expected in relation to its true suspending ability. Typical yield values necessary for suspension with Carbopol ETD 2020 polymer are ~ 200 dynes/cm². However, Carbopol Aqua SF-1 polymer passes the same stability testing with yield value levels of 100-150 dyn/cm². This is demonstrated in formula CL-H0001. Good stability has even been observed in Carbopol Aqua SF-1 polymer formulations with yield values as low as 50-80 dyn/cm².

As an example of the effect of polymer concentration in formulation, Figure 5 diagrams the increase in suspending properties (measured in yield value) and viscosity as Carbopol Aqua SF-1 polymer concentration is increased in a clear suspending shampoo/bath gel formula. This formulation utilizes sodium laureth sulfate and cocoamidopropylbetaine equaling 13.7 wt% total surfactant actives.

Figure 5
EFFECT OF POLYMER CONCENTRATION ON VISCOSITY AND YIELD VALUE



Carbopol Aqua SF-1 polymer is most effective in formulations containing at least 12 wt% total surfactant actives. In fact, increasing polymer efficiency is realized with increasing surfactant concentration.

II. Effect of Salt

Carbopol Aqua SF-1 polymer also functions synergistically with salt to suspend, stabilize, and thicken surfactant-based formulations. An example of these effects, as measured by viscosity and yield value, is graphically depicted in Figures 6 and 7, respectively. These diagrams show an antidandruff shampoo with 10.2 wt% surfactant levels and a final pH of 5.5. Surfactants include sodium lauryl sulfate, sodium laureth sulfate, and cocamidopropylbetaine.

While salt alone has the ability to thicken formulations at higher concentrations (Figure 6), excellent suspending properties are obtained using Carbopol Aqua SF-1 polymer (Figure 7).

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Figure 6
SYNERGISTIC THICKENING WITH SALT
Effect of Sodium Chloride on Viscosity

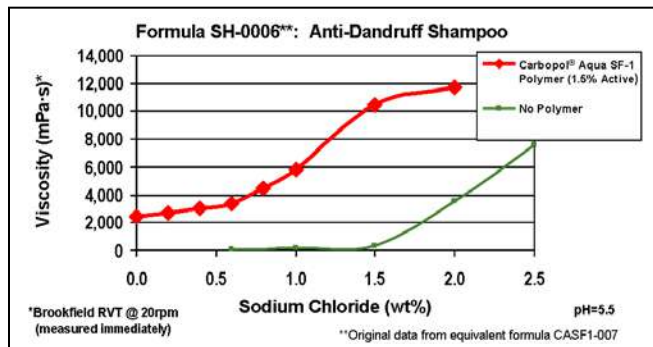
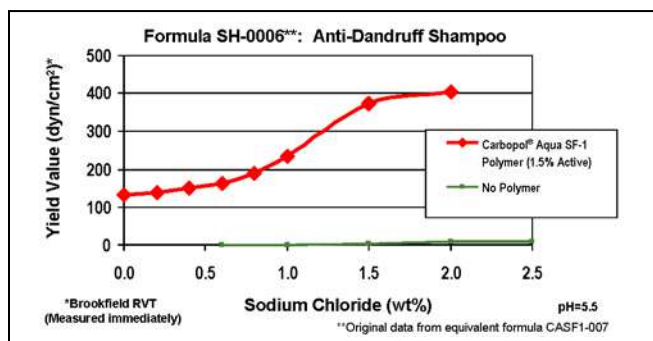


Figure 7
SYNERGISTIC THICKENING WITH SALT
Effect of Sodium Chloride on Yield Value



