Carbopol® Aqua SF-1 Polymer
Technical Data Sheet

Introduction

Noveon, Inc. is pleased to introduce Carbopol® Aqua SF-1 polymer, a new 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 was 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.

Noveon scientists 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 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
INCI Designation	acrylates copolymer
<u>1% Active Polymer in Water, pH 7.5</u>	
Viscosity **	4,500 mPa·s
Viscosity (0.2% NaCl) **	700 mPa·s
Turbidity	35 NTU

* Brookfield LV at 60 rpm
** Brookfield RVT at 20 rpm

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 wash formulations at neutral pH.

❖ **pH Flexibility. . .**
Carbopol® Aqua SF-1 polymer is effective in surfactant-based formulations over a wide pH range: from 3.8 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% 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 pearlizing 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
- Pearlized Cleansing Products
- Low pH Applications

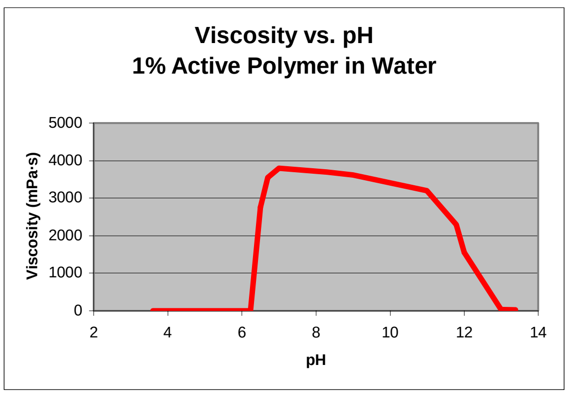
Performance Properties

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, and enhancement of pearlization.

Basic Polymer Properties in Water

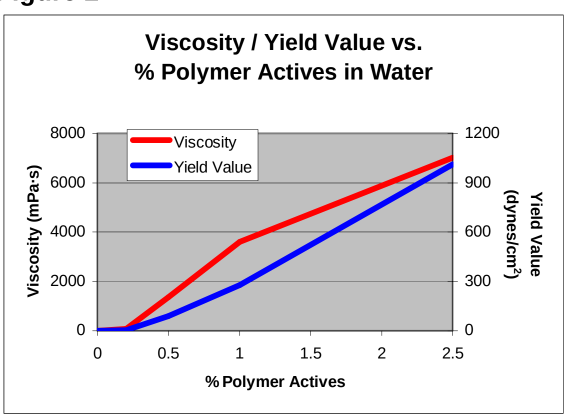
With that in mind, Figures 1 and 2 show basic polymer properties in water. Figure 1 illustrates how Carbopol® Aqua SF-1 polymer begins to thicken an aqueous system at pH 6.2. Therefore, it is usually necessary to adjust the formulation pH above 6.5 to obtain initial rheological properties.

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.

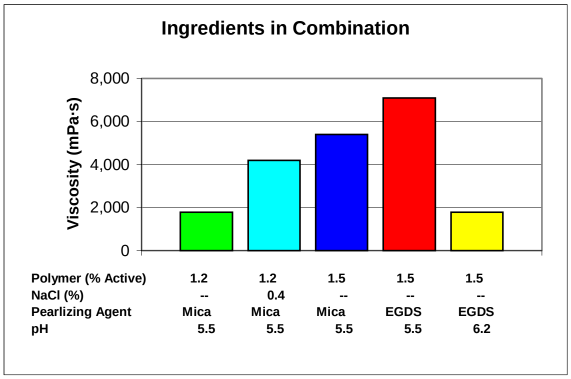
The suspending and stabilizing properties, as well as thickening capabilities, of formulas utilizing Carbopol® Aqua SF-1 rheology modifier are dependent on the surfactant type and level, salt content, pH and polymer concentration. A variety of ingredients typically used in shampoo, body wash and other 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. A few general guidelines are shown in Figure 3.

Figure 3

Factor	When Factor Is . . .	Suspending and Viscosity Properties . . .
Polymer Concentation	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, cocamidopropyl hydroxysultaine, and disodium laureth sulfosuccinate for a total active surfactant level of 17.4%.

