

INTRODUCTION

Sekisui offers a complete line of polyvinyl alcohol resins for adhesive 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.

This brochure is intended to highlight the many diverse applications for polyvinyl alcohol in compounding adhesives. For information on the preparation of polyvinyl alcohol solutions, please refer to our Selvol Polyvinyl Alcohol Solution Preparation Guidelines brochure.



ENVIRONMENTAL, HEALTH, AND SAFETY CONSIDERATIONS

Please refer to our 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

The Sekisui 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. Each standard 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 approximate specification limits.

Tackified Selvol polyvinyl alcohols are produced by controlled boration of super hydrolyzed and fully hydrolyzed grades. These borated alcohols yield viscous aqueous solutions which have a tailored degree of tack and, when applied onto surfaces such as paper, significantly reduce penetration.

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

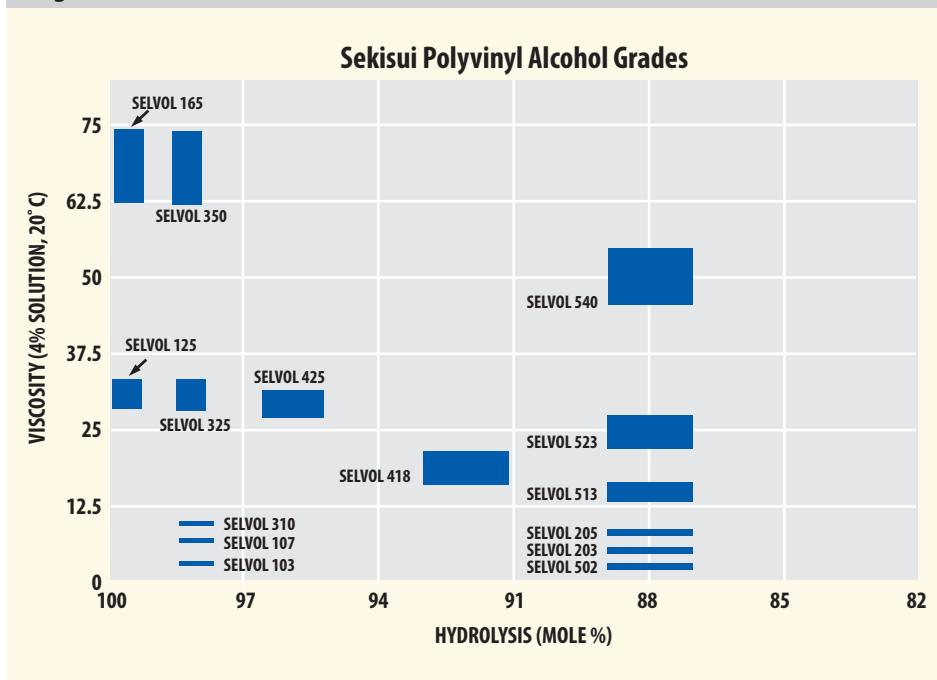


Table 2

Selvol Polyvinyl Alcohol Typical Properties

Standard Grades

Grade	Hydrolysis (%)	Viscosity (cps)¹	pH²	Volatiles (% Max)	VOC⁶ (% Max)	Ash³ (% Max)
Super Hydrolyzed						
Selvol 125	99.3 +	28 - 32	5.5 - 7.5	5	1	1.20
Selvol 165	99.3 +	62 - 72	5.5 - 7.5	5	1	1.20
Fully Hydrolyzed						
Selvol 103	98.0 - 98.8	3.5 - 4.5	5.0 - 7.0	5	1	1.20
Selvol 107	98.0 - 98.8	5.5 - 6.6	5.0 - 7.0	5	1	1.20
Selvol 310	98.0 - 98.8	9.0 - 11.0	5.0 - 7.0	5	1	1.20
Selvol 325	98.0 - 98.8	28.0 - 32.0	5.0 - 7.0	5	1	1.20
Selvol 350	98.0 - 98.8	62 - 72	5.0 - 7.0	5	1	1.20
Intermediate Hydrolyzed						
Selvol 418	91 - 93	14.5 - 19.5	4.5 - 7.0	5	1	0.90
Selvol 425	95.5 - 96.5	27 - 31	4.5 - 6.5	5	1	0.90
Partially Hydrolyzed						
Selvol 502	87.0 - 89.0	3.0 - 3.7	4.5 - 6.5	5	1	0.90
Selvol 203	87.0 - 89.0	3.5 - 4.5	4.5 - 6.5	5	1	0.90
Selvol 205	87.0 - 89.0	5.2 - 6.2	4.5 - 6.5	5	1	0.70
Selvol 513	86.0 - 89.0	13 - 15	4.5 - 6.5	5	1	0.70
Selvol 523	87.0 - 89.0	23 - 27	4.5 - 6.5	5	1	0.50
Selvol 540	87.0 - 89.0	45 - 55	4.5 - 6.5	5	1	0.50
Tackified Grades						
Grade	Viscosity (cps)⁴	pH⁵				
Selvol MH-82	4200 - 5900	4.4 - 4.9	Derived from Fully Hydrolyzed Grades			
Selvol MM-81	1300 - 1700	4.4 - 4.9	Derived from Fully Hydrolyzed Grades			
