



Selvol™ Polyvinyl Alcohol... A Versatile Performer in Paper and Paperboard Applications



INTRODUCTION

Sekisui Specialty Chemicals offers a complete line of polyvinyl alcohol resins for paper applications. Our manufacturing facilities in Calvert City, Kentucky; Pasadena, Texas; and Tarragona, Spain employ advanced computer-controlled production technology, providing polyvinyl alcohol of the highest quality. All three plants are ISO 9002 certified.

As part of our commitment to the paper industry, Sekisui maintains a fully-staffed paper applications laboratory in Houston, Texas, able to provide technical services to customers world wide. The laboratory is equipped with a variety of state-of-the-art analytical instruments to support testing in paper applications.

This brochure is intended to highlight the many diverse applications for polyvinyl alcohol in paper. For more information, including greater detail on the preparation of polyvinyl alcohol solutions, please refer to our Selvol™ Polyvinyl Alcohol brochure on Solution Preparation (2011-PVOH-1060), visit our website at www.selvol.com, or call our Product Information Center at +1-281-280-3460.



ENVIRONMENTAL, HEALTH AND SAFETY CONSIDERATIONS

Please refer to your Material Safety Data Sheets (MSDSs) for information on the safe use and handling of Selvol polyvinyl alcohol, including toxicity, fire and explosion hazards as well as environmental effects. An MSDS can be obtained online at www.selvol.com.

FDA Compliance

Polyvinyl alcohol is used in many food contact applications including food packaging adhesives and coatings for paper and paperboard. For more specific information on the FDA status of any of our grades, please contact our Product Information Center at +1-281-280-3460.

Selvol POLYVINYL ALCOHOL PRODUCT LINE

Sekisui Specialty Chemical's Selvol polyvinyl alcohol product line, presented on the next page in Table 2, consists of 15 standard grades and several specialty grades. The products are classified by hydrolysis as partially, intermediate, fully and super hydrolyzed. To put it into a better perspective, each standard Selvol polyvinyl alcohol grade has been portrayed graphically in Figure 1 as a function of viscosity and hydrolysis. Each block on this grid illustrates product location on a linear scale and, by outer boundary, defines specification limits.

Our specialty grades include fine particle sized "S" grades, Selvol 203S, Selvol 205S and Selvol 165SF polyvinyl alcohols.

The "S" grades are identical to Selvol 203 and Selvol 205 polyvinyl alcohol grades, with the exception that they have been mechanically reduced in particle size to >99% through an 80 mesh screen. These products are designed for use as "noncook" additives in coating color formulations. Selvol 165SF polyvinyl alcohol is a super-fine grind version of Selvol 165 with a particle size of >99% through a 120 mesh screen.

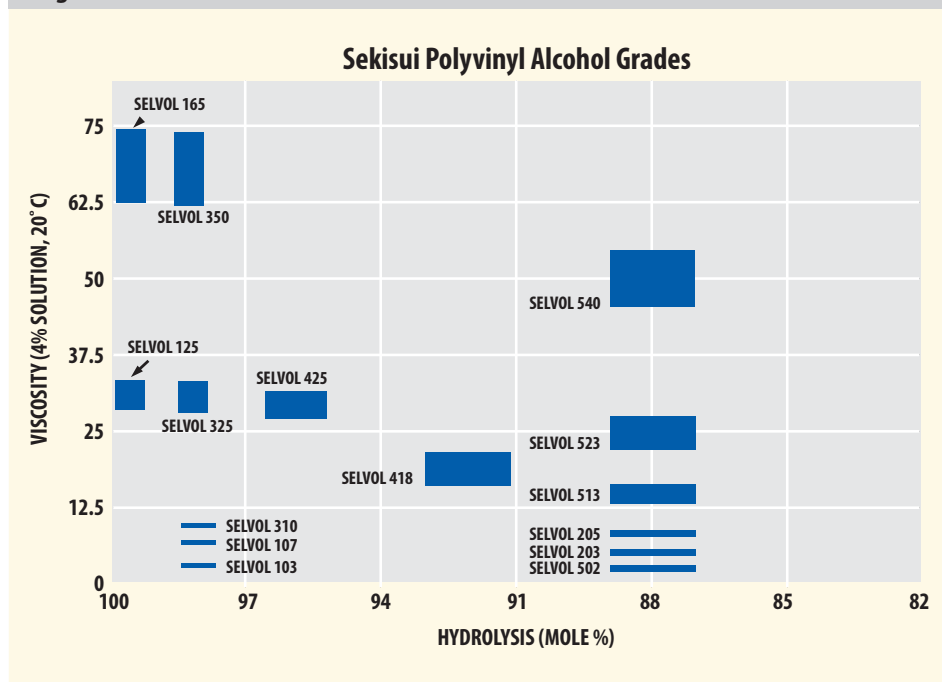
MM-51 is a blend of Selvol 325 and Selvol 350 polyvinyl alcohols with boric acid. The addition of boric acid results in a controlled gelation mechanism as the solution begins

Table 1

Selvol Polyvinyl Alcohol Right-to-Know Information

Ingredient	CAS Number
Polyvinyl Alcohol	
• Super and Fully Hydrolyzed	9002-89-5
• Partially and Intermediate Hydrolyzed	25213-24-5
Water	7732-18-5
Methanol	67-56-1
Sodium Acetate	127-08-3

Figure 1



to increase in solids after it is applied to the surface of paper. This mechanism provides for superior surface filming on some paper and paperboard substrates.

