



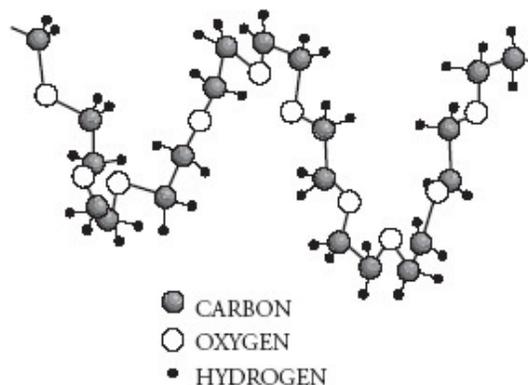
## Introduction to POLYOX Water-Soluble Resins

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.

- POLYOX Resins are thermoplastic materials that are readily calendared, extruded, injection molded, or cast.
- Films of POLYOX Resins are flexible, tough, and resistant to most oils and greases.
- With their very high molecular weight, POLYOX Resins are viscoelastic, so their aqueous solutions can reduce spattering and misting potential.

With branched polymers, as molecular weights go up and as chain entanglement increases, products can begin to feel tacky or unctuous. **POLYOX Water-Soluble Resins are linear homopolymers that are derived from ethylene oxide (see figure below). This linearity lends a certain degree of physics to the basic chemistry of the polymer. POLYOX Water-Soluble Resins make water wetter.**

### Idealized Structure of POLYOX Water-Soluble Resins



Adapted from: Tasaki, K. Poly(oxyethylene)-Water Interactions; A Molecular Dynamics Study. J. Am. Chem. Soc. 1996, 118, 8459.

**The turbulence of flowing water increases drag. Adding POLYOX Water-Soluble Resins to water decreases hydrodynamic drag by altering the dynamics at the interface between the water and the surface with which it is in contact.**

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**Our scientists have found that the straightness of the POLYOX Water-Soluble Resins allows the molecule to stretch. They also found that as a solution containing POLYOX Water-Soluble Resins is subjected to greater and greater linear forces (known as laminar flow), the POLYOX Water-Soluble Resins extend and stretch in solution. The resultant increase in the length of the POLYOX Water-Soluble Resin chain removes energy from the flowing system to decrease the building turbulence that accompanies the mounting force of the flowing solution. The overall effect is that the entire solution flows more smoothly. Adding just a small amount of a POLYOX Water-Soluble Resin to virtually any liquid makes the liquid more slippery.**

In many settings, from oil pipelines to food extrusion, POLYOX Water-Soluble Resins are utilized to increase the flow rates of the materials.

**For applications that require a higher degree of pseudoplasticity, a POLYOX Water-Soluble Resin with a high molecular weight should be selected. The POLYOX Water-Soluble Resins that have lower molecular weights (the WSR-N series) are less pseudoplastic and shear sensitive than their higher molecular weight siblings.**

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**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 below.

### Typical Physical Properties<sup>(1)</sup> of **POLYOX** Water-Soluble Resins

Appearance	Off-white powder
Crystalline Melting Point <sup>(2)</sup> (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 <sup>3</sup> (kg/m <sup>3</sup> )	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
Average through 20-mesh	96

<sup>(1)</sup> Data listed here are considered to be typical properties, not specifications.

<sup>(2)</sup> At temperatures far above the crystalline melting point, high polymers of **POLYOX** Water-Soluble Resins still retain a very high degree of crystalline character.

<sup>TM</sup>Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

**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).

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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.

**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

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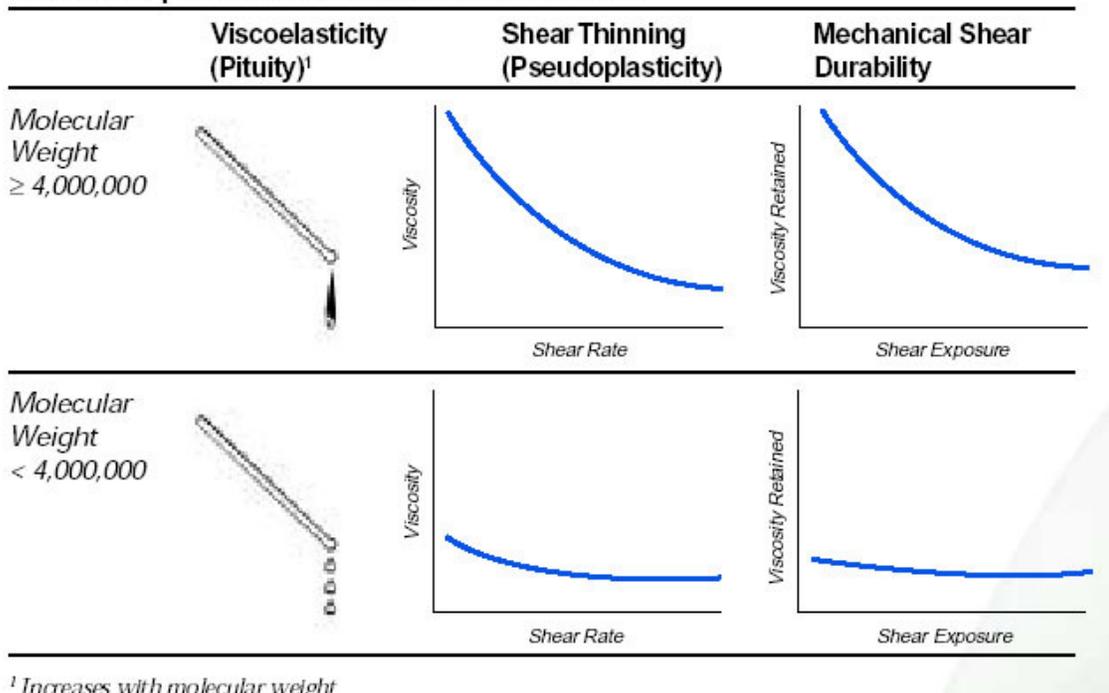
weight, water-soluble resins, they do not exhibit an inverse solubility-temperature relationship, except near the boiling point.

POLYOX Water-Soluble Resins are extremely effective thick-ening 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.

#### Solution Properties of POLYOX Water-Soluble Resins



<sup>1</sup> Increases with molecular weight

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**Polyox Resin make home and personal care products go on smoothly and leave hair and skin feeling silky.**

- POLYOX Water-Soluble Resins improve the density and fullness of the foam in shampoos, body washes and liquid soaps without interfering with foam height or the cleansing mechanism.
- In any surfactant system, POLYOX Water-Soluble Resins will improve foam stability and retention. In short, they make your product feel rich. But, because they are incorporated at extremely low usage levels, their impact on the cost of your product is negligible.
- Just a little POLYOX Water-Soluble Resin in a cream, lotion, gel or stick product will go a long way toward making your products glide on smoothly and build the kind of customer appeal that keeps them flying off the shelves.
- In virtually any product, POLYOX Water-Soluble Resins increase slip and reduce drag to enhance feel at the time of application and lighten the afterfeel. It may even be possible to incorporate POLYOX Water-Soluble Resins into wipe-type products to help them feel more pleasant and soothing.

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## **Polyox Water Soluble Resins in Pharmaceutical Application:**

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, freeflowing 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

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