Figure 4



Viscosity measured after 24 hours. Brookfield RVT at 20 rpm. Formula CASF1-002.

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

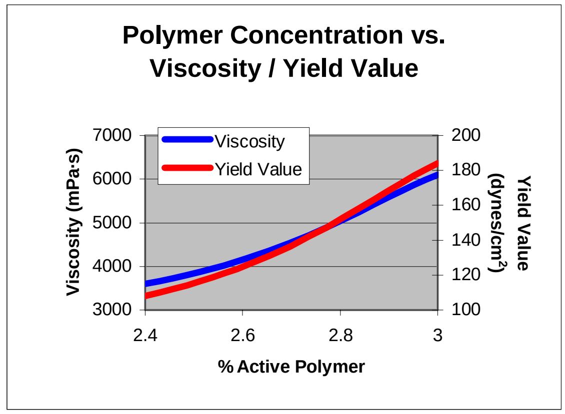
The suspending ability of Carbopol® Aqua SF-1 polymer is very significant in surfactant-based formulations. Many types of insoluble ingredients are easily suspended and stabilized including:

- 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/cm^2. However, Carbopol® Aqua SF-1 polymer passes the same stability testing with yield value levels of 70-100 dynes/cm^2. This is demonstrated in formula CASF-012. Good stability has even been observed in Carbopol® Aqua SF-1 polymer formulations with yield values as low as 40 dynes/cm^2.

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 12.9% total surfactant actives.

Figure 5



Brookfield RVT at 20 rpm. pH 6.5. Formula CASF1-008.
Formulas pass stability for 12 weeks at 45 °C.

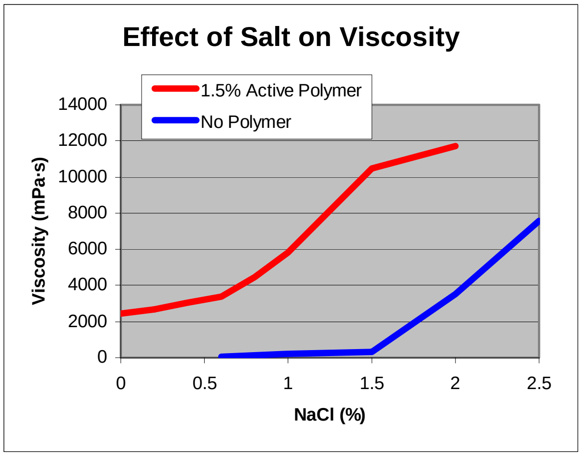
Carbopol® Aqua SF-1 polymer is most effective in formulations containing at least 12% total surfactant actives. In fact, increasing polymer efficiency is realized with increasing surfactant concentration.

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 12.9% surfactant levels and a final pH of 5.5. Surfactants include sodium lauryl sulfate, sodium laureth sulfate, and cocamidopropyl-betaine.

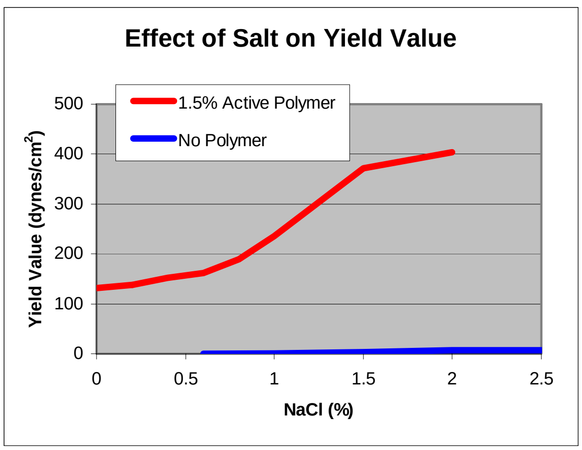
While salt alone has the ability to thicken formulations at higher concentrations (Figure 6), excellent suspending properties are obtained using Carbopol® Aqua SF-1 polymer (Figure 7).

Figure 6



Brookfield RVT at 20 rpm. pH 5.5. Formula CASF1-007.

