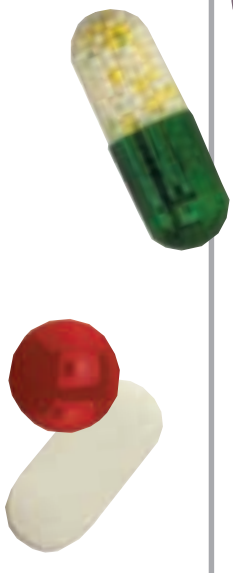
POLYOX

Water-Soluble Resins

Unique Resins for Binding, Lubricity, Adhesion and Emollient Performance



Water-Soluble Resins

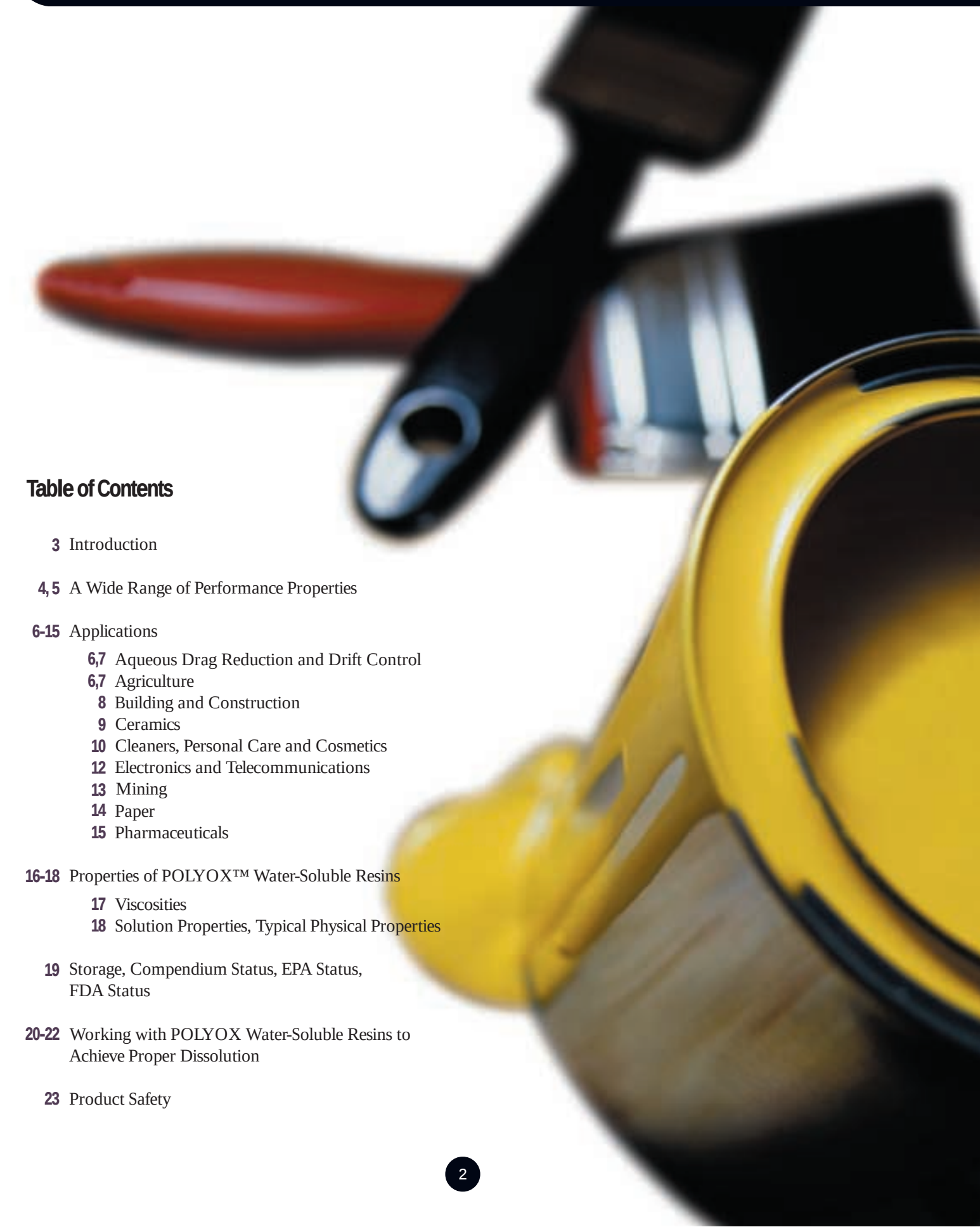


Table of Contents

Introduction

POLYOX Water-Soluble Resins are nonionic, high molecular weight water-soluble poly (ethylene oxide) polymers. Molecular weights range from 100,000 to about 8,000,000. They exhibit many properties that are typical of other classes of water-soluble polymers – lubricity, binding, water retention, thickening, and film formation.

But POLYOX Water-Soluble Resins can do even more. They're thermoplastic materials that are readily calendared, extruded, injection molded, or cast. Films of POLYOX Water-Soluble Resins are flexible, tough, and resistant to most oils and greases. With their very high molecular weight, POLYOX Water-Soluble Resins are viscoelastic, so their aqueous solutions can reduce spattering and misting potential. And POLYOX Water-Soluble Resins can form association compounds with many other substances to achieve a wide variety of additional, useful formulation properties.

An unusually wide range of performance properties that

High Binding Efficiency

POLYOX Water-Soluble Resins have high-binding efficiency for pigments, fillers, metal powders and ceramics. These binders easily burn off at low temperatures with little or no tendency to char.

Form Novel Complexes

The strong hydrogen bonding affinity of POLYOX Water-Soluble Resins accounts for the association of these polyethers with various polar compounds, such as phenolic resins, mineral acids, halogens, ureas, lignin sulfonic acids and poly (carboxylic acids). These novel complexes can be discrete chemical entities resulting from very strong intermolecular association and often exhibit properties markedly different from either component.

Crosslinkable

POLYOX Water-Soluble Resins can be crosslinked to form gels that are highly water-retentive.

Emollient

When applied to the skin and hair, POLYOX Water-Soluble Resins produce a soft and “silky” feel.

Film Former, Excipient

POLYOX Water-Soluble Resins can be formed into flexible films both by thermoplastic processing and casting techniques. Such films may be made of POLYOX Water-Soluble Resins alone or blended with a wide variety of other polymers, such as polyethylene, polystyrene, polycaprolactone, ethylene vinyl acetate, nylon, etc.