Table 2

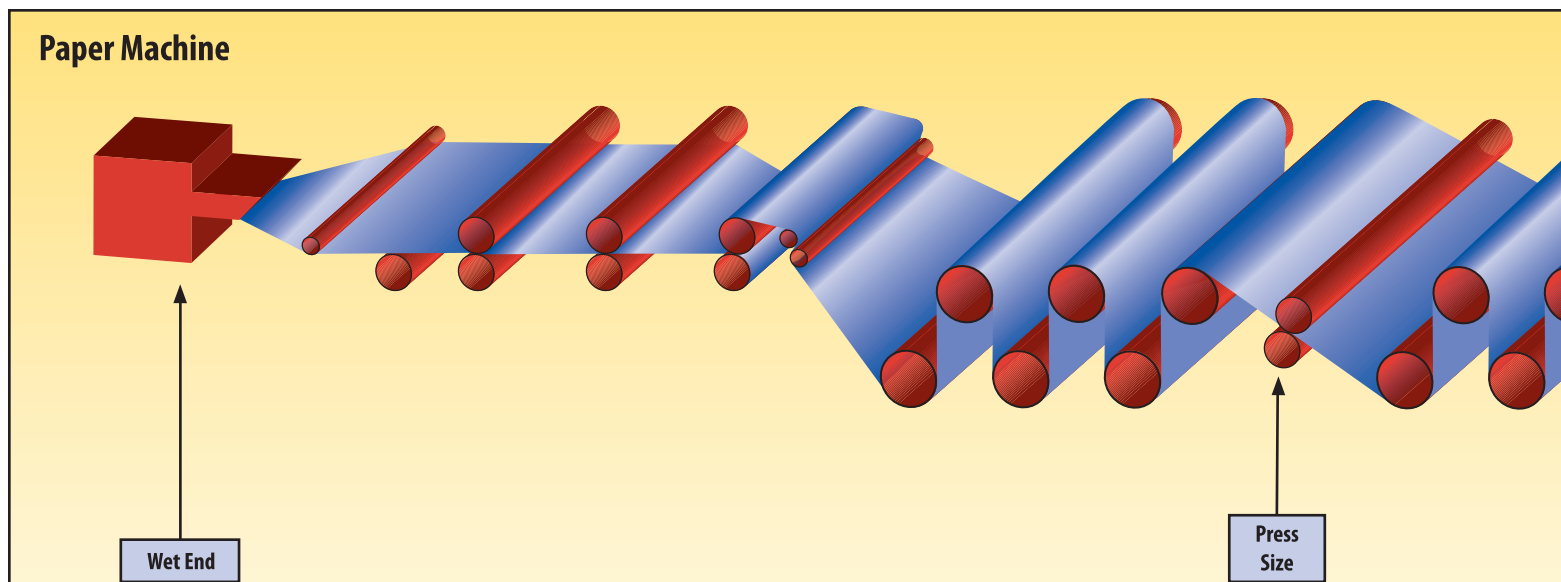
Selvol Polyvinyl Alcohol Typical Properties**Standard Grades**