III. pH: “Back-Acid” Thickening†

Carbopol Aqua SF-1 provides the formulator with the benefit of Lubrizol Advanced Materials’ proprietary “Back-Acid” thickening technology in surfactant-based personal cleansing formulations, a technique of reducing formulation pH subsequent to neutralization. It is in the presence of surfactants that Carbopol Aqua SF-1 polymer displays one of its most unique features: the ability to “Back-Acid” thicken. Figures 8 and 9 depict this phenomenon as measured by viscosity and yield value. After the polymer-surfactant formulation has been neutralized (increasing pH as depicted in the figures with red lines), pH can then be lowered to give a resulting increase in suspension and viscosity (as depicted by blue lines). Figures 8 and 9 represent a brilliant gold 2-in-1 shampoo formulation using 24.4 wt% surfactants. This surfactant system includes ammonium lauryl sulfate, ammonium laureth sulfate, PEG-7 glyceryl soyate and disodium cocoamphodiacetate.

This “Back-Acid” thickening feature may be utilized to further increase the efficiency of Carbopol Aqua SF-1 polymer and/or to formulate into an acidic region. Upon acidification, suspension and viscosity will increase as the formula is lowered to a pH of approximately 3.8. Continued “Back-Acidification” using citric acid (below approximately pH 3.8) may result in decreasing suspension and viscosity when using citric acid.

Figure 8
“BACK-ACID” THICKENING EFFECT ON VISCOSITY

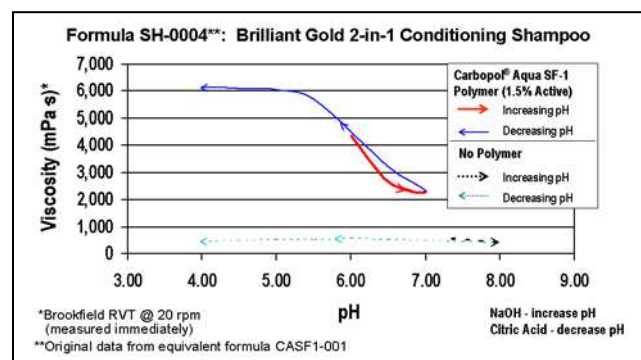
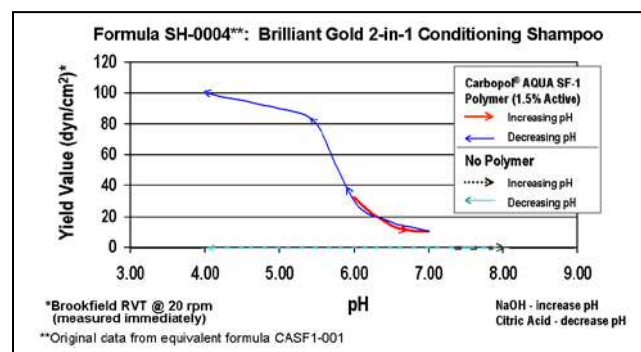


Figure 9
“BACK-ACID” THICKENING EFFECT ON YIELD VALUE



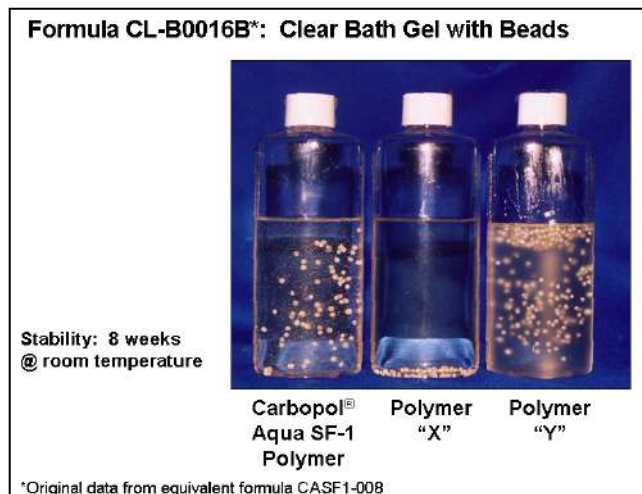
IV. Clarity

Carbopol Aqua SF-1 polymer can be used to suspend larger particulates and thicken surfactant systems in surfactant cleansing products that exhibit transparency. As a general guideline, it is recommended that formulations should be adjusted to pH 6.5 - 6.8 to maximize clarity and efficiency. The addition of electrolytes will tend to decrease clarity. However, some formulations may tolerate 0.1 - 0.2 wt% salt and still retain high clarity. This is demonstrated by formulation [CL-B0004](#).

