Clear conditioning gels with Eastman AQ™ 48 polymer and UCARE polymers JR

Eastman AQ™ polymers, INCI name Polyester-5, are water-dispersible sulfopolyesters that serve as film formers in hair-styling, sun-care, and color-cosmetic products. The AQ polymer most suitable for an application depends on the properties desired, such as clarity, flexibility, water resistance, and solvent tolerance. Eastman AQ 48 ultra and Eastman AQ 55S polymers are used as hair fixatives, contributing high-humidity hold and gloss in hairspray, hair gels, and hair-wax styling products.

It has been discovered that Eastman AQ™ 48 ultra polymer forms clear gels when combined with UCARE polymers JR-125 or JR-400 (INCI name Polyquaternium-10). The films made from the gels are clear and glossy. In aqueous systems, Eastman AQ 48 and JR polymers form a polyelectrolyte complex, where the anionic sulfonate groups of the AQ polymers associate with the cationic quaternary ammonium groups of the JR polymers. The gels are clear over a broad concentration range, as long as the concentration of JR is high enough to solubilize the AQ/JR polyelectrolyte complex. Although Eastman AQ 48 and 55S polymers form gels with a select group of other quaternium polymers, it is the AQ 48/JR gel that is unique in its clarity and the clarity of the films it produces.

Gel properties

To produce an aqueous gel, the total solids content of the mixture of Eastman AQ™ 48 polymer and JR polymer should be at least 0.5 wt %. The maximum concentration is limited by the ability to mix the two components as the viscosity of the mixture builds to form the gel. As the AQ/JR ratio increases, the viscosity is higher and the gels become more elastic. The maximum weight ratio for a workable viscosity and good clarity is about 0.5 AQ/JR.

An experiment was designed to study the properties of Eastman AQ™ 48 polymer and JR-125 gels over a concentration range of 2.4 wt % to 3.5 wt % total solids with AQ/JR weight ratios ranging from 0.13 to 0.67. The properties were compared to those of a commercial "maximum-hold, texturizing gel."

Clarity **–** The Eastman AQ™ 48 polymer and JR-125 gels are clear over a broad range of concentrations as shown in Figure 1. The turbidity contours indicate that the gels become hazy at higher concentrations as the AQ/JR ratio increases. A hazy gel indicates the presence of precipitates. For a clear gel, there must be enough excess aqueous JR polymer to solubilize the AQ/JR complex. Figure 2 shows the percent haze for films made from the gels. The films were made at a wet-film thickness of 3 mils and were dried 1 hour at room temperature followed by 15 minutes at 70°C.

Figure 1

Gel clarity for mixtures of Eastman AQ™ 48 polymer and JR-125. Gels with turbidity values less than about 20 NTU are essentially clear. The turbidity of the commercial gel was 15 NTU.

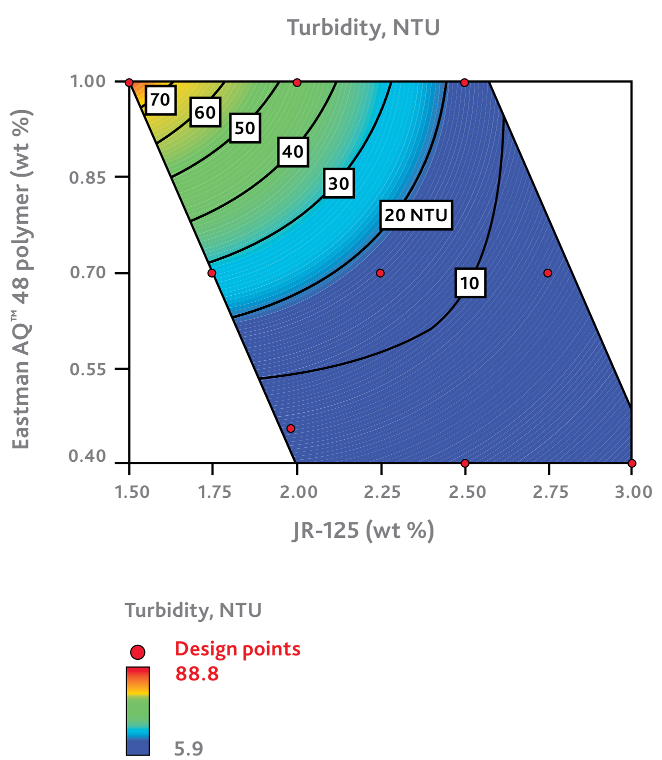


Figure 2

Film clarity of mixtures of Eastman™ AQ 48 polymer and JR-125. Films with haze less than about 2% are essentially clear. The haze of the commercial gel was 22%.

