VANZAN®

Xanthan Gum

Vanderbilt Minerals, LLC

A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.

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VANZAN®

Xanthan Gum

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INTRODUCTION

Xanthan gum is a high molecular weight exocellular polysaccharide derived from the bacterium *Xanthomonas campestris* using a natural, aerobic fermentation process. The process is conducted in a sterile environment where the pH, oxygen content and temperature are rigorously controlled. After fermentation is complete, the broth is sterilized and the gum is recovered by precipitation with isopropyl alcohol, then dried, milled and packaged under aseptic conditions.

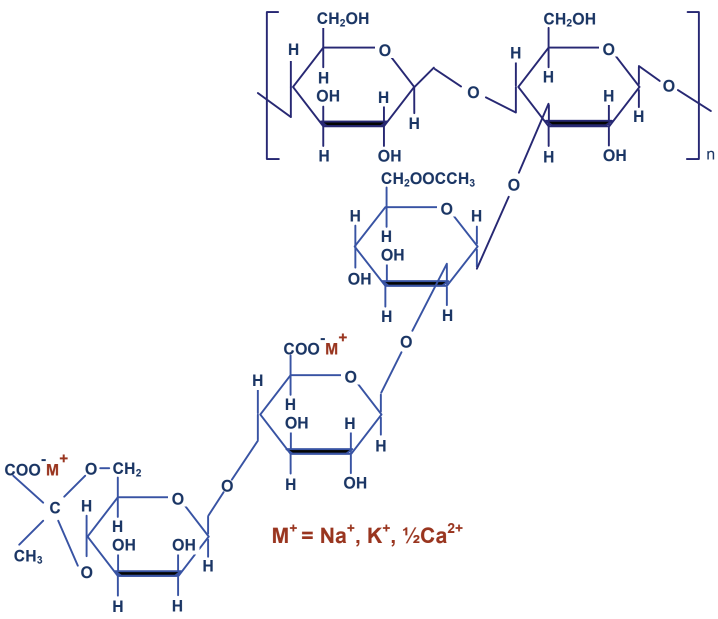
VANZAN is widely used as a rheology control agent for aqueous systems. It increases viscosity, helps to stabilize emulsions, and prevents the settling of solids in a wide variety of consumer and industrial applications.

VANZAN grades are available for pharmaceutical, personal care, agricultural, household & institutional and industrial applications.

STRUCTURE

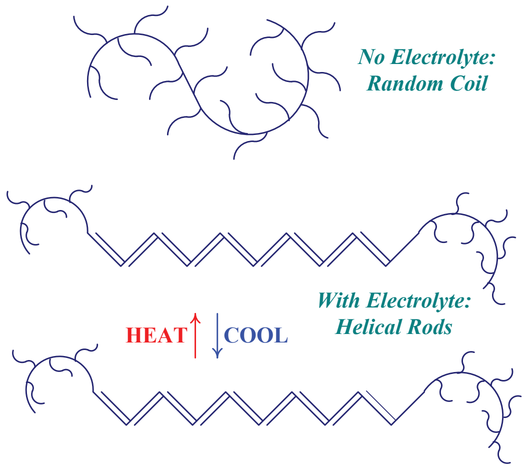
The molecular structure of **VANZAN** is illustrated in Figure 1. The xanthan polymer backbone is identical to that of cellulose, but the unique character of xanthan gum is derived from the trisaccharide side chain on alternate sugar units. This chain is composed of a glucuronic acid salt between a mannose acetate and a terminal mannose unit. A pyruvate is attached to about 60% of these terminal units. The glucuronic acid and pyruvic acid groups on the side chains give xanthan gum its anionic charge. The interaction of these anionic side chains with the polymer backbone and with each other determines the beneficial properties of xanthan gum solutions.

Figure 1: Structure of VANZAN Xanthan Gum



In solutions of low ionic strength or at high temperature, the xanthan gum chains adopt a random coil configuration, because the anionic side chains repel each other. However, the addition of even small amounts of electrolyte reduces the electrostatic repulsion among the side chains, allowing them to wrap around and hydrogen bond to the backbone. The polymer chain straightens into a relatively rigid helical rod. This shape reverts to the random coil if the gum solution is highly diluted or heated. With increasing electrolyte concentration, however, the rod shape is maintained at higher temperatures and greater dilutions. At ionic strengths above approximately 0.15M, it is retained up to 100°C. Figure 2 shows the effect of electrolyte on xanthan gum molecular configuration.