†Back-Acid Thickening is a Lubrizol Advanced Materials, Inc. proprietary process covered globally by one or more patents and pending applications.

Figure 10 shows a clear bath gel with suspended beads after 8 weeks at room temperature. This figure demonstrates the excellent clarity, suspending ability and long-term stability provided by Carbopol Aqua SF-1 polymer.

Figure 10
SUSPENSION AND STABILITY



V. Pearlescence

Ingredients such as mica, glycol stearate (EGMS) and glycol distearate (EGDS) have been used in shampoo and body or personal wash products to confer a pearlescent appearance to the formulation. However, the intensity of the pearlescence is often minimal and not stable; the product may require shaking to rejuvenate the pearlescence.

Carbopol Aqua SF-1 polymer has a unique ability to increase the luster and intensity of the pearlescence conferred by these ingredients as well as the stability of the pearlescence. This effect is most pronounced when mica is used as the pearlizing agent. Enhancement of pearlization is demonstrated in Figure 11, a 2-in-1 pearlized conditioning shampoo.

Figure 11
ENHANCEMENT OF PEARLIZATION

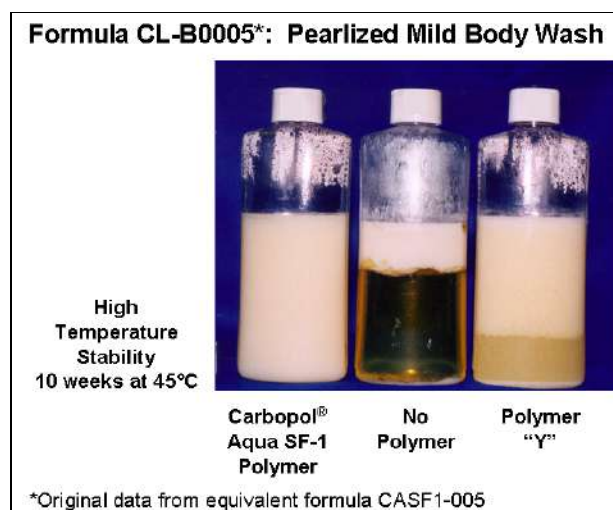


VI. Co-Emulsification and Stabilization

Carbopol Aqua SF-1 polymer aids in the stabilization of silicones and other insoluble liquids in surfactant-based products. The polymer suspends and may co-emulsify these ingredients, and conveys long-term stability to cleansing products formulated with a variety of insolubles.

Figure 12 shows a pearlized body wash after high temperature stability testing. Carbopol Aqua SF-1 polymer shows no separation or sign of instability after 10 weeks at 45°C.

Figure 12
SUSPENSION AND STABILIZATION



VII. Shear

Carbopol Aqua SF-1 polymer displays classic shear-thinning behavior. At low shear rates, viscosity and yield value are high and suspended and insoluble ingredients can be stabilized. At high shear rates, viscosity is low and product can easily be pumped or dispensed. The viscosity recovers immediately as shear is decreased. Furthermore, Carbopol Aqua SF-1 rheology modifier does not degrade under high shear agitation as is the case with typical carbomers.

Formulating and Processing

In most situations, Carbopol Aqua SF-1 polymer should be added to the free water of a formulation with gentle mixing at the start of the batch process. At this point, the pH will be about 3, resulting in very low viscosity. Upon addition of the primary surfactant and the base, the polymer will be neutralized, resulting in an immediate increase in suspending properties and viscosity.