Low Toxicity

POLYOX Water-Soluble Resins show a very low order of toxicity in animal studies by all routes of exposure. At the maximum practical oral dose to rates of about 2 g/kg of body weight there were no deaths nor signs of toxicity. Because of their high molecular weights, the resins are poorly absorbed from the gastrointestinal tract and are completely and rapidly eliminated. These resins are neither skin irritants nor sensitizers, nor do they cause eye irritation as the dry powder or as aqueous solutions.

Flocculant Activity

High molecular weight grades of POLYOX Water-Soluble Resins effectively adsorb onto many colloidal materials and perform as efficient flocculating agents. They exhibit a high affinity for a variety of materials, including silica, clays, oxidized coal fines, lignins and paper fines.

add value to products and processes.

Lubricity
POLYOX Water-Soluble Resins impart a high degree of lubricity when in contact with water.

Solubility/Thickening of Many Organic Solvents
POLYOX Water-Soluble Resins are readily soluble in and will thicken a wide variety of organic solvents at various temperatures. Typical organic solvents include most halogenated hydrocarbons, various ketones, alcohols, aromatic hydrocarbons and esters. POLYOX Water-Soluble Resins are not generally soluble in aliphatic hydrocarbon solvents, glycols, diols and aliphatic ethers.

Thermoplasticity
As thermoplastics, POLYOX Water-Soluble Resins are readily calendered, extruded, injection molded, or cast. Sheets and films of this material are heat-sealable and can be oriented to develop high strength. Films are inherently flexible, tough and resistant to most oils and greases. These resins are compatible with many natural and synthetic polymers. The combination of thermoplasticity and aqueous solubility and compatibility with "hydrophobic" polymers (e.g., polyethylene, polycaprolactone, ethylene vinyl acetate, nylon, etc.) make POLYOX Water-Soluble Resins a valuable asset for degradable plastics applications.

Wet Tack
POLYOX Water-Soluble Resins exhibit a high degree of wet tack and, thus, are useful as wet adhesives. The dried residue is non-tacky.

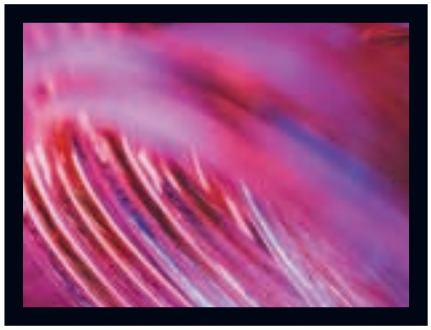
Thickening Power (Aqueous)
POLYOX Water-Soluble Resins are nonionic and completely water-soluble at all temperatures up to the boiling point of water. Unlike most other high molecular weight, water-soluble resins, they do not exhibit an inverse solubility-temperature relationship, except near the boiling point.

POLYOX Water-Soluble Resins are extremely effective thickening agents in both fresh and salt water. Aqueous solutions are pseudoplastic (i.e., shear thinning).

Drag Reduction/ Drift Control
Very low concentrations of the higher molecular weight POLYOX Water-Soluble Resins can reduce the turbulent frictional drag of the water in which they are dissolved by as much as 80 percent.

Viscoelasticity
The flexibility of ether linkages combined with the extremely high molecular weight of POLYOX Water-Soluble Resins produces solutions with elastic behavior. Such solutions will climb a rotating shaft! This property also tends to reduce both the spattering and misting potential of aqueous solutions.

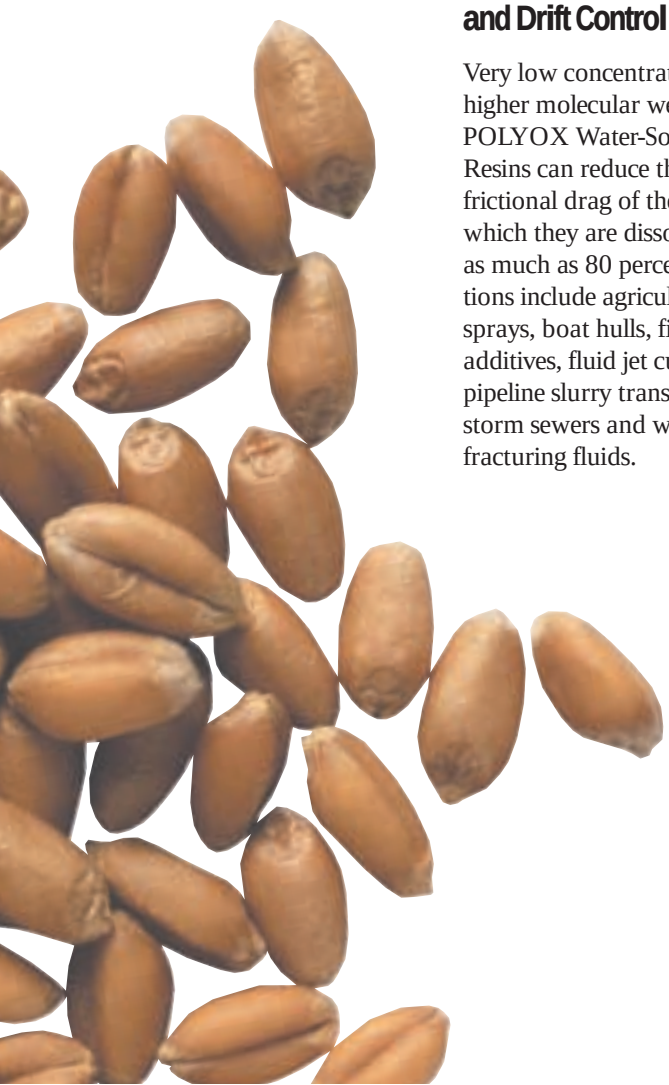
Available in Many Grades
POLYOX Water-Soluble Resins are supplied in a wide variety of molecular weight grades and formulated compounds in standard and NF (National Formulary) grades.



POLYOX Water-Soluble Resins have an unusual array of properties that make them useful in a wide variety of applications. Here's an overview of the many ways they can be used and the values they bring to so many different industries. For more information, see corresponding tables.

Aqueous Drag Reduction and Drift Control

Very low concentrations of the higher molecular weight POLYOX Water-Soluble Resins can reduce the turbulent frictional drag of the water in which they are dissolved by as much as 80 percent. Applications include agricultural sprays, boat hulls, fire-fighting additives, fluid jet cutting, pipeline slurry transport, storm sewers and well-fracturing fluids.