Selvol MM-51	1100 - 1500	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 ⁶ Volatile organic contents primarily methanol with methyl acetate						

Table 3

Applications

	Solid Fiber Laminating		Tube and Core Winding	Wood-High Performance	Consumer / Craft Glue	Remoistenable Adhesive	Envelope - Side Seam	Wood - General Assembly	Padding	Bookbinding	Cup Forming	Case Sealing	Consumer / Craft Glue	Paper Laminating	Bag Seams	Labels	Carton Sealing	Bag Bottom Paste
	Sole Adhesive		Compounding Additive															
Super Hydrolyzed																		
Selvol 125	●	●																
Selvol 165	●	●																
Fully Hydrolyzed																		
Selvol 103	●	●	◎		○	●	◎	●	●	●	●		●	●		●		
Selvol107	●	●	◎		○	●	◎	●	●	●	●		●	●		●		
Selvol 310	●	●	◎		○	●	◎	●	●	●	●		●	●		●		
Selvol 325	●	●	◎		○	●	◎	●	●	●	●		●	●		●		
Selvol 350	●	●	◎		○	●	◎	●	●	●	●		●	●		●		
Intermediate Hydrolyzed																		
Selvol 418	◎	◎	◎		◎	●	◎	●	●	●	●		●		●			
Selvol 425	◎	◎	◎		◎	●	◎	●	●	●	●		●		●			
Partially Hydrolyzed																		
Selvol 502			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Selvol 203			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Selvol 205			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Selvol 513			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Selvol 523			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Selvol 540			●	●	●	●	●	●	●		◎	●		◎	●	●	●	
Tackified Grades																		
Selvol MH-82	●	●	◎				◎								●			
Selvol MM-81	●	●	◎				◎								●			
Selvol MM-51	●	●	◎				◎								●			

● - Typically Used ◎ - Sometimes Used ○ - Can Be Used

ADHESIVE APPLICATIONS

SOLE OR PRIMARY ADHESIVES... IN THESE APPLICATIONS, POLYVINYL ALCOHOL IS USED AS THE SOLE OR PRIMARY BINDER IN THE ADHESIVE

Solid Fiber Laminating. Tackified polyvinyl alcohol, produced through the boration of super and fully hydrolyzed grades, is used to provide a tailored degree of wet tack, set speed, viscosity and penetration into the substrate. Tackified polyvinyl alcohol allows high levels of extender, such as clay, to be added to the formulation. Tackified grades derived from fully hydrolyzed polyvinyl alcohol (see Tables 2 and 3) provide a combination of good pot life and excellent water resistance.

Tube and Core Winding. Similar to solid fiber laminating. Polymer emulsion may be added to boost solids and set speed and lower viscosity.