Order of Addition

While the order of addition of other ingredients will vary depending on the composition and the percentage of an individual material, the order of addition is nonetheless very important in obtaining optimal benefit from the polymer. The following general guidelines should be observed:

1. Add Carbopol Aqua SF-1 polymer to the (deionized) free water of the formulation.
2. Add primary anionic/ nonionic surfactants. (Example: lauryl sulfates, lauryl ether sulfates.)
3. Neutralize to pH 6.5 - 6.8.
4. Add remaining surfactants. (Example: amphoteric.)
5. Add conditioning and ancillary ingredients. (Example: silicones, cationics, EDTA.)
6. If desired, add pearlizing ingredients. (Example: mica, EGDS, EGMS.)
7. Add fragrance, dyes and preservatives.
8. If desired, decrease pH[†]. (This will increase efficiency; citric acid is suggested.)
9. If desired, add sodium chloride to further increase viscosity.

Amphoteric Surfactant Blends

Surfactant blends containing amphoteric surfactants should be added prior to neutralization.

Nonionic Surfactant Blends

Nonionic blends, such as those used in baby shampoos, should be added prior to neutralization.

Neutralizing Agents

Either inorganic bases (such as sodium hydroxide) or organic bases (such as triethanolamine) can be used to neutralize Carbopol Aqua SF-1 polymer.

Post-Thickening

Carbopol Aqua SF-1 polymer can be added after producing the batch to adjust (increase) the final viscosity of the batch. However, care must be taken if Carbopol Aqua SF-1 polymer is added at the end of the batch cycle to avoid forming lumps due to localized thickening with surfactants and concentrated polymer levels.

The recommended process to use Carbopol Aqua SF-1 polymer for post-thickening is to dilute Carbopol Aqua SF-1 at least 1:2 (polymer : water) and add very slowly to the batch. The pH should be re-adjusted to pH 6.5 after post adding the polymer.

Use Levels

Polymer Use Level

The minimum recommended use level of Carbopol Aqua SF-1 polymer in surfactant-based products is 4.0 wt% as supplied (1.2 wt% active). The polymer use level depends on the amount of surfactant and assumes use of salt for additional thickening. For clear formulations containing no salt and low surfactant actives, typical polymer use levels are 8 - 10 wt% as supplied (2.4 - 3.0 wt% active).

[†]Back-Acid Thickening is a Lubrizol Advanced Materials, Inc. proprietary process covered globally by one or more patents and pending applications.

Surfactant Use Level

For maximum efficiency, the total amount of surfactants used should typically be 12 - 23 wt%. High levels of nonionic, anionic, and amphoteric surfactants can easily be formulated and processed with Carbopol Aqua SF-1 polymer. In fact, polymer efficiency increases with higher surfactant concentrations.

Finished Product Stability

Surfactant-based products formulated with Carbopol Aqua SF-1 polymer tend to be highly stable over time; viscosity is controlled at a more constant value. Refer to Figures 10 and 12 for examples of product stability including excellent suspending properties and silicone stabilization over time.

Compatibility

Surfactants

Carbopol Aqua SF-1 polymer is compatible with virtually all commercially utilized surfactants, including, for example:

- Sodium Laureth Sulfate (2 and 3 mole)
- Sodium Lauryl Sulfate
- Ammonium Laureth Sulfate (3 mole)
- Ammonium Lauryl Sulfate
- Sodium Lauroyl Sarcosinate
- Cocoyl Isethionate / Taurate blend
- PPG-2 Hydroxyethyl Cocamide
- Cocamidopropyl Betaine
- Lauryl Glucoside
- Disodium Cocoamphoacetate
- Cocamidopropyl Hydroxysultaine
- Disodium Laureth Sulfosuccinate
- Cocamide MEA
- Sodium C14-16 Olefin Sulfonate
- Potassium C12-13 Phosphate

Cationic Polymers

Carbopol Aqua SF-1 polymer is compatible with a variety of cationic conditioning polymers when used in shampoo and wash products. Among the cationic polymers that are compatible with Carbopol Aqua SF-1 are, for example:

- Guar Hydroxypropyl Trimonium Chloride
- Polyquaternium-4
- Polyquaternium-7
- Polyquaternium-10
- Polyquaternium-11
- Polyquaternium-16
- Polyquaternium-39

In cases where clarity is a concern, Polyquaternium-10, Polyquaternium-11 and Polyquaternium-39 should be considered.