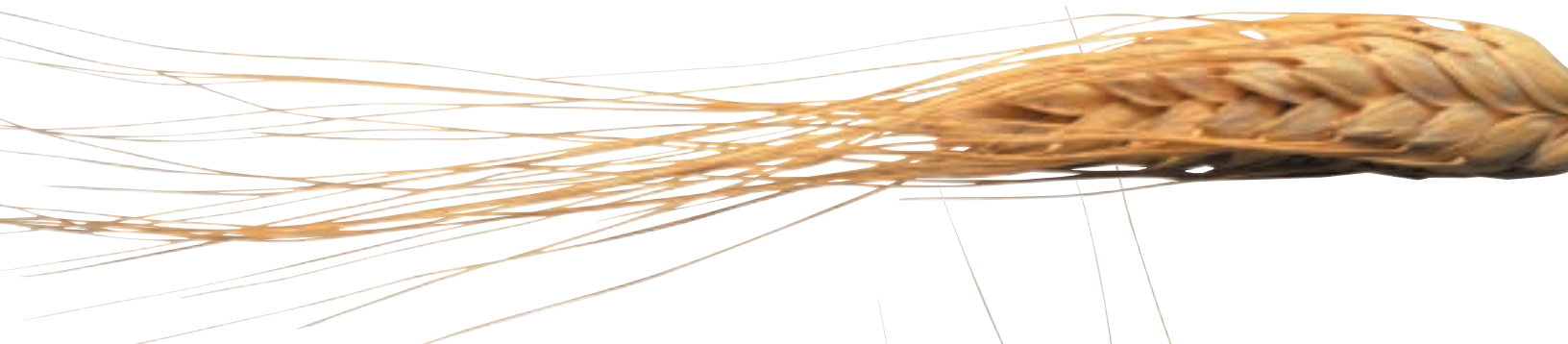
Agriculture

Seed Coatings – As film-formers, POLYOX Water-Soluble Resins can be used in undiluted form as seed coatings. POLYOX WSR N-10 and WSR N-750 products are typically used for this application.

Seed Tape – The thermoplastic nature and film-forming characteristics of POLYOX Water-Soluble Resins make them ideal for tape coating and adhering seed. Because they're water-soluble, POLYOX Water-Soluble Resins release seeds after planting and don't interfere with germination and growth.

Drift Control – POLYOX Water-Soluble Resins are used for drift control of agricultural sprays, reducing carryover to other areas and permitting more efficient spray directly on foliage.

Water-Soluble Packaging – POLYOX Water-Soluble Resins can be used as water-soluble protective coatings for premeasured doses of pesticides and other solid agricultural formulations.



POLYOX Water-Soluble Resins in Aqueous Drag Reduction and Drift Control

Application	Recommended grades	Use Levels, PPM	Benefits
Fire-fighting additives	WSR-30 WSR-303 WSR Coagulant	5-100	Reduces turbulent frictional drag by as much as 80%.
Storm sewers	WSR-301 WSR-303	About 200	Reduces turbulent frictional drag by as much as 80%.

POLYOX Water-Soluble Resins in Agriculture

Application	Recommended grades	Use Levels wt%	Benefits
Seed Coatings	WSR N-10 WSR N-750	100	Excellent film-forming characteristics.
Seed Tape	WSR N-10 WSR N-80 WSR N-750	100	Excellent film-forming characteristics and thermoplasticity. Doesn't interfere with germination and growth of seeds after planting.
Water-soluble packaging	WSR N-10 WSR-205	2.0	Totally water soluble; packaging dissolves readily.
Agricultural drift control	WSR-301	0.05-0.2	Reduced carry over to other areas. Permits more efficient sprays directly on foliage.

Building and Construction

POLYOX Water-Soluble Resins are used as thickeners, binders, and association compounds in paints, coatings, paint removers, cements, and concrete.

Paints, Coatings, and Paint Removers– POLYOX Water-Soluble Resins may be used as aqueous phase thickeners for latex paints. And they're also excellent thickeners for many organic solvents. POLYOX WSR N-750 resin is typically used at 3.0 % by weight in paint and varnish removers.

Cements and Concrete– In cement mortars, POLYOX Water-Soluble Resins provide aqueous thickening to provide proper body and application properties. Because they form pseudoplastic (shear thinning) solutions, they enhance workability of cements and mortars.

POLYOX WSR-301 resin adds excellent lubricity to concrete mixes at 0.005 to 0.01% of formulation weight to assist pumpability.

POLYOX Water-Soluble Resins in Building and Construction

Application	Recommended grades	Use Levels wt%	Benefits
Paints & Coatings	WSR N-750	3.0	Provides proper body and application properties. Reduces splattering and dripping.
Cements & Concrete	WSR-301	0.005 to 0.01	Provides aqueous thickening for proper body and application properties. Also forms pseudoplastic solutions that enhance workability of cements and mortars. Film forming properties provide excellent encapsulation of mineral powders and aggregates.
Asbestos cement extrusion aid	WSR-301 WSR Coagulant	0.4 based on dry ingredients	Lubricity reduces energy requirements for extrusion.
Paint and varnish removers	WSR N-750	3.0	Good solubility in many organic solvents.
Concrete pumping	WSR-301	0.005-0.01	Lubricity assists pumping.

Ceramics

POLYOX Water-Soluble Resins are used as binders and forming aids in ceramic parts, ceramic bricks, ceramic fibers, and ceramic extrusion.

In ceramic applications, POLYOX Water-Soluble Resins serve primarily as binders and forming aids. They effectively bind components of ceramic mixes for the formation of bricks and ceramic parts. They also serve as excellent binders for ceramic fibers. For binding, POLYOX WSR-301 and WSR-303 are typically used at 0.001 - 0.7% by weight of the ceramic mix.

POLYOX Water-Soluble Resins also provide excellent lubricity, aiding the extrusion of products like bricks and asbestos cement.

POLYOX Water-Soluble Resins in Ceramics

Application	Recommended grades	Use Levels, wt%	Benefits
Ceramic forming aid	WSR-301	0.001-0.7	Lubricity aids mixing and extrusion. High binding efficiency. Burns off at low temperatures with little or no tendency to char.

Cleaners, Personal Care, and Cosmetic Products

POLYOX Water-Soluble Resins add many important functional and sensory properties to cleaners and personal care products. Perhaps the most valuable is their contribution of emollient properties to personal care products – hair care products, creams, and lotions get the smooth, soft feel that consumers expect. POLYOX Water-Soluble Resins also serve as thickeners, binders, lubricants, and water-retention agents in many other cleaning and personal care products.

Cleaners– POLYOX Water-Soluble Resins can be used to thicken both aqueous cleaners and those containing many organic solvents. They also act as emollients in liquid detergents like dishwashing liquids. With their film-forming activity, POLYOX Water-Soluble Resins can be used for water-soluble packaging of solid detergent products. POLYOX Water-Soluble Resins add lubricity to polishes and waxes for easier application.

Hair Care Products– In shampoos and conditioners, POLYOX Water-Soluble Resins serve as emollients and aqueous thickeners. They also add aqueous thickening to hair set lotions.