Wood—High Performance. Partially hydrolyzed grades are recommended for penetration into the wood and development of fiber tear. Polyvinyl alcohol imparts strength and heat resistance to the bond. Lower-molecular-weight partially hydrolyzed polyvinyl alcohol penetrates the wood pores and dramatically boosts fiber tear. Higher-molecular-weight partially hydrolyzed polyvinyl alcohol allows the adhesive to sit on the surface of the wood, thus improving adhesive holdout. A proper balance of penetration and holdout serves to distribute the strain over a wider area of the glue line that develops fiber tear. The polyvinyl alcohol may be borated to enhance wet tack.

Consumer/Craft Glue. Partially hydrolyzed polyvinyl alcohol is used for good adhesion to wood and paper and for easy clean-up. Addition of boric acid is possible.

COMPOUNDED ADHESIVES... IN THESE APPLICATIONS, POLYVINYL ALCOHOL IS TYPICALLY USED AS AN ADDITIVE TO A BASE EMULSION

Remoistenable Adhesives. Partially hydrolyzed polyvinyl alcohol grades increase the water sensitivity of adhesive films, making them useful for formulating remoistenable adhesives. Selvol 203 polyvinyl alcohol is especially useful in remoistenable adhesives due to its ultra-low viscosity. The ultra-low viscosity permits the use of a large amount of resin, which results in a very tacky, fast-grabbing envelope front seal adhesive.

Envelope—Side Seam. Partially hydrolyzed polyvinyl alcohol is added to the base emulsion to increase viscosity and adjust solids.

Wood—General Assembly. Partially hydrolyzed polyvinyl alcohol is used to boost the performance of wood assembly glues, usually in combination with a base emulsion, starch and clay. Polyvinyl alcohol will bring strength, heat resistance and fiber tear to the formulation. The addition of partially hydrolyzed polyvinyl alcohol to polyvinyl acetate wood glues (white glues) permits the adhesive to wet the wood and penetrate



the pores, thereby increasing the strength and fiber tear of these adhesives. Low-molecular-weight grades, such as Selvol 205 polyvinyl alcohol, will allow greater polyvinyl alcohol incorporation into the adhesive, while a grade such as Selvol 540 polyvinyl alcohol will allow high viscosity at lower polyvinyl alcohol levels. The polyvinyl alcohol may need to be borated to achieve the required level of wet tack and set speed.

Padding. Polyvinyl alcohol is added to the base emulsion to increase toughness and as a thickener to increase viscosity and control solids. When a high-viscosity but low-solids formula is needed, a small amount of a high-viscosity polyvinyl alcohol should be added.

Bookbinding. Addition of polyvinyl alcohol to the base emulsion improves toughness and strength of the bond. It can also be used to thicken the adhesive formulation.

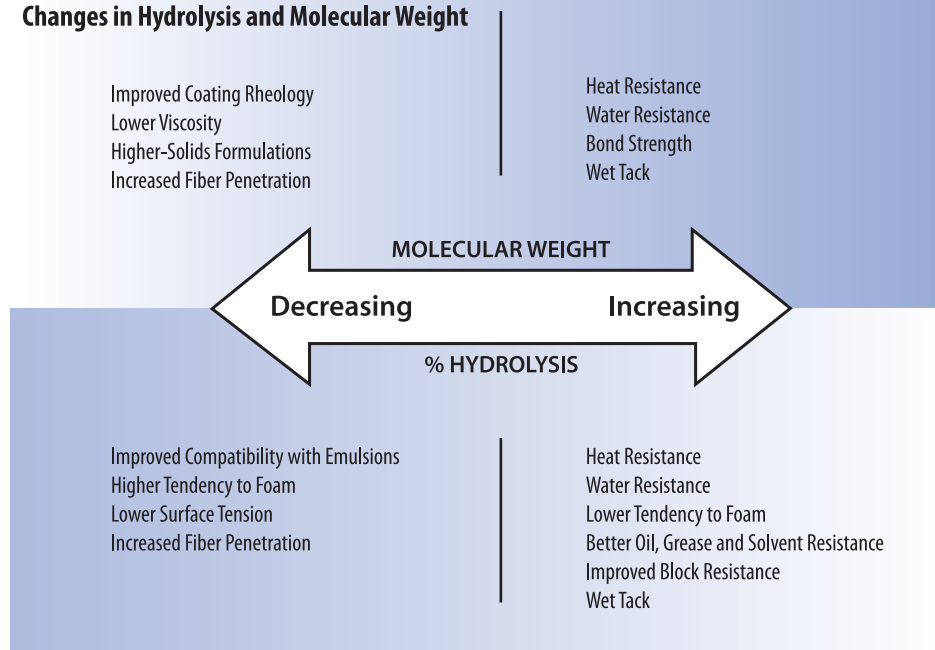
Cup Forming. Fully hydrolyzed polyvinyl alcohol may be added to improve water resistance.