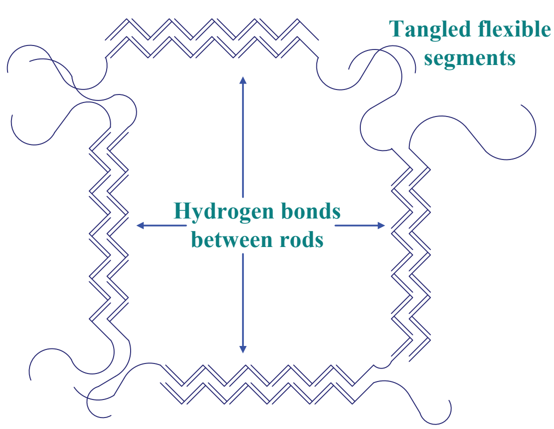
Figure 2: Effect of Electrolyte on Xanthan Molecular Configuration



RHEOLOGICAL PROPERTIES

The nature of the interaction among xanthan gum molecules in aqueous solution is not certain, although both hydrogen bonding and ionic interactions are believed to be involved. In salt-free solutions, viscosity is built through the entanglement of the random polymer coils, to the extent allowed by the mutual repulsion of the negatively charged side chains. When electrolyte is present, a colloidal network forms, which is based on intermolecular hydrogen bonding among the helical rod segments, in addition to limited polymer entanglement, as illustrated in Figure 3. This network of entangled stiff molecules accounts for the characteristic rheological properties of xanthan gum solutions.

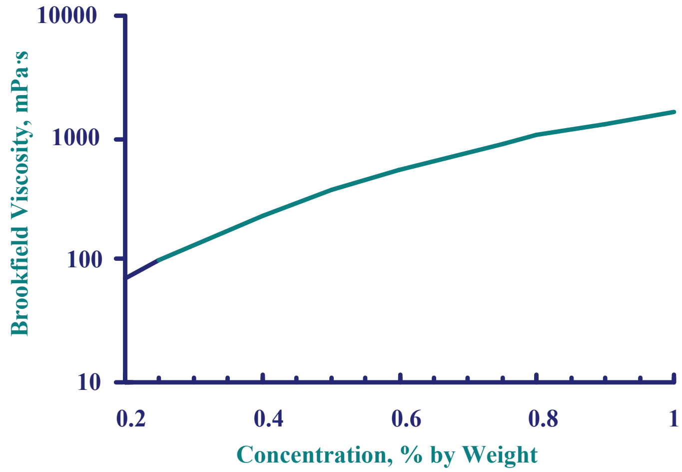
Figure 3: Xanthan Gum Polymer Network



THICKENING EFFICIENCY

The xanthan polymer network makes **VANZAN®** Xanthan Gum a highly efficient thickener for water-based systems. Concentrations as low as 0.1% by weight will cause a significant increase in viscosity. Concentrations greater than 1.0% by weight will result in very high viscosity systems with gel-like consistency. The relationship between the concentration and viscosity of **VANZAN NF** solutions is shown in Figure 4.

Figure 4: Viscosity vs. Concentration of VANZAN NF



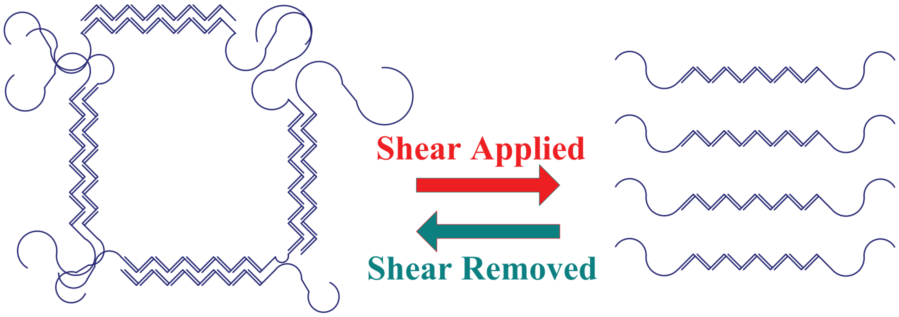
YIELD VALUE

VANZAN imparts yield value in aqueous compositions. Yield value reflects the minimum force (the yield stress) that must be applied to start disrupting the cohesive polymer network. In practical terms, solids, oils and gases are trapped and segregated by the polymer network unless the force of gravity or buoyancy can exert a force greater than the yield stress. The greater the yield value, the more stable the suspension, emulsion or foam. Other polymeric hydrocolloids can provide thickening efficiency, but few provide the yield value obtained from xanthan gum.