Figure 7



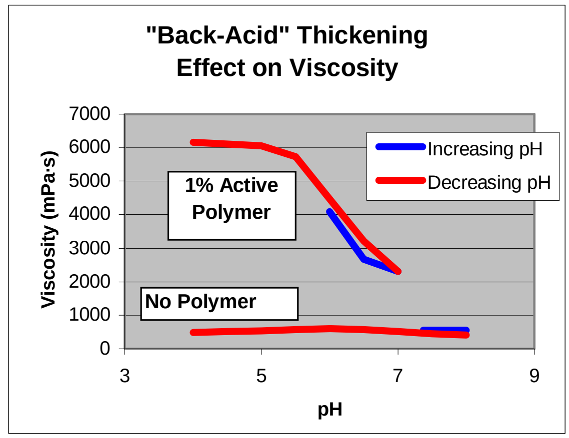
Brookfield RVT at 20 rpm. pH 5.5. Formula CASF1-007.

III. pH: "Back-Acid" Thickening

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 blue lines), pH can then be lowered to give a resulting increase in suspension and viscosity (as depicted by red lines). Figures 8 and 9 represent a brilliant gold 2-in-1 shampoo formulation using 24.4% surfactants. This surfactant system includes ammonium lauryl sulfate, ammonium laureth sulfate, PPG-2 hydroxyethyl cocamide, and disodium cocoamphoacetate.

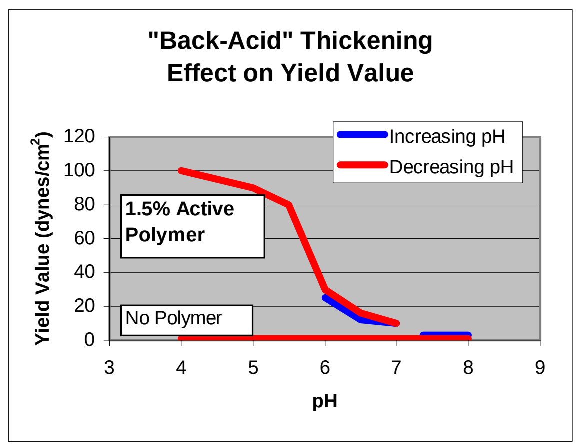
This "Back-Acid" thickening feature may be utilized to further increase the efficiency of Carbopol® Aqua SF-1 polymer and/or to formulate into an acidic region. Upon acidification, suspension and viscosity will increase as the formula is lowered to a pH of approximately 3.8. Continued back-acidification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

Figure 8



Brookfield RVT at 20 rpm. Formula CASF1-001. NaOH used to increase pH. Citric acid used to decrease pH.

Figure 9



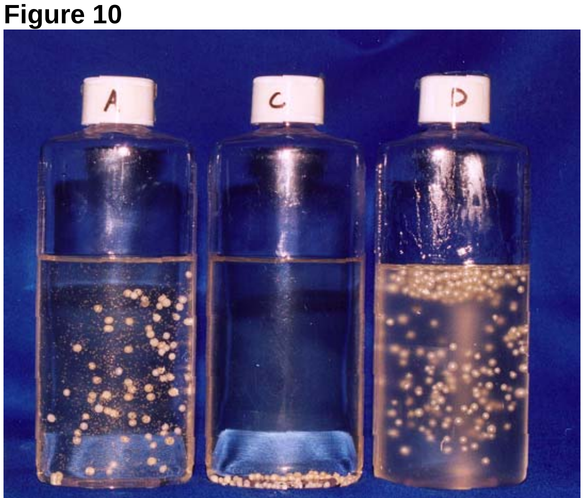
Brookfield RVT at 20 rpm. Formula CASF1-001. NaOH used to increase pH. Citric acid used to decrease pH.

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 the pH of such formulations be adjusted to approximately 6.2 – 6.5 in order to maximize clarity. The addition of electrolytes will tend to decrease clarity. However, some formulations may tolerate 0.1-0.2% salt and still retain high clarity. This is demonstrated by formula CASF-014.

Figure 10 shows a clear shampoo/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



Carbopol® Aqua SF-1 Polymer	Polymer 'X'	Carbopol® ETD 2020 Polymer

Formula CASF1-008.