Case Sealing. Fully hydrolyzed polyvinyl alcohol, particularly the medium and high-molecular-weight grades such as Selvol 325 and 350 polyvinyl alcohol, are used to increase water resistance.

Consumer/Craft Glue. Adding partially hydrolyzed grades like Selvol 523 polyvinyl alcohol will increase fiber tear and improve clean-up.

Paper Laminating. In paper-to-foil laminations, fully hydrolyzed polyvinyl alcohol is added to boost viscosity at low solids and to increase heat and water resistance.

Figure 2
Changes in Polyvinyl Alcohol Properties with Changes in Hydrolysis and Molecular Weight



Bag Seams. Fully hydrolyzed polyvinyl alcohol compounding improves heat and water resistance.

Labels. Partially hydrolyzed polyvinyl alcohol is added for adhesion to glass, wet tack and viscosity control.

Carton Sealing. Fully hydrolyzed polyvinyl alcohol is recommended for water-resistant applications.

Bag Bottom Paste. For this application where very high viscosity is needed, borated partially hydrolyzed polyvinyl alcohol is used with starch. The alcohol adds strength to the glue line.

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.

Compatibility with Emulsions

Partially hydrolyzed polyvinyl alcohol (Selvol 203,205,523, and 540 resins) is compatible with most typical emulsions. Solutions of partially hydrolyzed polyvinyl alcohol can be added to the emulsion at all levels.



Intermediate hydrolyzed polyvinyl alcohol (Selvol 418 and 425 resins) shows some compatibility while fully hydrolyzed polyvinyl alcohol (Selvol 103,107,310,325, and 350 resins) shows incompatibility with emulsions stabilized with partially hydrolyzed polyvinyl alcohol. When incompatibility does occur, the adhesive will separate into two phases: a bottom phase which is rich in emulsion and a top phase which is rich in polyvinyl alcohol. This phenomenon is commonly called syneresis or creaming. There are commercial emulsions available that are compatible with both partially and fully hydrolyzed polyvinyl alcohol that can be used to avoid this problem.

Foaming

When polyvinyl alcohol solutions are utilized in compounding, foam control is critical. The tendency for polyvinyl alcohol to generate foam is highly dependent upon the degree of hydrolysis (see Figure 3). Generally, the higher the hydrolysis, the less the 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 4 for recommended defoamers.

The following guidelines should be utilized to minimize the foam in the adhesive:

- The adhesive tank should be agitated fast enough to move the adhesive surface, but not so fast as to whip air into the adhesive.
- The adhesive with or without additional polyvinyl alcohol should not be permitted to free-fall.
- Polyvinyl alcohol solutions should not be overcooked (for example, boiled).

Surface Tension and Wetting

The surface tension of polyvinyl alcohol is largely dependent on the degree of hydrolysis. Partially hydrolyzed grades yield solutions with the lowest surface tension as shown in Figure 4.

Partially hydrolyzed polyvinyl alcohol wets surfaces better than the fully or super hydrolyzed grades and, as a result, works well in wood adhesives. Lower-molecular-weight partially hydrolyzed polyvinyl alcohol penetrates the wood pores and dramatically boosts fiber tear. Higher-molecular-weight partially hydrolyzed polyvinyl alcohol allows the adhesive to sit on the surface of the wood, thus improving adhesive holdout. A proper balance of penetration and holdout serves to distribute the strain over a wider area of the glue line that develops fiber tear.