Skin Care Products– POLYOX Water-Soluble Resins are outstanding emollients for creams and lotions, providing a soft feel and smooth application. These resins are also crosslinkable to form water-retentive matrices for cosmetic gels.

Shaving Products– POLYOX Water-Soluble Resins provide the primary lubricant action in lubricant strips for razors — injection molded, or cast to the desired shape. In shaving gels, POLYOX Water-Soluble Resins work as emollients and lubricants.

Oral Care Products– POLYOX Water-Soluble Resins provide excellent thickening with low toxicity in toothpaste, mouthwashes, and denture creams. They also provide wet tack for dental cements and dental adhesives.

POLYOX Water-Soluble Resins in Cleaners, Personal Care and Cosmetic Products

Application	Recommended grades	Use Levels, wt%	Benefits
Creams and lotions	WSR-205 WSR N-60K	0.25-0.75	Provides a soft feel and smooth application. The resins are also crosslinkable to form water-retentive matrices for cosmetic gels.
Cold Cream	WSR-205	0.5	Provides a soft feel and smooth application. The resins are also crosslinkable to form water-retentive matrices for cosmetic gels.
Denture adhesives	WSR-301	0.5	Provides excellent thickening with low toxicity, plus wet tack.
Denture creams	WSR-301 NF	12-15	Provides excellent thickening with low toxicity.
Detergent liquids	WSR N-3000	0.05-0.1	Thickens aqueous cleaners, acts as an emollient. Film-forming activity useful for water-soluble packaging of solid detergent products.
Hair conditioner	WSR-205	0.25	Provides a soft feel and smooth application, also adds aqueous thickening.
Hand soaps (bar and liquid)	WSR N-750 WSR N-3000 WSR-205 WSR N-12K WSR N-60	0.1-1.5 0.1-2.0 0.2 0.3	Provides a soft feel and smooth application. Excellent binding properties.
Rubbing alcohol	WSR-301	0.1	Provides a soft feel and reduces astringent sensation.
Shampoos	WSR N-750 WSR-205 WSR N-60K	0.25-0.5	Provides a soft feel and smooth application, also adds aqueous thickening.
Shaving gels	WSR-205	0.1	Provides a soft feel and smooth application; lubricant action reduces razor drag.
Shaving/Razors	WSR N-80 WSR N-750 WSR-301 WSR Coagulant	50-75	Provides the primary lubricant action in lubricant strips for razors.
Toothpaste	WSR-205 NF	0.3-1.0	Provides excellent thickening with low toxicity.

Electronics and Telecommunication

Batteries– POLYOX Water-Soluble Resins are used as binders for battery electrodes and separators for batteries. They can dissolve a large amount of the inorganic salts and therefore can be used as ionically conductive polymer electrolytes in rechargeable batteries. The polymer electrolytes can be made into strong and flexible thin films to improve the battery safety and performance. This approach also opens the door to new battery designs.

Fluorescent Lamps and Cathode Ray Tubes– POLYOX Water-Soluble Resins are widely used as binders for fluorescent lamp phosphors. POLYOX WSR N-750 and N-3000 are typically used at concentrations of 1-5%. These polymers also see utility as phosphor binders in cathode ray tubes.

Wire, Cable, and Optical Fibers– To assist in assembly and installation operations, POLYOX Water-Soluble Resins may be used as lubricants for wire, cable, and optical fibers.

POLYOX Water-Soluble Resins in Electronics and Telecommunications

Application	Recommended grades	Use Levels wt%	Benefits
Batteries	WSR N-750 WSR N-80	20 ~ 80	Efficient binding for battery electrodes. Form ionically conducting polymer electrolytes with many inorganic salts.
Wire, Cable and Optical Fibers	WSR-301	0.1	Lubricity aids in assembly and installation operations.
Fluorescent lamp phosphor binder	WSR N-750 WSR N-3000	0.1-2.0 4.0-6.0	Burn off at low temperatures with little or no tendency to char.

Mining

POLYOX Water-Soluble Resins are used extensively as flocculating agents in mining operations. High molecular weight grades of POLYOX Water-Soluble Resins, sold under the UCARFLOC™ name, effectively adsorb onto many colloidal materials and perform as efficient flocculating agents. They exhibit a high affinity for a variety of materials, including silica, clays, and oxidized coal fines. See the table at right.

POLYOX Water-Soluble Resins are used as lubricants and drag reduction agents for pipeline slurry transport. They also have utility as dust suppressants.