PSEUDOPLASTICITY

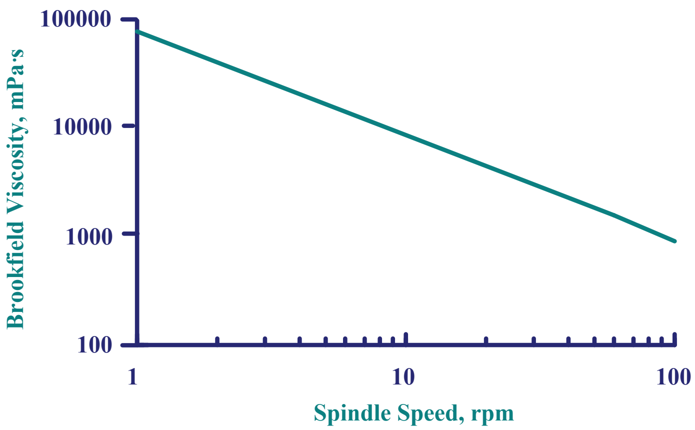
Once the yield stress is exceeded, xanthan gum solutions are pseudoplastic. The network disaggregates as individual polymer molecules align in the direction of the shear force. The extent of this disaggregation is proportional to the shear rate. The network reforms rapidly, however, when shear is removed. The effect of mechanical shear on the xanthan polymer network is illustrated in Figure 5.

Figure 5: Effect of Shear on the Xanthan Polymer Network



Aqueous solutions and formulated products containing **VANZAN**® Xanthan Gum exhibit a high degree of pseudoplasticity. The viscosity of the solution decreases significantly as the rate of shear increases, as shown in Figure 6. The viscosity is very high when the composition is at rest or subjected to low levels of shear. At high shear, which is frequently encountered when the formulated product is used, the viscosity is significantly lower.

Figure 6: Pseudoplasticity of a 1% VANZAN Solution



EFFECT OF TEMPERATURE

The rheology of **VANZAN** solutions is remarkably stable over a broad temperature range, as shown in Table 1. The viscosity and yield value of compositions containing the gum will not change significantly between ambient temperature and 60°C.

VANZAN provides the same thickening, stabilizing and suspending properties during long-term storage at elevated temperature as it does at ambient conditions. In addition, it imparts excellent freeze/thaw stability to most compositions.

Table 1: Effect of Temperature on Solution Viscosity

VANZAN® Xanthan Gum, **wt.%**	**Temperature, °C**	**Viscosity, mPa • s**
1.0	20	1550
1.0	40	1550
1.0	60	1500
0.5	20	550
0.5	40	500
0.5	60	450

EFFECT of pH

VANZAN is recommended for use in both acidic and alkaline systems. As shown in Table 2, the viscosity remains nearly constant between pH 2 and pH 12. Below pH 2 and above pH 12, the viscosity tends to decrease slightly. This makes **VANZAN** an excellent choice for compositions containing relatively high concentrations of acids or bases.

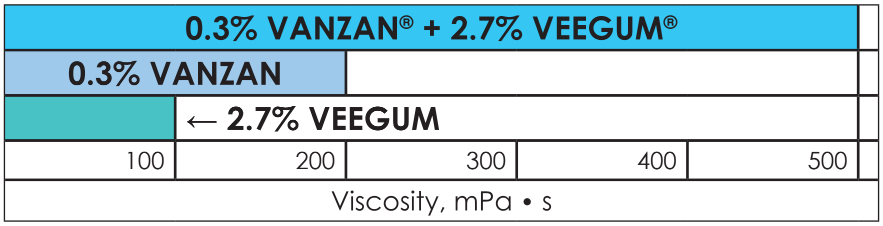
Table 2: Viscosity vs. pH in VANZAN Solutions