Grade	Hydrolysis, %	Viscosity, CPS¹	pH²	Volatiles, % Max.	Ash, % Max.³
Super Hydrolyzed					
Selvol 125	99.3+	28–32	5.5–7.5	5	1.20
Selvol 165	99.3+	62–72	5.5–7.5	5	1.20
Fully Hydrolyzed					
Selvol 103	98.0–98.8	3.5–4.5	5.0–7.0	5	1.20
Selvol 107	98.0–98.8	5.5–6.6	5.0–7.0	5	1.20
Selvol 310	98.0–98.8	9.0–11.0	5.0–7.0	5	1.20
Selvol 325	98.0–98.8	28.0–32.0	5.0–7.0	5	1.20
Selvol 350	98.0–98.8	62–72	5.0–7.0	5	1.20
Intermediate Hydrolyzed					
Selvol 425	95.5–96.5	27–31	4.5–6.5	5	0.90
Partially Hydrolyzed					
Selvol 502	87.0–89.0	3.0–3.7	4.5–6.5	5	0.90
Selvol 203	87.0–89.0	3.5–4.5	4.5–6.5	5	0.90
Selvol 205	87.0–89.0	5.2–6.2	4.5–6.5	5	0.70
Selvol 523	87.0–89.0	23–27	4.0–6.0	5	0.50
Selvol 540	87.0–89.0	45–55	4.0–6.0	5	0.50
“S” Grades					
Selvol 165SF	Similar to above for Selvol 165 except for having a finer particle size.				
Selvol 203S	Similar to above for Selvol grades 203 and 205 except for having a finer particle size.				
Selvol 205S	Hydrolysis specification is 87.0%–90.0%				
Borated Grades					
Grade	Viscosity, CPS⁴	pH⁵			
MM-51	1100.0–1500.0	4.4–4.9	Derived from Fully Hydrolyzed Grades.		
¹ 4% aqueous solution, 20°C.					
² 4% aqueous solution.					
³ As % Na ₂ O, corrected volatiles.					
⁴ 10% aqueous solution, 25°C.					
⁵ 10% aqueous solution.					

Applications

	Wet End	Size Press	Calendar Stack	Coatings
Super Hydrolyzed				
Selvol 125				
Selvol 165				
Fully Hydrolyzed				
Selvol 103				
Selvol 107				
Selvol 310				
Selvol 325				
Selvol 350				
Intermediate Hydrolyzed				
Selvol 425				
Partially Hydrolyzed				
Selvol 502				
Selvol 203				
Selvol 205				
Selvol 523				
Selvol 540				
"S" Grades				
Selvol 165SF				
Selvol 203S				
Selvol 205S				
Borated Grades				
MM-51				

Stickers Control
 Dry and Wet Strength
 Clear Sizing
 Pigmented Sizing
 Ink Jet Papers
 Optical Brightener Carrier
 Oil & Grease Resistance
 Fluorochemical Carrier
 Hydrophobicity
 Silicone Holdout
 Backend Linting
 Oil & Grease Resistance
 Fluorochemical Carrier
 Hydrophobicity
 Plybond Adhesion
 Cobinder
 Ink Jet Papers
 Optical Brightener Carrier



At the Wet End

Stickies Control

Polyvinyl alcohol is used to control the deposition of stickies associated with the use of secondary fiber. The polyvinyl alcohol encapsulates the stickies and forms a multilayer shield that effectively covers the surface, rendering it non tacky. Features of this technology may be covered by U.S. Patent 4,886,575 assigned to Betz laboratories.

Polyvinyl alcohol may also be effective in controlling deposition in Kraft, acid sulfite and ground wood papermaking systems. Features of this technology may be covered by U.S. Patent 4,871,424 also assigned to Betz Laboratories, Inc.

Dry and Wet Strength

Selvol 165SF polyvinyl alcohol, a super fine grind version of Selvol 165 (99% of the particles pass through a 120 mesh screen) can be added to the fiber slurry to improve dry and wet strength properties. When mixed with the fiber slurry, the Selvol 165SF particles swell to about three times their original size but do not solubilize. Retention is accomplished through simple mechanical entrapment (polyvinyl alcohol is nonionic). The Selvol 165SF polyvinyl alcohol particles

* These applications may be subject to certain U.S. patents and equivalents issued in other countries. No license is granted with the purchase of Selvol polyvinyl alcohol. Please contact your Sekisui sales representative for additional information.

then solubilize in the first few cans of the dryer section and flow between the adjacent fibers. A release agent can be used to avoid dryer can sticking. Further down the dryer section, the Selvol 165SF particles resolidify and create a very strong fiber/polyvinyl alcohol matrix. Features of this technology may be covered by U.S. Patent 5,328,567 assigned to Custom Papers Group Inc.

At the Size Press

Clear Sizing

Polyvinyl alcohol finds use at the size press as a clear size to impart surface strength and barrier properties. In this capacity, it is often used to upgrade the performance of starch. Polyvinyl alcohol performs well at this function because it is much stronger and much more resistant to oils, greases, waxes and organic solvents than other surface sizing agents.

Pigmented Surface Sizing

Because of its superior strength, polyvinyl alcohol can be formulated at much lower levels than other binders, thus optimizing the brightness and opacity effects of the pigment system.

Ink Jet Papers

Polyvinyl alcohol is the preferred binder for inkjet size press coating formulations

using silica pigments. Its superior binding strength controls the dusting which may occur with starch. Polyvinyl alcohol is a hydrophilic polymer which acts in concert with the silica pigment to quickly absorb the waterbased ink into the coating layer, thus minimizing wicking, mottle and bleeding.