Rheology

The flow characteristic of the adhesive in use directly influences the adhesive's penetration and performance. As the viscosity increases, penetration decreases. Conversely, as the viscosity decreases, penetration increases. The viscosity also determines the amount of mileage or spread of an adhesive. An optimum viscosity exists for each substrate and set of machine conditions. In order to manufacture an efficient adhesive, this optimum viscosity must be achieved. If the viscosity is too low for the specific substrate and machine conditions, too much adhesive will be deposited. If the viscosity is too high, insufficient adhesive will be applied. In either case, the final adhesive will not perform as well as possible.

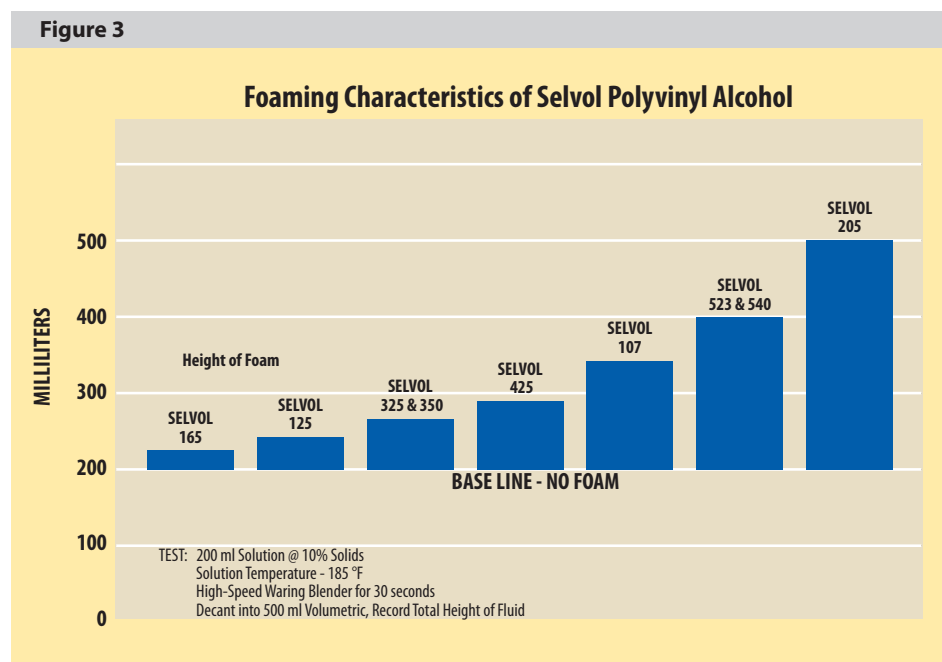


Table 11

Recommended Defoamers for Selvol Polyvinyl Alcohol*

Brand or Generic Name	Manufacturer	Suggested Use Level
Industrol DF 132	BASF	<1% d/d
Foamaster KB	Henkel	<1% d/d
Foamaster V	Henkel	<1% d/d