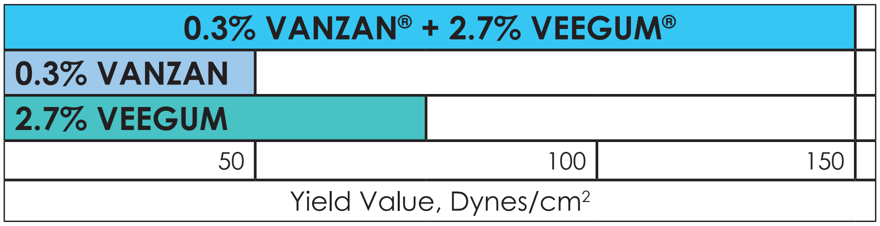
pH	**2**	**4**	**6**	**8**	**10**	**12**
Viscosity @ 1.0%, mPa • s	1550	1550	1550	1550	1550	1550
Viscosity @ 0.5%, mPa • s	500	550	550	550	550	500

RHEOLOGY SYNERGISM

Mixtures of xanthan gum with water-swellable clays or certain galactomannans produce synergistic rheological effects. The mixtures produce greater viscosity and yield value (and therefore greater thickening, stabilizing and suspending properties) than those developed by the individual components of the mixture. Water-swellable clays that are particularly effective in combination with **VANZAN®** Xanthan Gum are **VEEGUM®** Magnesium Aluminum Silicate products, which are also available from R.T. Vanderbilt Company, Inc. A weight-to-weight ratio of **VANZAN** to **VEEGUM** between 1:9 and 1:2 generally produces the most desirable results. Figure 7 demonstrates the synergism between **VANZAN** and **VEEGUM**.

Figure 7: VANZAN - VEEGUM Synergism





Mixtures of **VANZAN** and **VEEGUM** clays produce 1.4 to 1.8 times the viscosity as compared to the sum of the viscosity developed by individual components of the mixture. The combination also produces 1.7 to 2.1 times the yield value as compared to that expected from the sum of the individual components.

Strong synergistic effects are exhibited by mixtures of xanthan gum with galactomannans like guar gum and locust bean gum. Weight-to-weight ratios of **VANZAN** to guar gum between 1:9 and 1:1 are recommended. The synergism with locust bean gum is even stronger than that with guar gum. A weight-to-weight ratio of 1:1 is recommended for most applications. At concentrations greater than 0.2%, mixtures of xanthan gum and locust bean gum will form thermally reversible gels when heated above 55°C and subsequently cooled.

COMPATIBILITY GUIDELINES

Because **VANZAN** is an anionic polysaccharide, it is compatible with other anionic and nonionic ingredients. However, xanthan gum is not generally compatible with cationic species, which can cause interactions that lead to the precipitation of both components. It is also incompatible with strong oxidizing agents such as NaOCl (bleach) and H_2O_2 (hydrogen peroxide), which can cause rapid and severe degradation of the polymer.

SOLVENTS

Xanthan gum is compatible with aqueous solutions of common water-miscible solvents. One percent **VANZAN** solutions, for example, can contain up to 40% to 50% glycerol, glycols, glycol ethers, and alcohols without precipitation of the gum.

ACIDS and BASES

VANZAN® Xanthan Gum exhibits good compatibility in many strong mineral acid solutions, as shown in Table 3. **VANZAN** also provides long-term viscosity stability in alkaline systems, including those containing sodium carbonate, sodium hydroxide, sodium metasilicate or sodium phosphate.

Table 3: Compatibility of 1% VANZAN with Acids

Acid	Acid Concentration	Viscosity Retained after 3 Months[1]
Citric Acid	10%	80%
Citric Acid	20%	80%
Acetic Acid	10%	75%
Acetic Acid	20%	75%
Sulfuric Acid	5%	85%
Sulfuric Acid	10%	85%
[1]Viscosity measured with Brookfield LVTD, Spindle 3, 60 rpm		

SALTS

VANZAN is stable in the presence of high concentrations of many inorganic salts. Table 4 lists a number of salt solutions containing 0.5% xanthan gum that exhibit stable viscosity with extended storage.

Table 4: Compatibility of 0.5% VANZAN with Salts

Salts	Salt Concentration	Viscosity Retained after 3 Months[1]
NaCl	5%	105%
NaCl	10%	110%
NaCl	20%	105%
KCl	5%	110%
KCl	10%	105%
KCl	20%	105%
$MgSO_4$	5%	105%
$MgSO_4$	10%	110%
$MgSO_4$	20%	105%
$CaCl_2$	5%	115%
$CaCl_2$	10%	105%
$CaCl_2$	20%	110%
[1]Viscosity measured with Brookfield LVTD, Spindle 3, 60 rpm		

Divalent salts, such as those of calcium, magnesium, and barium can cause the gelation and/or precipitation of xanthan gum at alkaline pH (pH>10). Trivalent salts, such as those of aluminum, iron and chromium can cause gelation at acid and neutral pH levels as well.