Cationic Surfactants

As a general rule, cationic surfactants may have limited compatibility with Carbopol Aqua SF-1 polymer. Low levels of cetrimonium chloride have been shown to be compatible with the polymer in a shampoo formulation. (Formulation [SH-0004](#) is an example of such a system.)

Cationic Hair Dyes

Cationic hair dyes display good compatibility with Carbopol Aqua SF-1 polymer in surfactant-based formulations.

Hydrogen Peroxide

Carbopol Aqua SF-1 polymer is stable in acidic systems containing hydrogen peroxide, pH 2.5-4.0.

Toxicology

Carbopol Aqua SF-1 polymer has low acrylate monomer residuals providing an excellent toxicity profile. It is suited for all types of personal care formulations, including those for baby care and for sensitive skin. A complete summary of toxicological effects is available upon request.

Regulatory Status

Carbopol Aqua SF-1 polymer is compliant for cosmetic use in most countries, including the USA and Europe. It is compliant with various chemical inventories, which are cited on the Material Safety Data Sheet.

Carbopol Aqua SF-1 polymer is listed in the International Cosmetic Ingredient Dictionary and Handbook under the INCI labeling name of Acrylates Copolymer.

Handling and Storage

For in-depth handling and storage information, please consult and review the separate handling guide for Carbopol Aqua SF-1 polymer (HSG-001).

Packaging

Carbopol Aqua SF-1 polymer is supplied in plastic drums having net weights of either 441 lbs (200 kg) or 480 lbs (218 kg), and plastic IBC Totes having net weights of 2200 lbs (1000 kg).

Storage Conditions

Carbopol Aqua SF-1 polymer should be stored at ambient room temperature conditions, 5 - 30°C (40 - 85°F). Do Not Freeze.

Carbopol Aqua SF-1 polymer is not freeze thaw stable as supplied. The polymer in finished applications, however, is freeze-thaw stable. Drums or storage tanks can be equipped with jackets or external coils to keep the product in the desired temperature range – internal heating or immersion coils are not recommended.

Shelf-Life

The shelf life of Carbopol Aqua SF-1 polymer is nine months from date of manufacture.

Material Handling

The product should be filtered prior to use or unloading into another storage vessel. Transfer of the product should be done using a low shear pump. (High shear pumping of the concentrated raw polymer will promote coagulation.) For storage in tanks, it is further recommended that the tank be periodically agitated to prevent and correct any settling that may occur. The storage and mixing tanks should ideally be constructed with stainless steel. Do not use low carbon steel, manganese, copper, aluminum or zinc storage containers.

To prevent “skinning” on the surface of the liquid, drums should not be opened until use. When storing the polymer in bulk the storage tank should be closed, insulated and mildly agitated. If skinning occurs, surface coagulant should be removed prior to use via filtration; a very low percentage of polymer content will be removed. Pressure-driven filtration may be effectively accomplished through the use of a coarse (15-20 mesh) stainless steel screen followed by a basket filter (for example, GAF-type with 50-150 micron fiber bags).

Preservation

Carbopol Aqua SF-1 polymer is unpreserved as supplied. Unpreserved samples of Carbopol Aqua SF-1 polymer passed the standard USP Preservative Efficacy challenge test. Carbopol Aqua SF-1 polymer does not support bacteria or fungal growth, but neither does it prevent such growth on nutrients found in normal water systems. The addition of a preservative is recommended for applications inclined to these issues.