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

Carbopol® Aqua SF-1 Polymer	Carbopol® ETD 2020 Polymer

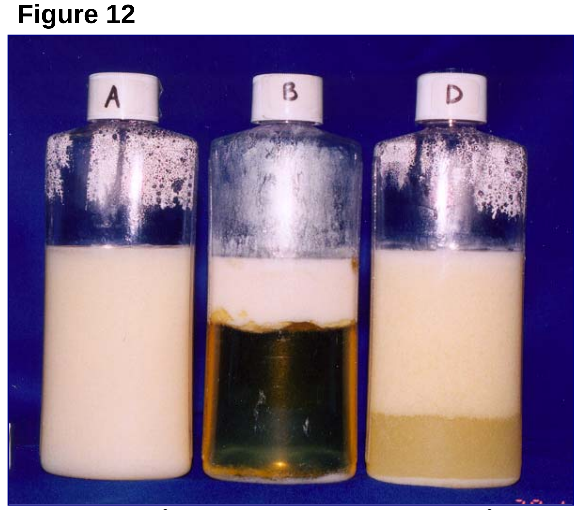
Formula CASF1-002.

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 (product A) shows no separation or sign of instability after 10 weeks at 45 °C.

Figure 12



Carbopol® Aqua SF-1 Polymer	No Polymer	Carbopol® ETD 2020 Polymer

Formula CASF1-005.

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 can be added to the free water of a formulation with gentle mixing at the start of the batching process. At this point, the pH will be about 3, resulting in very low viscosity. Upon addition of a base, the polymer will be neutralized, resulting in 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:

❶ Add Carbopol® Aqua SF-1 polymer to the (deionized) free water of the formulation.

❷ Add primary surfactants. (Example: lauryl sulfates, lauryl ether sulfates.)

❸ Neutralize to pH 6.2 – 6.6.

❹ Add remaining surfactants. (Example: amphoterics.)

❺ Add conditioning and ancillary ingredients. (Example: silicones, cationics, EDTA.)

❻ If desired, add pearlizing ingredients. (Example: mica, EGDS, EGMS.)

❼ Add fragrance, dyes and preservatives.

❽ If desired, decrease pH. (This will increase efficiency; citric acid is suggested.)

❾ 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 batching 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 at 6.5 or higher before adding the polymer. Citric acid, salts, and cationic ingredients must be added after the addition of the polymer.

Use Levels

Polymer Use Level

The minimum recommended use level of Carbopol® Aqua SF-1 polymer in surfactant-based products is 5.0% as supplied (1.5% 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% as supplied (2.4-3.0% active). Carbopol® Aqua SF-1 polymer is most efficient when formulated with typical levels of anionic surfactants.

Surfactant Use Level

For maximum efficiency, the total amount of surfactants used should be 15-23%, although surfactant levels as low as 8% and as high as 25% may work with Carbopol® Aqua SF-1 polymer. High levels of nonionic, anionic, and amphoteric surfactants can easily be formulated and processed with Carbopol® Aqua SF-1 polymer. In fact, increasing polymer efficiency is realized with increasing surfactant concentration.

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 CASF1-001 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. (See Formula CASF1-011 as an example of such compatibility.)

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 registered in the U.S.A. and other countries. All components are in the following registration lists:

United States	TSCA
Canada	DSL
Japan	MITI
Korea	ECL
Australia	AICS
China	NEPA
Europe	EINECS

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

In Japan, Carbopol® Aqua SF-1 meets the Japanese Cosmetic Ingredients Codex (JCIC) monograph for Alkyl Acrylate Copolymer Emulsion (1), CLS number 522007. CLS 522007 can be used in all cosmetic categories without limits, except bath preparations where no precedent for use has yet been established.

Handling and Storage

Packaging

Carbopol® Aqua SF-1 polymer is supplied in 55 gallon plastic drums, 480 pound (217 kilogram) net weight.

Shelf-Life

The shelf life of Carbopol® Aqua SF-1 polymer is six months although it is recommended that the product be used within 90 days of delivery.

Storage Conditions

Carbopol® Aqua SF-1 polymer should be stored at ambient room temperature conditions, 15-30°C (60-86°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.

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 polymer can 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 used and holding tanks (containing bulk polymer dispersion) should ideally be nitrogen blanketed. 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.