Optical Brightener Carrier

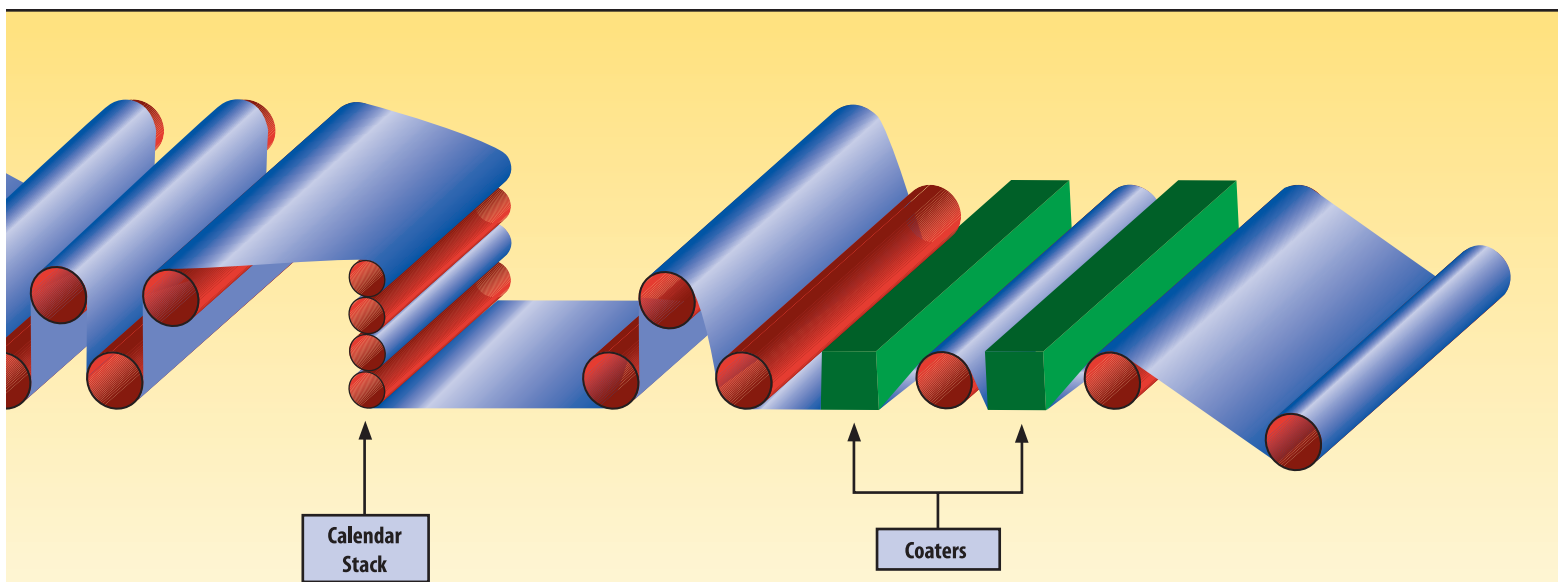
Compared with starch, polyvinyl alcohol delivers 2.0-2.5 more UV brightness units (or conversely, a reduction in the level of expensive fluorescent dye at equal brightness). This greater efficiency may allow the reduction or elimination of fluorescent dyes at the wet end.

Oil and Grease Resistance

Polyvinyl alcohol exhibits excellent barrier properties to oils, greases, waxes and solvents. It can be used alone or with starch to meet Vanceometer, Turpentine, K&N ink holdout and other specifications. Polyvinyl alcohol is also a very effective carrier for fluorochemicals. Blends of polyvinyl alcohol and fluorochemicals achieve high 3M Kit Ratings at a much lower cost than with the use of a fluorochemical by itself.

Hydrophobicity

Surface applications of polyvinyl alcohol and alkyl ketene dimer (AKD) blends demonstrate outstanding improvements in Cobb and Hercules Sizing (HST) values on both



acid and alkaline papers, with little or no loss in size values upon aging. Unlike starch, a surface application of polyvinyl alcohol does not degrade the internal sizing effect of a wet end additive like AKD or ASA.

Silicone Holdout

The ability to significantly reduce porosity makes polyvinyl alcohol a candidate to hold-out or extend expensive silicone coatings.

At the Calendar Stack

Backside Linting

Polyvinyl alcohol is used as a clear or pigment surface size to control the back-side linting associated with recycled board manufacture. It is often utilized to upgrade the performance of starch. Since polyvinyl alcohol is much stronger than starch, it can be used at lower usage levels.

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Plybond Adhesion

The superior strength of polyvinyl alcohol provides an effective means of achieving plybond adhesion on multiply paperboard.

At the Coater

Cobinder

Because of its superior strength, coatings formulated with polyvinyl alcohol can achieve a significant reduction in total binder level. This may provide for substantial cost savings while providing a significant improvement in brightness, gloss and opacity. The water retention properties of polyvinyl alcohol also allow coatings to be formulated with a reduced or zero level of hydrocolloid. Unlike some natural cobinders, polyvinyl alcohol does not require use of a base like ammonia to be solubilized.