Pharmaceutical and Personal Care Grades

Three grades of **VANZAN** are available to the pharmaceutical and personal products industries. Key physical properties and features of these grades are summarized in Table 5. All pharmaceutical grades of **VANZAN** (those designated with the suffix "NF") conform to the requirements of the Xanthan Gum NF monograph as well as those of the European Pharmacopoeia and Japanese Pharmaceutical Excipients.

Table 5: VANZAN Pharmaceutical/Personal Care Grades

	Viscosity, mPa • s[1]	pH[2]	Moisture, %	Particle Size
VANZAN® NF Xanthan Gum	1400 - 1600	6.0 - 8.0	15 max.	95% min. - 80 mesh (180 µm)
VANZAN NF-F	1400 - 1600	6.0 - 8.0	15 max.	92% min. - 200 mesh (75 µm)
VANZAN NF-C	1300 - 1700	6.0 - 8.0	12 max.	95% min. - 80 mesh (180 µm)
[1]1% xanthan gum in 1% KCl solution, measured at 20°C using Brookfield Model LV viscometer at 60 rpm with Spindle #3.				
[2]1% xanthan gum in deionized water at 25°C.				

VANZAN NF is the general purpose grade suitable for most pharmaceutical and personal care applications.

VANZAN NF-F is a finely ground powder for applications such as tablets and dry mix powder formulas.

VANZAN NF-C produces clear solutions for applications where product clarity is essential, such as syrups and gels.

TECHNICAL GRADES

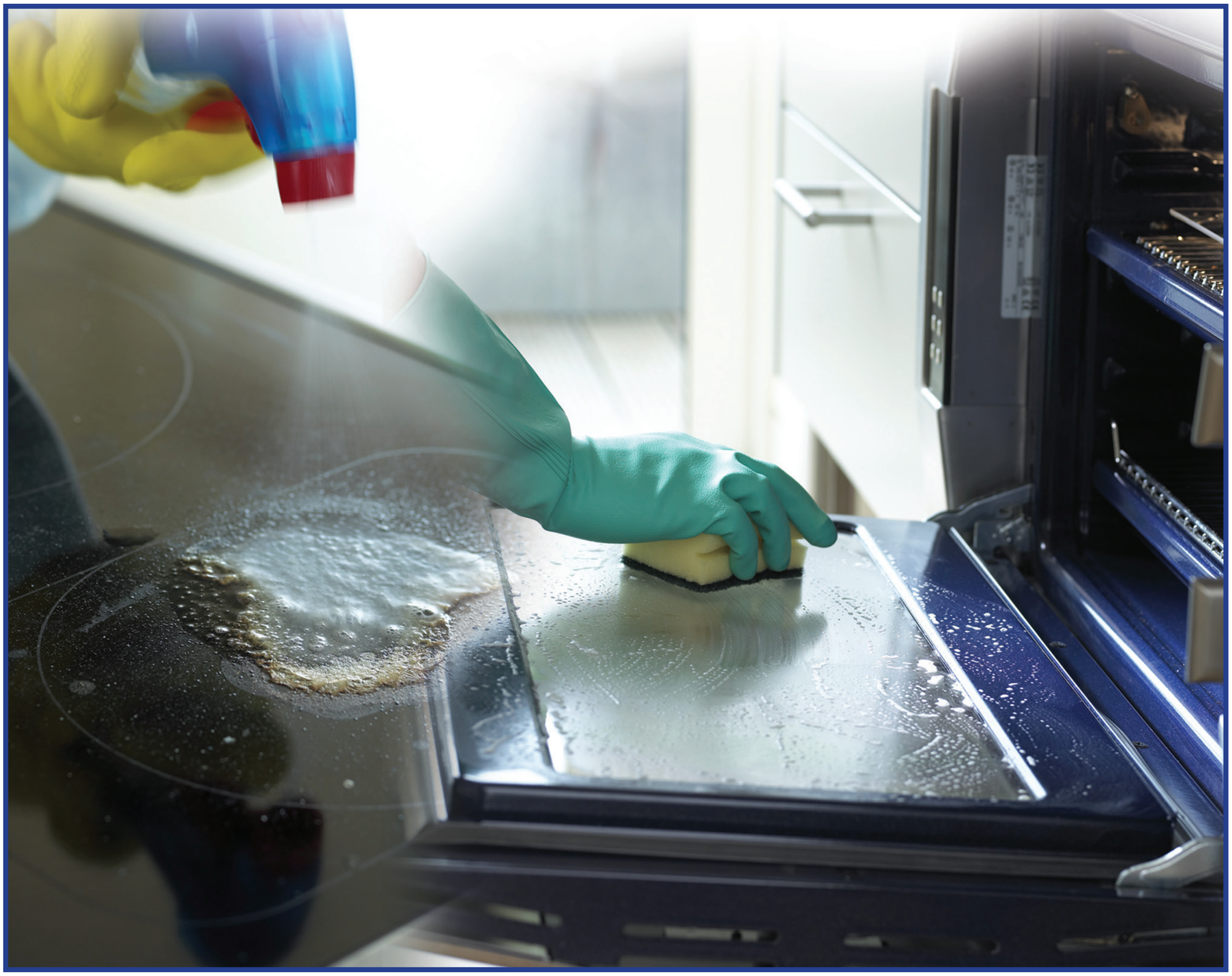
These grades are recommended for agricultural, household and institutional products, as well as for a variety of industrial applications. Key properties of these technical grades are summarized in Table 6.