UCARFLOC Flocculating Agents In Mining Applications

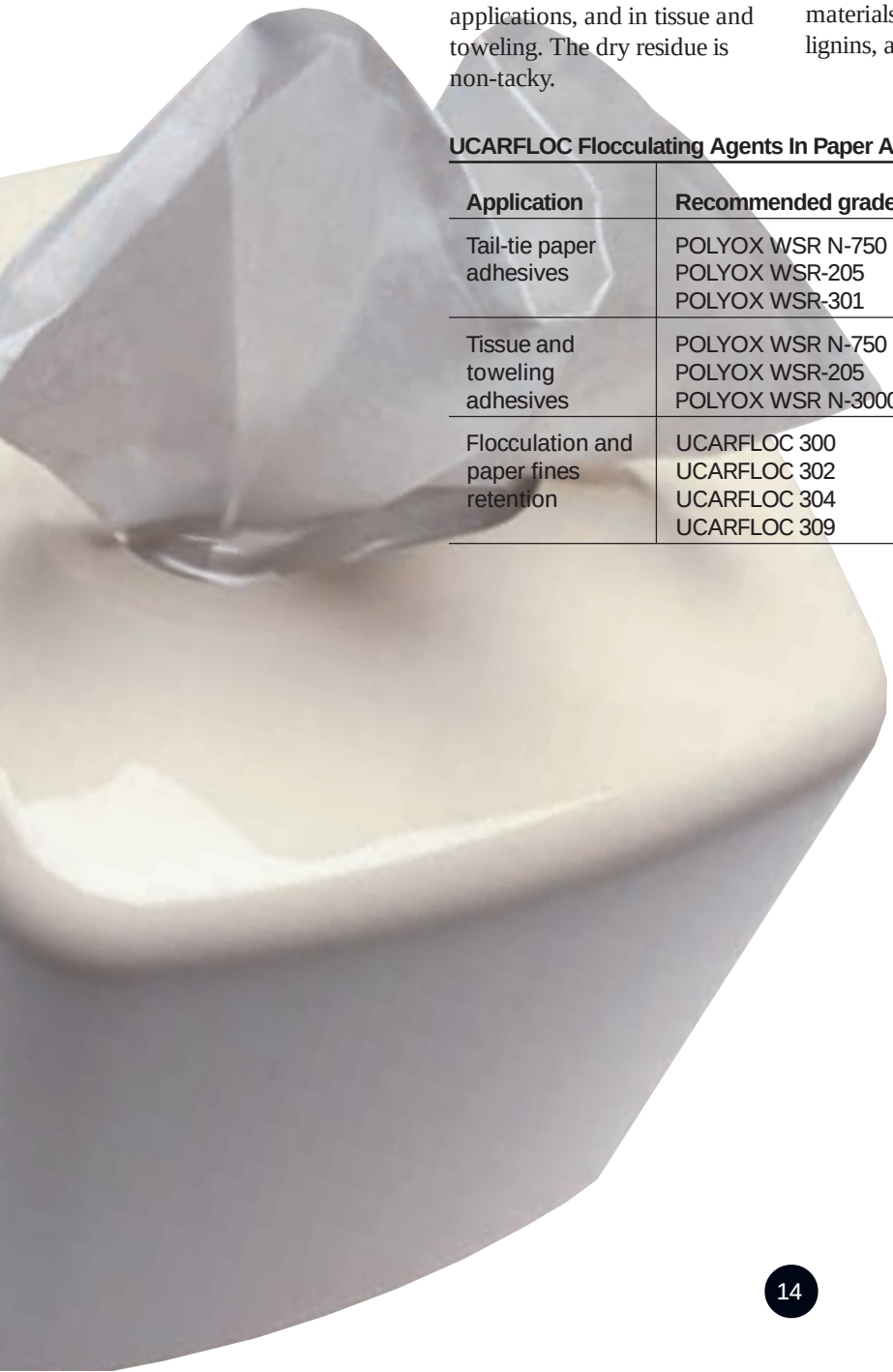
Application	Recommended grades	Use Levels	Benefits
Clay suspensions	UCARFLOC 302 UCARFLOC 304 UCARFLOC 309	5 ppm - 0.2% of total clay suspension	High affinity for many materials; effective adsorption onto surfaces and efficient flocculating action.
Heavy metal ore flocculation	UCARFLOC 300 UCARFLOC 302 UCARFLOC 309	0.01 - 0.1% of solids	
Oxidized coal slurries	UCARFLOC 302 UCARFLOC 304 UCARFLOC 309	0.01 to 0.1% of slurry solids	
Phosphate slimes	UCARFLOC 300 UCARFLOC 304	0.01 - 0.1% of clay solids	
Rock drilling enhancer	UCARFLOC 300	10 - 20 ppm	
Silica suspensions	UCARFLOC 302 UCARFLOC 304 UCARFLOC 309	5 - 10 ppm	
Reducing spontaneous combustion of coal	WSR N-750	2.0	Excellent film formation.

Paper

In papermaking, POLYOX Water-Soluble Resins serve as processing aids and components of finished products. Their primary roles are as adhesives and flocculants.

Adhesives– Solutions of POLYOX Water-Soluble Resins exhibit a high degree of wet tack and thus are useful as wet adhesives for tail-tie applications, and in tissue and toweling. The dry residue is non-tacky.

Flocculation– High molecular weight grades of POLYOX Water-Soluble Resins, sold under the UCARFLOC name, are used in paper making due to their high affinity for pulps, fillers, and pitch. POLYOX Water-Soluble Resins are used in fines retention, drainage enhancement and in paper waste systems. They exhibit a high affinity for a variety of materials, including silica, clays, lignins, and paper fines.



UCARFLOC Flocculating Agents In Paper Applications

Application	Recommended grades	Use Levels wt%	Benefits
Tail-tie paper adhesives	POLYOX WSR N-750 POLYOX WSR-205 POLYOX WSR-301	3 - 7	High degree of wet-tack with dry residue that's non-tacky.
Tissue and toweling adhesives	POLYOX WSR N-750 POLYOX WSR-205 POLYOX WSR N-3000	4 - 7	High degree of wet-tack with dry residue that's non-tacky.
Flocculation and paper fines retention	UCARFLOC 300 UCARFLOC 302 UCARFLOC 304 UCARFLOC 309	0.005 - 0.25 of dry fiber	High affinity for a variety of materials; efficient flocculation.

Pharmaceuticals

POLYOX Water-Soluble Resins NF are nonionic poly(ethylene oxide) polymers. They meet the requirements of the Food Chemicals Codex, the International Codex Alimentarius and US Pharmacopoeia (USP) or National Formulary (NF). These products have also been approved in drug products sold in Britain and major European countries. They are white, free-flowing hydrophilic powders supplied in a wide variety of molecular weight grades, ranging from one hundred thousand to eight million. POLYOX Water-Soluble Resins NF have a long history of successful applications in pharmaceutical products, in uses such as controlled release solid dose matrix systems, tablet binding, transdermal drug delivery systems, and mucosal bioadhesives.

Controlled Release Matrix Systems– POLYOX Water-Soluble Resins NF are very versatile polymers for controlled release applications. Upon exposure to water or gastric juices, they hydrate and swell rapidly to form hydrogels with properties ideally suited for controlled drug-delivery vehicles. Because POLYOX Water-Soluble Resins NF are nonionic, no interaction between drug and polymers is to be expected.

Direct Compression Tablet Binding– POLYOX Water-Soluble Resins NF perform well as binders in direct compression systems. They often provide better flow and compaction properties than other binders. And their lubricity also assists tableting operations.

Mucosal Bioadhesives– POLYOX Water-Soluble Resins NF offer a number of important properties for mucoadhesion – water solubility, hydrophilicity, high molecular weight, hydrogen bonding functionality, and good biocompatibility. These resins have a long linear chain structure which allows them to form a strong interpenetrating network with mucus. Data indicate that molecular weights of 4,000,000 and higher have the highest level of adhesion.

Melt Extrusion– POLYOX Water-Soluble Resins NF provide good flow characteristics and can be used in conventional equipment.

POLYOX Water-Soluble Resins NF for Pharmaceutical Applications

POLYOX Water-Soluble Resin NF Product	Approximate Molecular Weight	Viscosity Range at 25°C, cP		
		5% Solution	2% Solution	1% Solution
WSR N-10	100,000	30-50		
WSR N-80	200,000	55-90		
WSR N-750	300,000	600-1,200		
WSR-205	600,000	4,500-8,800		
WSR-1105	900,000	8,800-17,600		
WSR N-12K	1,000,000		400-800	
WSR N-60K	2,000,000		2,000-4,000	
WSR-301	4,000,000			1,650-5,500
WSR Coagulant	5,000,000			5,500-7,500
WSR-303	7,000,000			7,500-10,000

POLYOX Water-Soluble Resins are supplied in a wide variety of molecular weight grades and formulated compounds in standard and NF (National Formulary) grades. Table 1 shows the current product range and their corresponding molecular weights and properties. Figure 1 summarizes the solution properties of each type. Both thickening efficiency and pituity (i.e., viscoelastic behavior) increase with increasing molecular weight.