Ink Jet Papers

Polyvinyl alcohol is the preferred binder for ink jet coatings utilizing silica pigments. It provides superior binding strength and improved ink jet print quality versus typical latex binders. Polyvinyl alcohol is a hydrophilic polymer which acts in concert with the silica pigment to quickly absorb the water-based ink into the coating layer, thus minimizing wicking, mottle and bleed.

Optical Brightener Carrier

Polyvinyl alcohol is recognized as the best carrier for fluorescent dyes. The addition of 0.5-2.0 parts (dry) polyvinyl alcohol per 100 parts pigment can boost brightness an additional 4+ units. Such improvements are significant for high 80s/low 90s brightness papers. Polyvinyl alcohol also provides superior binding strength and good water retention properties, enabling reductions in latex and hydrocolloid levels. Selvol 203S, a fine grind version of Selvol 203 polyvinyl alcohol (99% of the particles pass through an 80 mesh screen), can be used as a noncook carrier by adding it directly to a pigment dispersion or a pigmented formulation while under high shear agitation for a minimum of 15 minutes.

The concept of using Selvol 203S in coating color formulations as a "non-cook" product, either as a pigment binder or as a carrier for optical brighteners is described in U.S. Patent 5,057,5.

Selvol POLYVINYL ALCOHOL PROPERTIES

The performance properties of polyvinyl alcohol are influenced by molecular weight (measured as a 4% solution viscosity) and the degree of hydrolysis. The upper portion of Figure 2 shows the variation in properties with molecular weight at a constant degree of hydrolysis, while the effect of hydrolysis at constant molecular weight is given in the lower portion of the figure.

Solubility

All Selvol polyvinyl alcohol grades are readily soluble in water. Conditions for dissolution are governed primarily by degree of hydrolysis, but they are influenced by other factors such as molecular weight, particle size distribution and particle crystallinity.

Optimum solubility occurs at 87-89% hydrolysis. The partially hydrolyzed grades in this range exhibit a high degree of cold-water solubility. For total dissolution, however, they require water temperatures of about 185°F (85°C) with a hold time of 30 minutes.

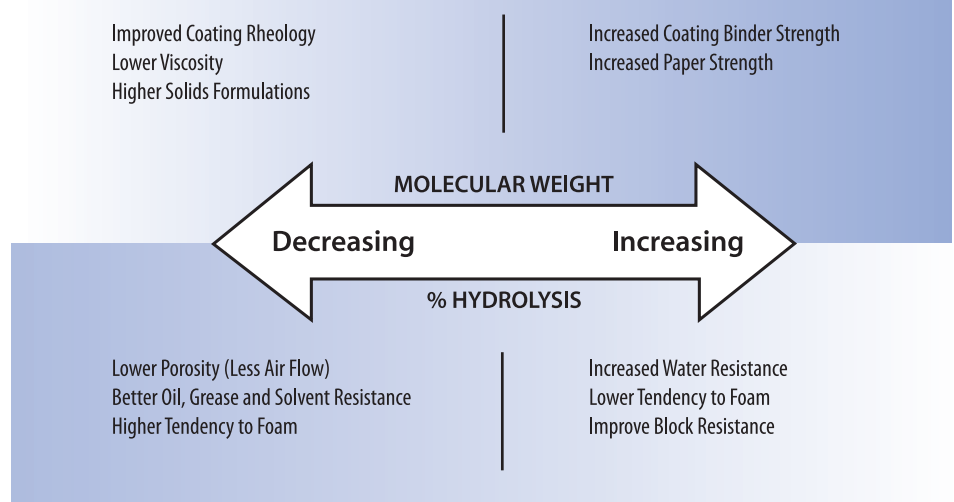
Higher hydrolysis grades, including intermediate, fully and super hydrolyzed, require progressively more energy to dissolve because of their greater number of tightly aligned, hydroxyl-bearing molecules. For dissolution, these grades require temperatures in the range of 195-205°F (91-96°C), with a hold time of 30 minutes.

Strength

Polyvinyl alcohol is widely recognized as the strongest binder in the paper industry. It exhibits superior IGT pick, Mullen burst, Instron tensile and MIT fold properties compared with other natural and synthetic binders. The strength of a specific grade of Selvol polyvinyl alcohol is determined primarily by its molecular weight (measured as a 4% solution viscosity). Therefore, high viscosity grades like Selvol 165, 350 and 540 polyvinyl alcohols yield maximum strength.