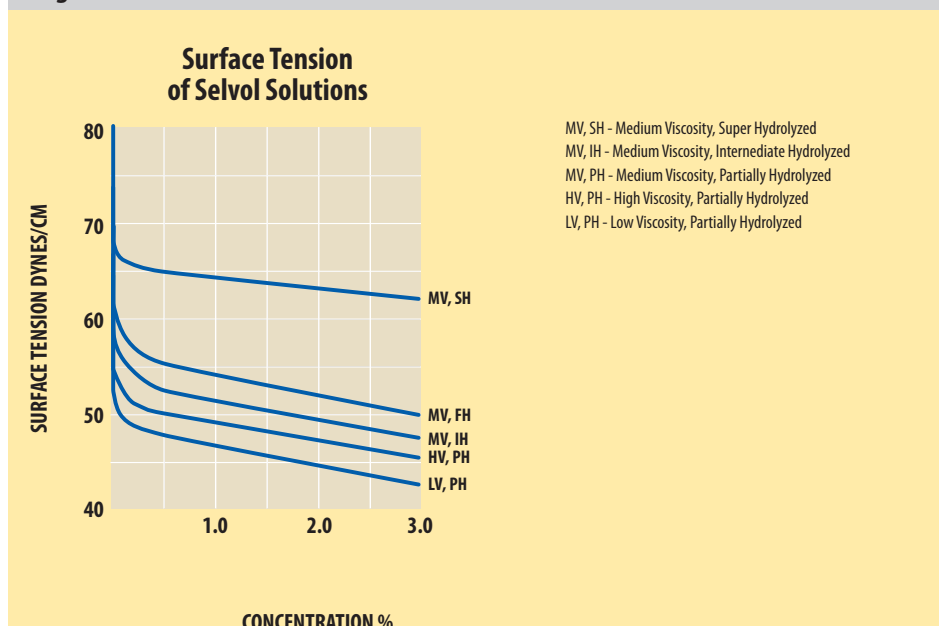
Polyvinyl alcohol is used as a thickener to increase the viscosity and control solids content of the adhesive. When a high-viscosity but low-solids formula is needed, a small amount of high-viscosity polyvinyl alcohol (Selvol 350 and 540 resins) should be added. In this case, the polyvinyl alcohol thickener added to an adhesive will raise the viscosity and permit dilution with water. This dilution reduces the total solids of the adhesive and also lowers its cost. The polyvinyl alcohol releases water slowly, and when combined with lower solids, it slows the setting of the adhesive. High-molecular-weight polyvinyl alcohol improves adhesion to porous substrates by reducing penetration of an emulsion into such substrates; thereby decreasing the likelihood of a starved glue line. When both a high-viscosity and high-solids formulation is needed, a medium-viscosity grade (Selvol 325 and 523 resins) should be added. Polyvinyl alcohol affords the best means of balancing the viscosity and solids content of an emulsion adhesive.

Wet Tack

Wet tack is the tack of an adhesive before the liquid carrier has fully evaporated. Wet tack, also called grab or initial tack, is often necessary in paper converting operations. Machines with little or no pressure in the compression section require emulsion-based adhesives with enough wet tack to bond strongly with little pressure. Wet tack is strongly influenced by solids, water release rate and viscosity.

Wet tack can be increased in the adhesive by adding a partially hydrolyzed polyvinyl alcohol solution to the emulsion. (Fully hydrolyzed polyvinyl alcohol offers improved wet tack and can be used with certain commercial emulsions without encountering syneresis.) Wet tack is further enhanced by adding tackified polyvinyl alcohol.

Figure 4



Open Time

In the case of emulsion-based adhesives, the loss of a relatively small amount of water will cause inversion of the emulsion and rapid setting of the adhesive. Because polyvinyl alcohol is a hydrophilic polymer, the polyvinyl alcohol functions as a humectant to retard the loss of water from the formulation. It prevents the surface of the compound from skinning by keeping it wet and, thereby, prolongs the open time of the adhesive film.

Open time, or open assembly time, is the maximum time lapse between applying the adhesive and bringing the substrates together, within which a satisfactory bond is obtained. Adhesives applied by right-angle machines, such as in carton making, need a relatively long open time. Open time may be prolonged by adding a partially hydrolyzed polyvinyl alcohol solution to the emulsion. Between one and three dry parts of polyvinyl alcohol should be added to the formulation for each 100 parts of the wet emulsion.

Water Sensitivity and Water Resistance

Partially hydrolyzed polyvinyl alcohol increases the water sensitivity of adhesive films, making them very useful in remoistenable adhesives or easy clean-up adhesives.

The water sensitivity of the adhesive can be further increased by adding sugars, glycerin, sorbitol, urea and salts, such as sodium nitrate and calcium chloride. The polyvinyl alcohol-containing films are actually plasticized by the addition of these hygroscopic agents that retain water.

Fully hydrolyzed polyvinyl alcohols, particularly the medium and high-molecular-weight grades, increase the water resistance of adhesive films.

Solutions of super hydrolyzed grades tend to increase in viscosity or gel when aged. Due to this aging profile, these grades of polyvinyl alcohol are not recommended as additives to polyvinyl acetate emulsion-based adhesives. It is possible to blend fully and super hydrolyzed grades to achieve increased water resistance without the gelling characteristics.