POLYOX Water-Soluble Resins are produced and supplied as white, granular powders, freely soluble in water and possessing a slightly ammoniacal odor. Typical properties are given in Table 2.

Table 1

Grades of POLYOX Water-Soluble Resins

POLYOX Grade	Approximate Molecular Weight (1)
WSR N-10	100,000
WSR N-80	200,000
WSR N-750	300,000
WSR N-3000	400,000
WSR-205	600,000
WSR-1105	900,000
WSR N-12K	1,000,000
WSR N-60K	2,000,000
WSR-301	4,000,000
WSR Coagulant	5,000,000
WSR-303	7,000,000
WSR-308	8,000,000
UCARFLOC Polymer 300	4,000,000
UCARFLOC Polymer 302	5,000,000
UCARFLOC Polymer 304	7,000,000
UCARFLOC Polymer 309	8,000,000
POLYOX NF Grades	

The physical property data listed are considered to be typical properties, not specifications.

(1) Based on rheological measurements. Molecular weights obtained by other methods, including light scattering and gel permeation chromatography, may not be directly comparable.

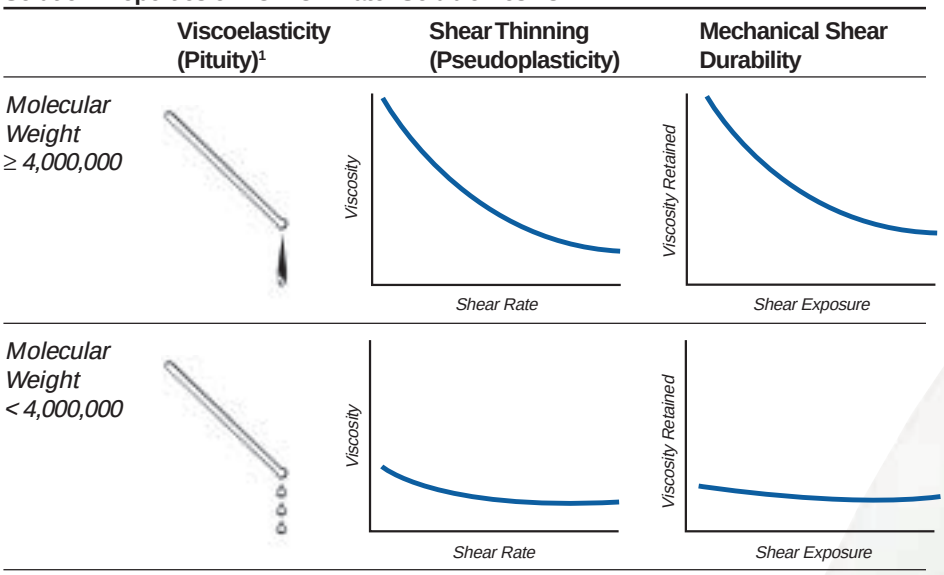
(2) Model RVT.

(3) POLYOX Water-Soluble Resins NF comply with The National Formulary standard for "Polyethylene Oxide" (page 2285-6) in USP 23-NF 18 issued in 1995.

Viscosity Range, mPa • sec (cP), Aqueous Solution at 25°C, Weight Percent			Brookfield Viscometer, Model RVF, Spindle No./Speed, rpm
5%	2%	1%	
12-50	—	—	1/50 [2]
65-115	—	—	1/50 [2]
600-1000	—	—	1/10
1000-1200	—	—	2/10
2250-4500	—	—	1/2
4500-8800	—	—	2/2
8800-17,600	—	—	2/2
—	400-800	—	1/10
—	2000-4000	—	3/10
—	—	1650-5500	2/2
—	—	5500-7500	2/2
—	—	7500-10,000	2/2
—	—	10,000-15,000	2/2
—	—	1650-5500	2/2
—	—	5500-7500	2/2
—	—	7500-10,000	2/2
—	—	10,000-15,000	2/2
Contact your Dow representative regarding resins that meet the NF standard [3].			

Figure 1

Solution Properties of POLYOX Water-Soluble Resins



[1] *Increases with molecular weight*

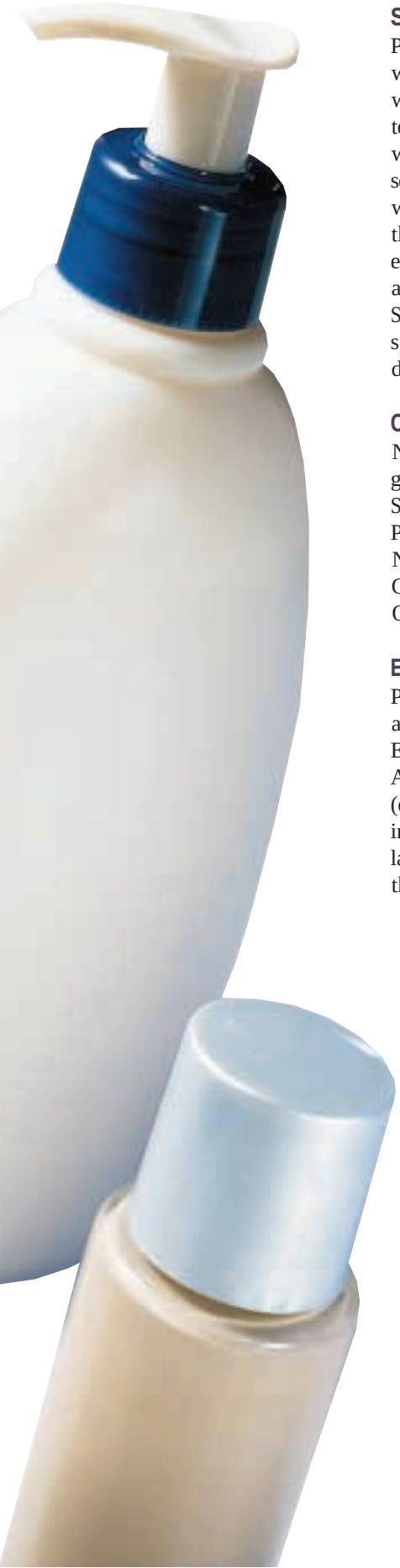
Table 2

Typical Physical Properties of POLYOX Water-Soluble Resins

Appearance	Off-white powder
Crystalline Melting Point (1) (X-ray and DSC), °C	62-67
Odor	Slightly ammoniacal
Melt Flow Temperature, °C	> 98
Volatiles Content, as packaged, % by wt (at 105 °C)	> 1.0
Alkaline Earth Metals, % by wt as CaO, max	1.0
Powder Bulk Density, lb/ft^3 (kg/m^3)	19-37 (304-593)
Polymer Density, g/cc	1.15-1.26
Moisture Content, as Packaged, %	< 1
Heat of Fusion, cal/gm	33
Solution pH	8-10
Particle Size, % by wt	
Average through 10-mesh (U.S. Standard)	100
20-mesh	96

The physical property data listed are considered to be typical properties, not specifications.