Figure 2

Changes in Polyvinyl Alcohol Properties with Changes in Molecular Weight and Hydrolysis Level

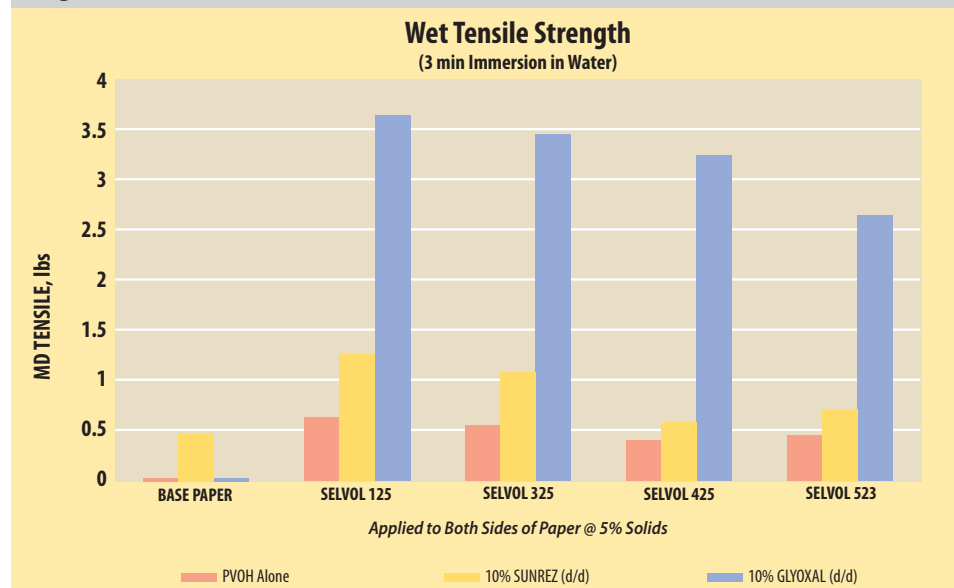


Water Resistance

Because polyvinyl alcohol is a water-soluble polymer, it is sometimes perceived as having little or no water resistance. However, by proper grade selection, and with the use of crosslinkers, an entire range of insolubilities is possible. The water resistance of a specific

grade of Selvol polyvinyl alcohol is primarily determined by its hydrolysis. Super hydrolyzed grades like Selvol 125 and 165 polyvinyl alcohol yield maximum water resistance. Figure 3 shows the effect of crosslinkers on the wet tensile properties of a paper surface-sized with polyvinyl alcohol.

Figure 3



Foaming

The tendency for polyvinyl alcohol to generate foam is highly dependent upon the degree of hydrolysis. Generally, the higher the hydrolysis, the less tendency to foam. Fully and super hydrolyzed grades are generally used without defoamers, whereas intermediate and partially hydrolyzed grades nearly always require a defoamer. See Table 3 for recommended defoamers.

The following good practice guidelines can minimize foam in your system:

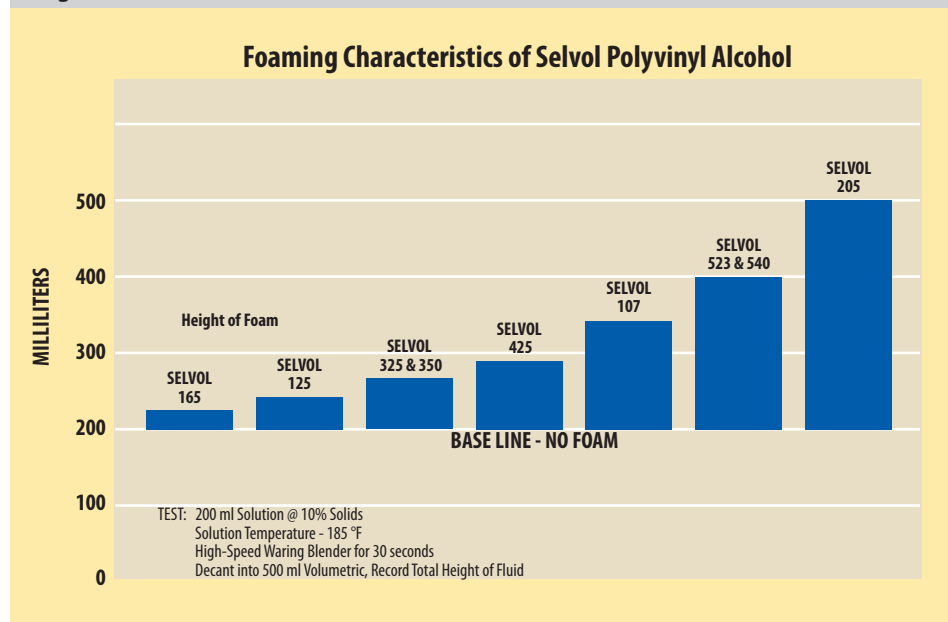
- Make-up tank should be agitated fast enough to move the water surface, but not so fast as to whip air into the solution.
- Height of the free-fall off the recirculation line should be minimized.
- Polyvinyl alcohol solutions should not be overcooked (e.g., boiled).