The water resistance of a polyvinyl alcohol-containing adhesive can be increased by adding glyoxal, glutaraldehyde, melamine-formaldehyde or certain salts (see Table 5—Insolubilizers for Selvol Polyvinyl Alcohol). Results of crosslinking on a paper substrate are shown in Figure 5.

Solvent and Oil Resistance

Solvent and oil resistance are increased by polyvinyl alcohol. Selvol polyvinyl alcohol resins are generally unaffected by greases,

petroleum hydrocarbons and animal or vegetable oils. Resistance to organic solvents increases with the degree of hydrolysis in the polyvinyl alcohol.

Heat Resistance/Heat Sealing

Since polyvinyl alcohol has a high melting point (180-230 °C), the addition to an adhesive formulation increases its overall heat resistance, especially compared to a base emulsion. This effect is seen in Figure 6, showing resistance to creep at elevated

temperatures. Common white glues based on polyvinyl acetate homopolymer resins have relatively poor heat resistance. At temperatures of 160 °F, these adhesives drop below 2000 pounds per square inch in compression strength and show very little fiber tear. The heat resistance of these adhesives can be improved by the addition of partially hydrolyzed polyvinyl alcohol. Some fillers, such as corn starch or clay, can also increase the shear strength of wood glues subjected to high temperatures.

Table 5

Insolubilizers for Selvol Polyvinyl Alcohol

<i>Category</i>	<i>Insolubilizer</i>	<i>Supplier</i>	<i>Recommended Amount of Insolubilizer (wt% Actives based on PVOH)</i>
Dialdehyde ¹	Glyoxal*	Eastman Kodak, Clariant	10
	Glutaraldehyde or Hydroxyadipaldehyde	Union Carbide	10
Melamine-Formaldehyde ¹	Parez 613	Cytec	10 - 30
	Cymel 303	Cytec	10 - 30
Urea-Formaldehyde	Beetle Resins	Cytec	10 - 30
Polyamide-epichlorohydrin	Polycup 172	Hercules	5
Inorganic Salts	Chromic nitrate		1 - 10
	Dichromate salts ^{2,3}		2 - 30
	Ammonium Zirconium Carbonate (Baycote 20)	Magnesium Electron, Inc.	1 - 10
Cyclic Amide	Sunrez 700	Sequa	1 - 4
Organic Titanates	Tyzor - TE	DuPont	5 - 10

¹ Though optional, the use of an acid catalyst (ammonium chloride, ammonium sulfate, ammonium nitrate, oxalic acid) is highly recommended. Use 1-2 wt % based on polyvinyl alcohol.

² Sodium dichromate, ammonium dichromate, potassium dichromate, cupric dicromate.

³ Ultraviolet light is required to complete insolubilization.