(1) *At temperatures far above the crystalline melting point, high polymers of POLYOX Water-Soluble Resins still retain a very high degree of crystalline character.*



Storage Stability

POLYOX Water-Soluble Resins will degrade to lower molecular weights with time and elevated temperature. Higher molecular weight grades are more sensitive than lower molecular weight grades. Samples past their expiration date should be evaluated to confirm that they are within specification limits. Samples that are out of specification should be discarded.

Compendium Status

NF (National Formulary) grades of POLYOX Water-Soluble Resins are available. POLYOX Water-Soluble Resins NF are identified in the Compendium as Polyethylene Oxide.

EPA Status

POLYOX Water-Soluble Resins are identified by the Federal Environmental Protection Agency in 40 CFR 180.1001 (d) for unrestricted use as inert ingredients in pesticide formulations applied to crops up to the time of harvest.

FDA Status

Considerable interest has been shown in POLYOX Water-Soluble Resins for diverse applications in food, drug and cosmetic products. Such uses fall within the scope of the Federal Food, Drug and Cosmetic Act. The FDA has recognized and approved the use of Poly(ethylene oxide) polymers (POLYOX Water-Soluble Resins) for specific food packaging uses, and as a direct additive to beer.

Table 3

FDA Status of POLYOX Water-Soluble Resins

FDA Regulation (21 CFR)	Permitted Uses
172.770	Foam stabilizer in fermented malt beverages (not to exceed 300 ppm by weight of the beverage) (WSR-301 and higher molecular weight grades).
175.300 (xxxiii) 175.300 (b) (3) (xxxiii)	Component of resinous and polymeric coatings applied as a continuous film or enamel over a metal substrate or applied as a continuous film or enamel to any suitable substrate provided that the coating serves as a functional barrier between the food and the substrate and is intended for repeated food-contact use (all grades).
175.380	Adjuvant in the production of or added to impart desired physical and technical properties to xylene-formaldehyde resins condensed with 4,4'-isopropylidene-diphenol-epichlorohydrin epoxy resins for use in coatings in contact with aqueous and dry foods, and beverages (all grades).
175.390	Preparation of zinc-silicon dioxide matrix coatings used as food-contact surfaces for bulk reusable containers intended for storing, handling and transporting food (all grades).
176.170 176.180	Component of the coated or uncoated food-contact surface of paper and paperboard in contact with fatty, aqueous, and dry food (all grades).
177.1210	Manufacture of closures with sealing gaskets for food containers (all grades).
177.1350	Adjuvant in the manufacture of ethylene-vinyl acetate copolymers used in food-contact applications (all grades).

Although POLYOX Water-Soluble Resins are totally water-soluble, care must be taken to make sure that they are dissolved completely. Detailed procedures and equipment recommendations for laboratory and commercial scale methods for dissolving POLYOX Water-Soluble Resins are described in this book.

The key to dissolution is good initial dispersion.
The most important step in the entire dissolving operation of POLYOX Water-Soluble Resins takes place in the first few seconds-separating the individual resin particles from each other.

High-shear agitators are not necessary and should be avoided.
In water, POLYOX Water-Soluble Resins are instantly wettable. If the POLYOX Water-Soluble Resin powder is not properly dispersed, the partially dissolved, wetted particles will agglomerate and form gels that may never dissolve. High-speed agitation of dissolved POLYOX Water-Soluble Resins must be avoided to prevent shear degradation of the resin. Organic solvents, because of their lower polarity, do not solvate ("wet") POLYOX Water-Soluble Resins as rapidly as water. As a result, particle agglomeration and gel formation are generally not problems when dissolving POLYOX Water-Soluble Resins in organic solvents.

Three major techniques provide good dispersion of resin particles.
For laboratory or plant requirements, these techniques fall into three major categories:

- Simple direct addition to water.
- Predispersion in water-miscible non-solvents.
- Use of mechanical devices that achieve dispersion with minimal shear.

Which technique you use will depend on the final viscosity and volume required.

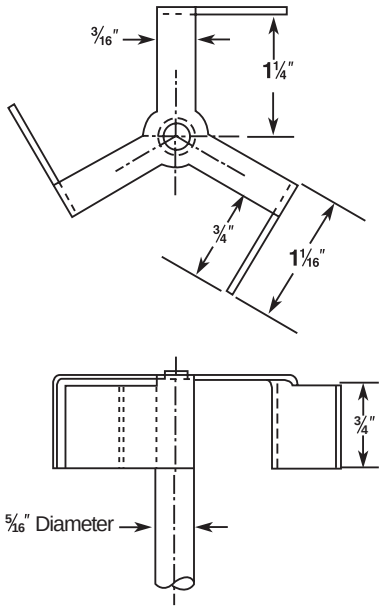
For laboratory and less than drum quantities, direct addition of the POLYOX Water-Soluble Resins to water, or non-solvent predispersion of POLYOX Water-Soluble Resins is recommended. For large volumes or continuous operation, special mechanical devices are available. Each of these techniques is described here.

Direct Addition to Water

The relative ease of dissolving POLYOX Water-Soluble Resins directly in water depends on three factors: (a) rate of viscosity buildup (which is a function of solution concentration and molecular weight), (b) particle size, and (c) type of agitation employed. The underlying factor, once again, is to obtain good resin dispersion before the solution viscosity builds to a point where it is no longer possible to disperse additional resin without high shear. This is best accomplished by adding the POLYOX Water-Soluble Resins at just the "right" rate of addition. If you add it too slowly, the viscosity will build too rapidly, and you will not be able to add the rest of the resin. On the other hand, if you add the resin too rapidly, it will clump up and not dissolve.