Table 6: VANZAN® Xanthan Gum Technical Grades

	Viscosity, mPa • s	pH	Moisture, %	Particle Size
VANZAN® Xanthan Gum	1400 - 1600[1]	5.5 - 8.5[3]	15 max.	95% min. - 80 mesh (180 µm)
VANZAN D	1400 - 1600[2]	4.5 - 7.0[3]	15 max.	95% min. - 45 mesh (355 µm)
[1]1% xanthan gum in 1% KCl solution, measured at 25°C using Brookfield Model LV viscometer at 60 rpm with Spindle #3.				
[2]1% xanthan gum in deionized water, measured at 25°C using Brookfield Model LV viscometer at 60 rpm with Spindle #3.				
[3]1% xanthan gum in deionized water at 25°C.				

VANZAN is the general purpose grade suitable for most technical applications.

VANZAN D is surface-treated to make it temporarily insoluble. This facilitates dispersion and prevents the gum from dissolving until the surface treatment is removed by raising the pH of the system to 9 or greater. It is particularly convenient for systems where the final pH is alkaline.



APPLICATIONS

Tables 7 to 9 summarize the recommended applications for **VANZAN®** Xanthan Gum, the functions performed in the application, and the grade(s) recommended for the specific application.

Table 7: Pharmaceutical Applications

Application	Thickener	Suspending Agent	Emulsion Stabilizer	Gelling Agent	Foam Stabilizer	Stabilizer	Recommended Grade(s)
Dental Care							
Dental Impression Materials				X		X	VANZAN® NF-F Xanthan Gum
Dental Treatment Gels	X			X			VANZAN NF, NF-C
Dentifrice Pastes, Gels	X			X		X	VANZAN NF, NF-C, NF-F
Therapeutic Products							
Acne Treatment Lotions	X	X	X				VANZAN NF
Antacid Suspensions		X					VANZAN NF
Antidiarrheal Suspensions		X					VANZAN NF
External Analgesics	X		X				VANZAN NF
Oral Syrups & Elixirs	X						VANZAN NF-C
Other Pharmaceuticals							
Anti-Dandruff Shampoos	X	X			X		VANZAN NF
Ophthalmic Liquids	X						VANZAN NF-C
Tablet Coatings	X	X				X	VANZAN NF-F

Table 8: Personal Care Applications

Application	Thickener	Suspending Agent	Emulsion Stabilizer	Gelling Agent	Foam Stabilizer	Stabilizer	Recommended Grade(s)
Dental Care							
Dentifrice Pastes, Gels	X			X		X	VANZAN® NF, NF-C, NF-F
Hair Care							
Shampoos	X				X		VANZAN NF, NF-C
Styling Creams & Gels	X			X			VANZAN NF, NF-C
Perms & Hair Straighteners	X		X				VANZAN NF
Liquid Soaps & Bath Gels	X			X	X		VANZAN NF, NF-C
Skin Care							
Color Cosmetics	X	X	X				VANZAN NF
Depilatories	X		X				VANZAN NF
Deodorants & Antiperspirants	X		X				VANZAN NF
Creams & Lotions	X		X				VANZAN NF
Sunscreens	X	X	X				VANZAN NF