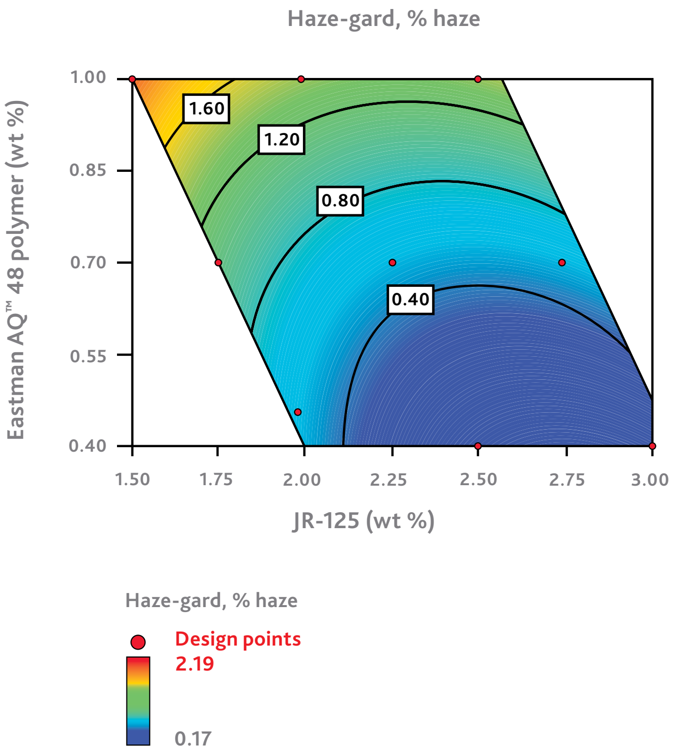


Figure 3

Shear thinning behavior of gels formed with Eastman AQ™ 48 polymer and JR-125 (log scale, broad frequency range). Viscosity was measured by oscillatory rheometry using a dynamic frequency sweep.

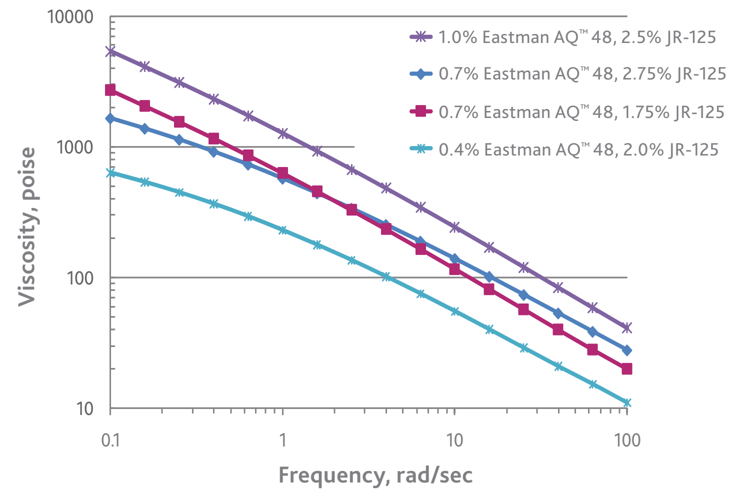
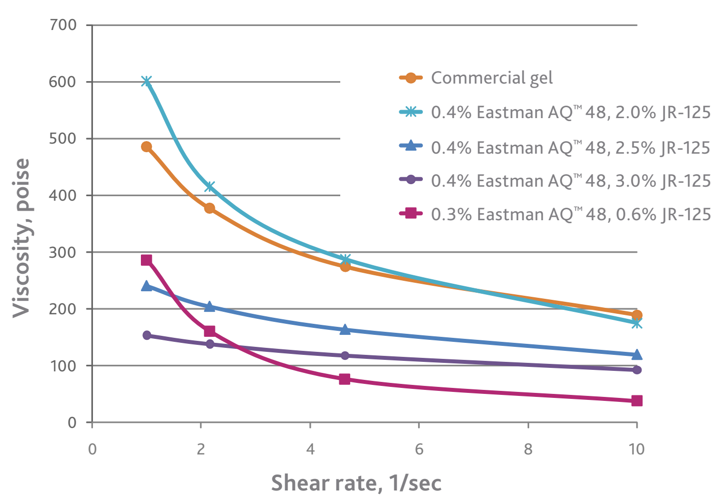