Figure 2

Standard Turbine Stirrer



Using the Proper Type Stirrer

A one-percent by weight solution of the high molecular weight POLYOX Water-Soluble Resins and a five-percent by weight solution of POLYOX Water-Soluble Resins can be prepared by direct addition of the dry resin to water if the proper type stirrer is used. We have found that either the standard turbine stirrer (see Figure 2) or the standard multi-propeller-type stirrer (see Figure 3) works well to dissolve POLYOX Water-Soluble Resins on a lab scale. These stirrers create a large vortex with only moderate shear. Stir rapidly to create a vortex initially (about 600 rpm), sprinkle in POLYOX Water-Soluble Resins at just the "right" rate, and then decrease the rpm to about 60. Continue stirring for 30 minutes to one hour until the solution appears homogeneous. In this way, as the viscosity increases, the shear degradation will be minimal. Other concentrations of both POLYOX WSR and WSRN series may also be prepared by this technique. Depending on the concentration selected and the molecular weight, longer stirring times–up to three hours–may be required.

Hot Water Method

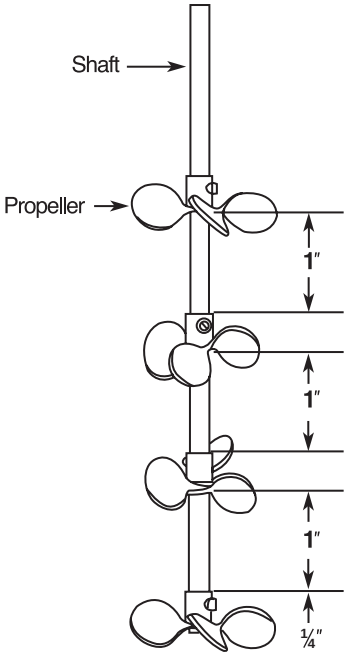
POLYOX Water-Soluble Resins are completely soluble in water at all temperatures, except near the boiling point. At this temperature, POLYOX Water-Soluble Resins precipitate. This phenomenon of inverse solubility provides an alternative technique for dispersing and dissolving POLYOX Water-Soluble Resins. If you choose this method, be careful not to let the steam from the boiling water wet the POLYOX Water-Soluble Resin powder! This may be done, for example, on a lab scale by using a small polypropylene or wooden scoop with curved sides. The curved sides will minimize the contact between the steam and the POLYOX Water-Soluble Resins.

Typically, all the water necessary is heated to near boiling (about 97°C). Condensation will generally appear on the container above the level of the water. If allowed to remain present, undesirable buildup of the POLYOX Water-Soluble Resins may occur. To avoid this, the near-boiling water should be stirred vigorously to create a vortex (500-600 rpm). This stirring will (1) raise the water level close to the top of the container and reduce or eliminate condensation on the walls and (2) aid in dispersing the POLYOX Water-Soluble Resin particles.

After about one minute, the stirring rate should be reduced to about 50-60 rpm. The source of heat is then removed and a stirring rate of 50-60 rpm is continued until solution is complete. This technique is adaptable to small-and medium-size dissolving operations, where minimal agitation equipment is available.

Figure 3

Multi-propeller-type Stirrer



Predispersion in Water-Miscible Non-Solvents

Dispersion of POLYOX Water-Soluble Resins in water-miscible non-solvents separates the individual resin particles from each other. When water is then added, each individual particle has a chance to swell, hydrate, and thereafter dissolve. This technique avoids the typical clumping that occurs if water alone is used. The use of alcohols or glycols also has the added benefit of reducing loss of solution viscosity on aging since these solvents behave as solution viscosity stabilizers.

For example, to make a one-percent solution by the predispersion technique, disperse 10 g of POLYOX Water-Soluble Resin in 40 g of anhydrous 2-propanol. Add this slurry to a beaker. Then add 950 g of distilled or tap water all at once. Stir at about 60 rpm and continue stirring for 30 minutes to 1-3 hours until the solution is homogeneous.

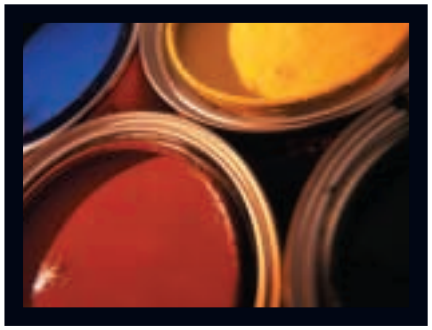
Most non-solvent techniques are suitable for large batch preparation of POLYOX Water-Soluble Resins solutions in plant-scale equipment. For convenience, in plant operation, the non-solvent is added to a stirred vessel. The POLYOX Water-Soluble Resins are then dispersed in the non-solvent followed by addition of the requisite amount of water. Stirring is continued within the guidelines discussed above.

Aqueous Salt and Alkali Solutions

The addition of salts to water will decrease the solubility of the POLYOX Water-Soluble Resins. With such salt or alkali solutions, a similar separation of particles is produced as previously described with organic non-solvents. Dissolution occurs upon dilution with water.

For example, a 1.5-percent POLYOX Water-Soluble Resins Coagulant solution can easily be prepared by first dispersing it in 20-percent sodium hydroxide solution. Specifically, 7.5 g of sodium hydroxide are dissolved in 30 g of distilled or tap water. Then, 15 g of POLYOX Water-Soluble Resin Coagulant are dispersed in the concentrated sodium hydroxide solution. Distilled or tap water (955 g) is added to the mixer. With the agitator turning about 600 rpm, the resin slurry is poured in. Agitation is reduced to about 300 rpm after all the slurry has been added. When the viscosity has become sufficiently high to prevent undissolved resin from settling out, agitation is reduced to about 60 rpm. This rpm is maintained until solution is complete.

Both methods — predispersion in water-miscible non-solvents and dispersion in aqueous salt and alkali solutions — are useful for either large or small operations where agitation facilities are limited, and where the dispersing medium is not objectionable.



Product Safety

When considering the use of any Dow products in a particular application, you should review our latest Material Safety Data Sheets and ensure that the use you intend can be accomplished safely. For Material Safety Data Sheets and other product safety information, contact Dow at the numbers on the back cover. Before handling any other products mentioned in the text, you should obtain available product safety information and take necessary steps to ensure safety of use.

For more information, complete literature, and product samples, you can reach a Dow representative at the following numbers:

From the United States and Canada
call 1-800-447-4369
fax 1-989-832-1465

In Europe
toll-free +800 3 694 6367†
call +32 3 450 2240
fax +32 3 450 2815

From Latin America and Other Global Areas:
call 1-989-832-1560
fax 1-989-832-1465

www.polyox.com

† Toll free from Austria (00), Belgium (00), Denmark (00), Finland (990), France (00), Germany (00), Hungary (00), Ireland (00), Italy (00), The Netherlands (00), Norway (00), Portugal (00), Spain (00), Sweden (00), Switzerland (00) and the United Kingdom (00).

Published March 2002

Printed in U.S.A.

Form No. 326-00001-0302 AMS