Table 9: Household, Institutional & Industrial Applications

Application	Thickener	Suspending Agent	Emulsion Stabilizer	Gelling Agent	Foam Stabilizer	Stabilizer	Recommended Grade(s)
Household/Institutional							
Acid Toilet Bowl Cleaners	X			X	X		VANZAN®
Auto Cleaners & Polishes	X	X	X				VANZAN
Auto Dishwasher Detergent (w/o Bleach)	X					X	VANZAN, VANZAN D
Basin, Tub & Tile Cleaners	X				X		VANZAN
Metal Cleaners & Polishes	X	X	X				VANZAN
Oven & Grill Cleaners	X						VANZAN, VANZAN D
Waterless Hand Cleaners	X		X				VANZAN
Industrial							
Agricultural Flow-ables	X	X	X				VANZAN
Adhesives	X						VANZAN
Textile Printing Pastes	X	X					VANZAN
Carpet Printing Pastes	X	X					VANZAN
Printing Inks	X	X					VANZAN
Ceramic Glazes	X	X					VANZAN
Paints & Coatings	X	X					VANZAN

PREPARATION OF SOLUTIONS

VANZAN® Xanthan Gum products are soluble in both cold and hot water. Proper preparation of xanthan gum solutions depends on four factors:

1. Dispersion of the gum particles

Xanthan gum must first be properly dispersed so that individual gum particles are surrounded by the aqueous medium. The individual particles then hydrate and dissolve. If the particles are not effectively dispersed, they will stick together, and the rapid hydration of the outer surface will form a gel layer which will block access of water to the rest of the particles. This will result in swollen lumps, also known as *fish eyes*. These lumps can require significant additional time and shear to dissolve.

Good dispersion is promoted by:

- High shear mixing.
- Blending of gum particles into a water-miscible non-solvent, such as glycol or alcohol, before addition to the aqueous phase; a ratio of gum to liquid between 1:2 and 1:10 is recommended.
- Dry blending with other formula ingredients, such as co-thickeners, salts, acids, abrasives or pigments before addition to the aqueous phase.

2. Shear rate

High shear mixing minimizes the tendency of the gum particles to come into contact and stick to each other, and thereby facilitates dissolution. Low shear mixing requires careful attention to dispersion technique.

3. Particle size

Particle size is an important factor with regard to dispersion and dissolution. The fine powder grade, **VANZAN NF-F**, has a larger particle surface area than the fine granule grades and will dissolve more quickly, but this requires particularly efficient dispersion to avoid swollen lumps.

4. Particle treatment

Surface treatment, as on **VANZAN D**, makes the gum particles temporarily insoluble. This facilitates dispersion without lumping, even with relatively slow mixing. After the particles are well dispersed, raising the pH to 9 or greater removes the coating and allows the particle to quickly dissolve.

The standard method of preparing **VANZAN** solutions starts by ensuring that the mixing vessel contains enough of the aqueous phase to cover the mixer blades when a vortex is developed. This avoids the incorporation of air bubbles. The gum is then added slowly, to avoid lumping, to the upper part of the vortex where the liquid velocity is greatest. Mixing is continued until the gum is dissolved.

An alternative method well-suited to large production batches is the introduction of the gum through an eductor, a funnel connected to the air inlet of a water-jet injector pump. Suction created by the high velocity water pulls xanthan gum particles from the funnel and into the water where they are efficiently dispersed before injection into a mixing tank to dissolve.

Either of the above methods can be used to prepare stock **VANZAN** solutions at 1-2% concentration. A suitable preservative should be added to a stock solution that will be held more than 24 hours.

STORAGE AND STABILITY

In its dry form, **VANZAN** is resistant to degradation by bacteria, and a shelf life of 3 years from the date of production is guaranteed if the product is stored in a cool and dry place. The use of a preservative is recommended if solutions of **VANZAN** are stored longer than 24 hours. **VANZAN** is compatible with most commonly used preservatives.

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