Figure 4

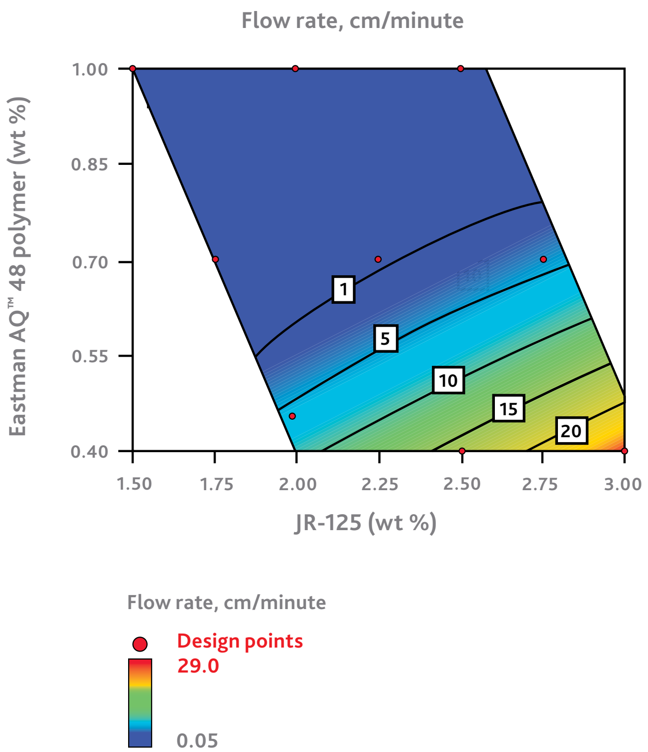
Shear thinning behavior of gels formed with Eastman AQ™ 48 polymer and JR-125 at low Eastman AQ 48 concentrations (linear scale, narrow shear-rate range). Viscosity was measured by rotational rheometry (TA Instruments, AR 2000 rheometer).



Viscosity **–** Gels of Eastman AQ™ 48 polymer and JR are extremely shear thinning as shown in Figures 3 and 4. Note that the viscosity curves for gels having similar concentrations of Eastman AQ 48 but different JR concentrations cross over one another. At low shear rates, the viscosity of the gels is higher at higher AQ/JR ratios. The gels with higher AQ/JR ratios are also more elastic. An explanation is that there is less free-moving JR polymer as the proportion of AQ to JR increases, i.e., a greater proportion of the JR polymer is "cross-linked" by association of its cationic groups with the AQ polymer's anionic groups. This is consistent with flow rates under static conditions. Figure 5 provides a guideline to predict the combinations of Eastman AQ 48 and JR-125 that will provide enough gravity flow to deliver product from a container. For example, comparing two gels containing 0.7 wt % Eastman AQ 48, the gel with 2.75% JR-125 flowed down to the opening of a squeeze tube within a short time after being dispensed, whereas the gel with 1.75% JR-125 did not flow quickly enough for a second application within a reasonable time. Therefore, the ratio of Eastman AQ 48 to JR can be adjusted to achieve the desired viscoelastic properties over a range of shear rates.

Figure 5

Flow rate of gels formed with Eastman AQ™ 48 polymer and JR-125 under static conditions.



Heat stability – The gels were heat stable when conditioned 1 hour at 80°C. Although the viscosity decreased when the gels were heated, the gels returned to their original viscosity when cooled to room temperature.

pH – The gels have a pH of 5.4 to 5.5.

Stiffness on hair – The gels were applied to 6-inch hair tresses in a controlled manner, allowed to dry at room temperature, and tested for stiffness using a 3-point bend test (Texture Analyzer). The results did not show a consistent trend that could be related to concentrations of the Eastman AQ™ 48 polymer and JR polymer. However, the average bend force for the AQ/JR gels was more than twice the bend force of the commercial gel. It is likely that ingredients added to enhance other properties on the hair would reduce stiffness.