Table 3

Recommended Defoamers for Selvol Polyvinyl Alcohol*

<i>Brand or Generic Name</i>	<i>Manufacturer</i>	<i>Suggested Use Level</i>
Antifoam 116 FG	Harcros Chemicals	<1% d/d
INDUSTROL DF 132	BASF	<1% d/d
Foamaster KB	Henkel	<1% d/d
Foamaster V	Henkel	<1% d/d

Figure 4



Gurley Porosity

Polyvinyl alcohol grades within the hydrolysis range of 88-96% impart much better surface coverage to paper, providing maximum barrier properties for oil, grease, solvents and air. Figure 5 shows how the hydrolysis level of polyvinyl alcohol grades affects Gurley Porosity, and Figure 6 shows how hydrolysis affects Mazola oil penetration on solid bleached board. As expected, the tighter sheet shows a corresponding improvement in oil resistance. However, while the 98% fully hydrolyzed grade (i.e., Selvol 325 polyvinyl alcohol) resisted Mazola penetration for 30 minutes, the 96% hydrolyzed grade (i.e., Selvol 425 polyvinyl alcohol) survived the test for 60 minutes. Though an 88% hydrolyzed grade like Selvol 523 polyvinyl alcohol also performs well, generally Selvol 425 is preferred as it offers the best balance in porosity reduction and size press runnability (i.e., lower tendency to foam).

Figure 5

Surface Effects vs. Degree of Hydrolysis
Gurley Porosity
Clear Size Application
(4% Solution)

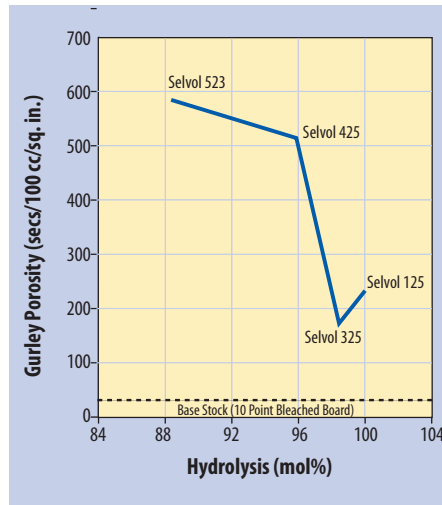
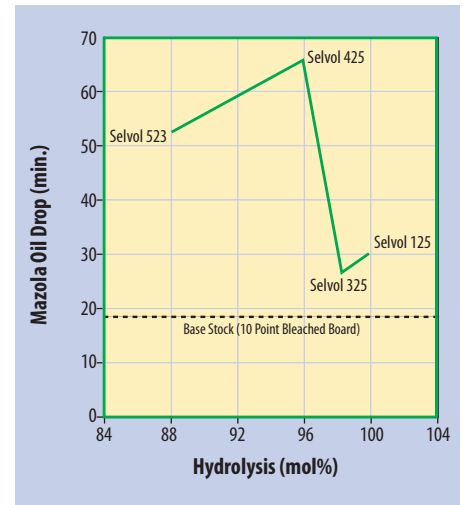


Figure 6

Surface Effects vs. Degree of Hydrolysis
Mazola Oil Drop Holdout
Clear Size Application
(4% Solution)



Water Retention

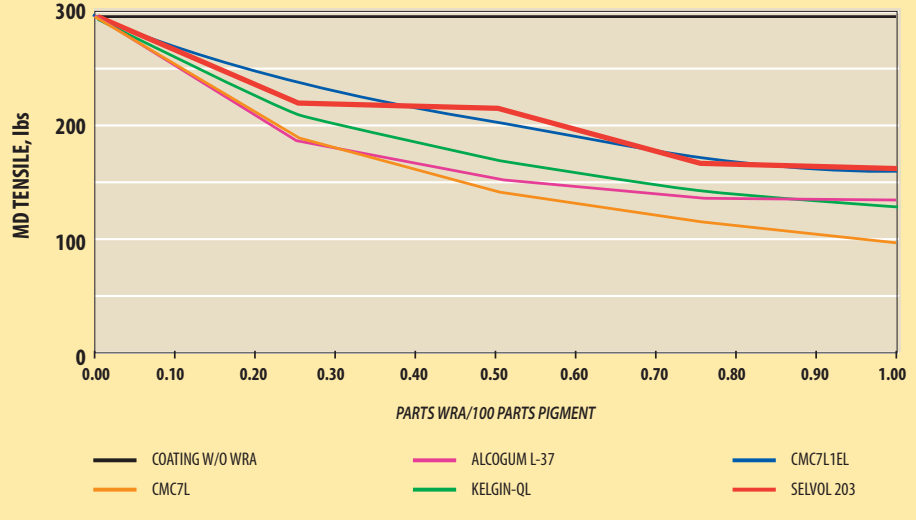
As a hydrophilic polymer, polyvinyl alcohol exhibits excellent water retention properties. Low viscosity grades like Selvol 103, 107, 502, 203 and 205 polyvinyl alcohols are preferred since they provide optimum coating rheology. Figure 7 compares Selvol 203 polyvinyl alcohol with other hydrocolloids using the dynamic ABO AKADEMI methodology. In this comparison, polyvinyl alcohol performed well. In addition, polyvinyl alcohol provides much higher binder strength and the ability to boost optical brightener performance.