* Most preferred insolubilizer

Figure 5

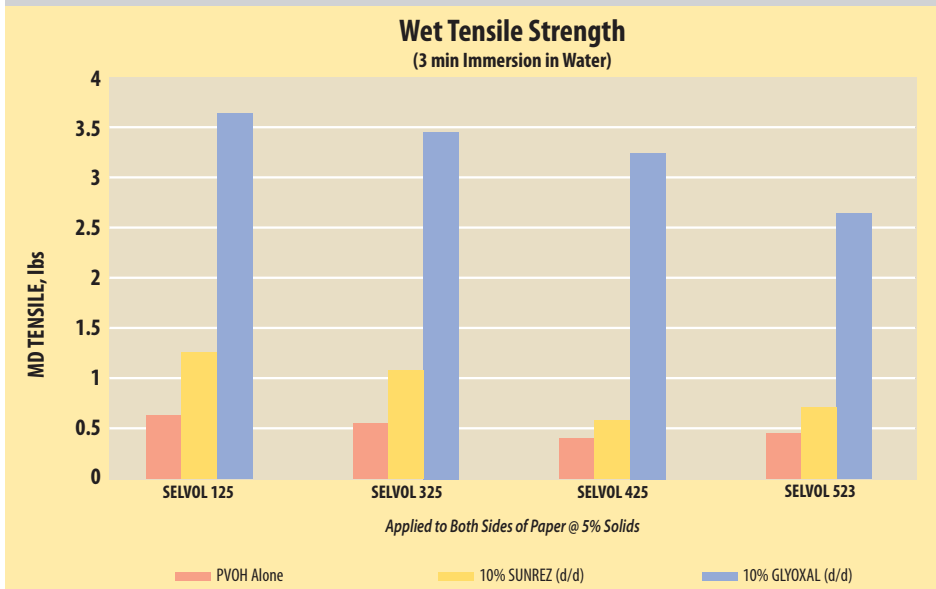
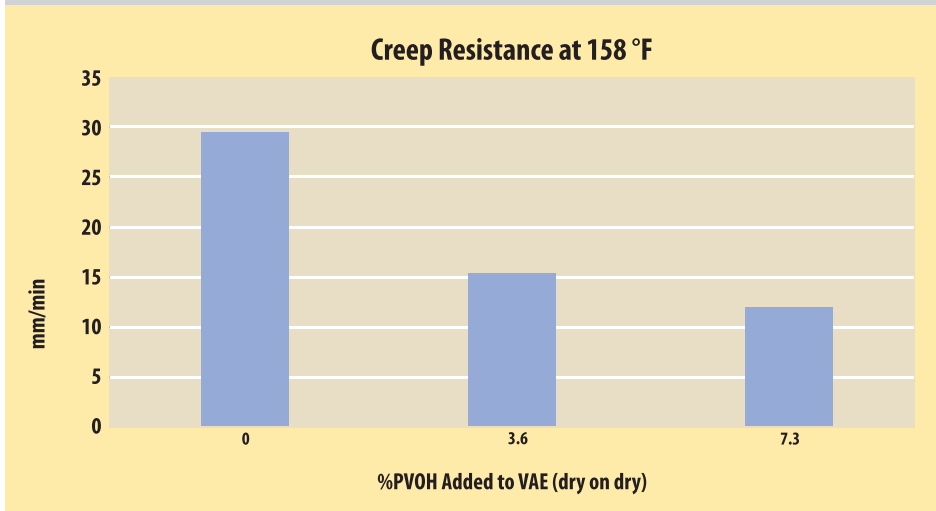


Figure 6



The temperature at which a dried adhesive film forms an instantaneous bond between surfaces when heat and pressure are applied is called the heat sealing temperature. Therefore, the higher the amount of polyvinyl alcohol, the higher the heat sealing tem-

perature. Blocking refers to dried adhesive surfaces that have become sticky, causing an unwanted bond. Factors affecting heat sealing temperature have the same effect on blocking temperature.

Machinability

Adhesives are most commonly applied by machine. Each type of machine has its own viscosity and rheology requirements.

All polyvinyl alcohol grades improve the machinability of emulsion adhesives. All grades impart smooth flow from applicator reservoirs and shear resistance at high speeds. Polyvinyl alcohol prevents the adhesive from spitting and throwing during high-speed applications. In addition, the polyvinyl alcohol permits the adhesive to transfer cleanly and break. All grades have surface-active properties that promote thorough wetting of roller applicators and the substrate. The lower surface tension of the partially hydrolyzed grades permits better wetting of hydrophobic surfaces.

Coagulation with Borax

All grades of polyvinyl alcohol carry the same caution:

Do not use polyvinyl alcohol in borax-containing adhesives, on borax-treated surfaces, or in borax-contaminated equipment at alkaline pH, or the polyvinyl alcohol will gel.

Adhesives containing emulsions stabilized with polyvinyl alcohol or neat polyvinyl alcohol coagulate in the presence of borax or its derivatives. Coagulation can be a problem in packaging operations where borated dextrin is used. If applicator pans and lines are not scrupulously cleaned after using a borated dextrin, an adhesive compounded with a polyvinyl alcohol-protected emulsion or containing neat polyvinyl alcohol will gel and foul the lines and application equipment.

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