Conditioning – UCARE Polymer JR and other cationic conditioning polymers are known to deposit on hair because of the attraction between the negatively-charged surface of the hair and the positively-charged polymer. The substantivity of cationic polymers to hair is related to the charge density of the cationic polymer.[1] Calculations based on the charge densities of Eastman AQ™ 48 polymer and JR-125 show that 8% of the total JR cations are associated with AQ anions at an AQ/JR weight ratio of 0.13. At the upper end of the AQ/JR weight ratio range, i.e., 0.50 AQ/JR, 30% of the JR cations are associated with AQ anions. Therefore, the AQ/JR gels have a significantly large net positive charge to provide affinity and conditioning for negatively-charged hair.

Suggested preparation of a test formulation

- Prepare a 4% solution of UCARE polymer JR-125 or JR-400 by sifting the polymer powder into water and mixing at room temperature.
- Prepare a 4% dispersion of Eastman AQ™ 48 polymer by heating water to about 45°C, adding the pellets made of Eastman AQ polymer and stirring until dispersed.
- Add a preservative to the JR solution and dispersion of Eastman AQ if they will be stored for a period of time.
- Add the appropriate amount of dispersion of Eastman AQ to the JR solution; then add the appropriate amount of water (and other additives) to get the desired concentration of JR and Eastman AQ polymers. Mix with a rotor-stator type mixer for about 5 minutes. Slow mixing typically produces a white precipitate rather than a clear gel.

Additives

Other ingredients can be added before or after mixing the Eastman AQ™ 48 polymers and JR-125 polymer to form the gel. Adding ingredients before mixing avoids any difficulty of dispersing the materials after the gel has formed. For example, the structure and clarity of the gels was maintained when the following ingredients were added before and after mixing: 2 wt % glycerin, 2 wt % propylene glycol, 2 wt % ceteareth-25, 0.5 wt % PEG-12 dimethicone, and 0.2 wt % sodium chloride. The addition of anionic ingredients would require further modification to the composition to maintain gel stability and clarity.

[1] *Product brochure, "UCARE Polymers, Cationic conditioners that revitalize hair and skin," Amerchol Corporation, subsidiary of The Dow Chemical Company, March 2005, pp 7-8.*

Viscosity modifications

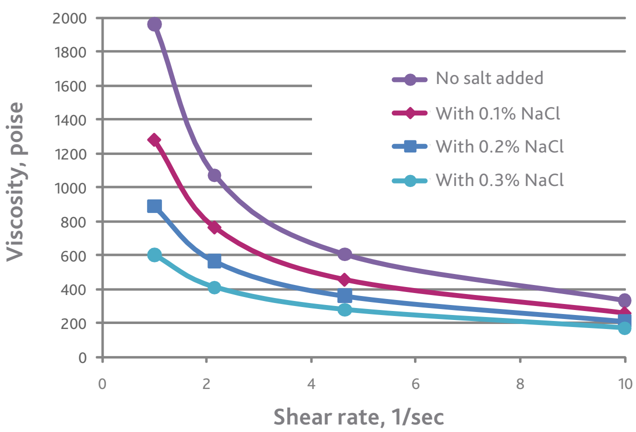
In addition to adjusting the ratio of Eastman AQ™ 48 polymer to JR polymer, the viscosity of the gels can be modified as follows while maintaining the desired solids content.

Increase viscosity: Use a higher-molecular-weight JR. For example, use UCARE polymer JR-400 instead of JR-125.

Reduce viscosity: Add salt. Salts such as sodium chloride disrupt the ionic cross-linking, reducing the viscosity of the gels (see Figure 6).

Figure 6

Effect of salt on gel containing 0.7% Eastman AQ™ 48 polymer and 2.25% JR-125.



Applications

Many hair-styling products, including hairspray, take advantage of the excellent properties of Eastman AQ™ 48 polymer as a hair fixative. Therefore, the AQ/JR gels are likely to provide clear and glossy hair-styling products having both conditioning effects and strong hold. It has been found that such products benefit from the addition of an ethoxylated alcohol to improve comb-ability and manageability. Also, gels having very low concentrations of Eastman AQ 48 and JR-125, but high AQ/JR weight ratios (about 0.5), were found to be sufficiently shear thinning for application as spray gels.

The gels formed with Eastman AQ™ polymers and JR could be used in other personal-care products contributing viscosity build, film forming, and conditioning to hair and skin, provided that the other ingredients of the formulation do not disrupt the AQ/JR gel structure. Possibilities include shave gels, other types of skin care products, and hand sanitizers.

Figures 1, 2 and 5 were created using Design-Expert™ software; the mathematical models used for graphing were those "suggested" by the software.

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