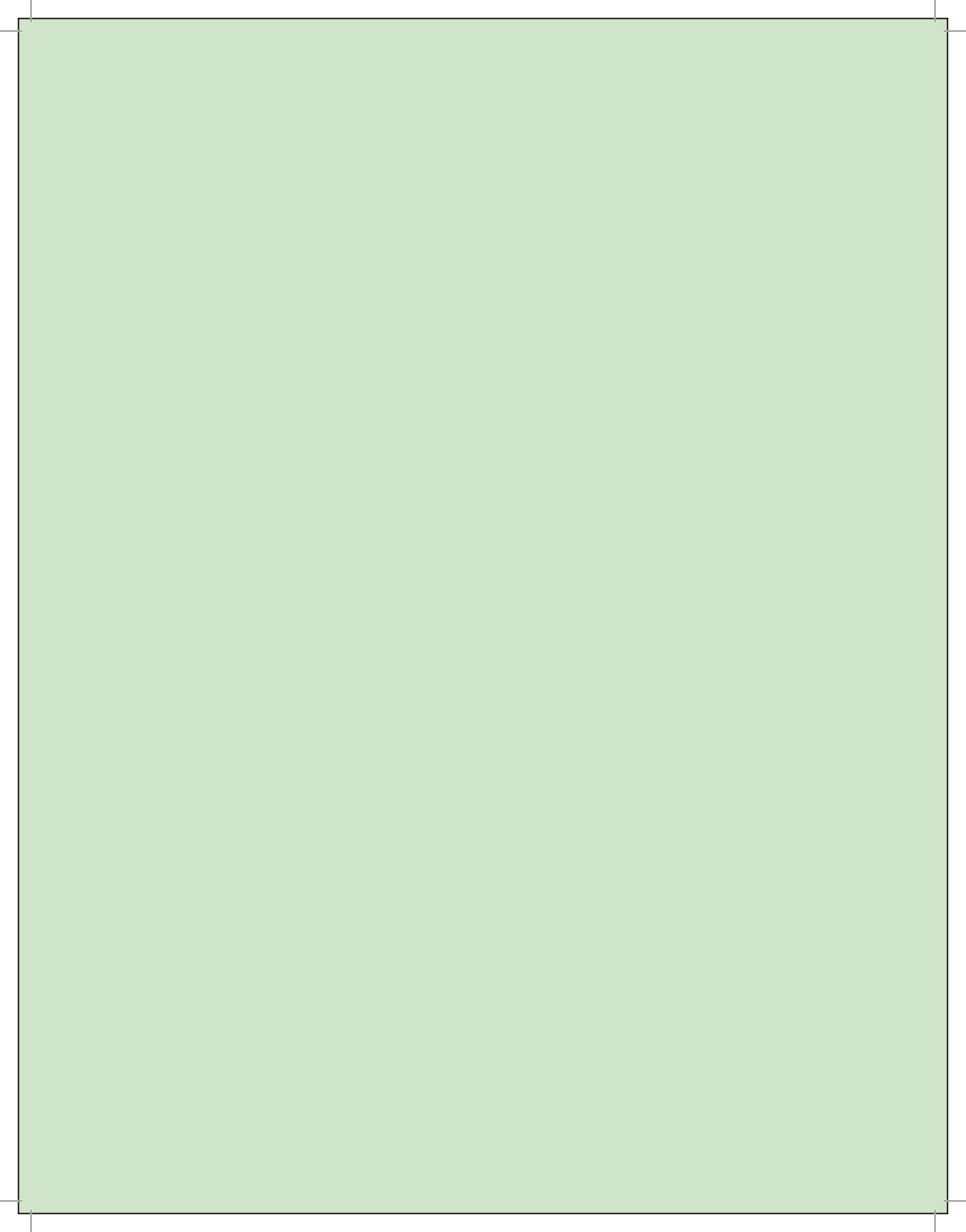
Figure 7

PVOH vs. Hydrocolloids
Coating Color Water Retention Aids

ABO AKADEMI METHODOLOGY

FORMULATION: 100 PTS. #1 Clay, 12 PTS. VINAC 884, X PTS. WRA @ 65% solids





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