SEKISUI

A Versatile Polymer for Adhesive Applications

SELVOL™
POLYVINYL ALCOHOL

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About the Company

The Sekisui Chemical Group is a global company that operates in three major businesses: High Performance Plastics, Urban Infrastructure and Environmental Products, and Housing. Founded in 1947 and currently headquartered in Osaka and Tokyo, Japan, Sekisui strives to deliver a wide range of products and services to enrich people's lives and the social infrastructure.

Architectural Glass

Urban Intrastructure and Environmental Product

Our Promise

Through prominence in technology and quality, Sekisui Chemical Group will contribute to improving the lives of the people of the world and the Earth's environment, by continuing to open up new frontiers in residential and social infrastructure creation and chemical solutions.

Housing

Sekisui Specialty Chemicals

Sekisui produces and sells one of the most complete lines of polyvinyl alcohol in the world. Since the introduction of Selvol Polyvinyl Alcohol, we have developed a high level of expertise in both the production and use of PVOH.

Based in Dallas, Texas, Sekisui Specialty Chemicals is a leading polyvinyl alcohol supplier with manufacturing facilities in Calvert City, Kentucky, Pasadena, Texas and Tarragona, Spain. The combined capacity of the three plants makes Sekisui a leading global merchant supplier of polyvinyl alcohol.

Sekisui's commitment to polyvinyl alcohol is especially evident in our research and applications support activities. We have one of the largest technical services, product application, and analytical services groups in the world. Research and application development is carried out at our facilities in Houston, Texas. Sekisui also has a global sales force located in offices worldwide to respond more quickly to the needs of our customers.

SELVOL™ POLYVINYL ALCOHOL

Introduction

This brochure is intended to highlight the many diverse applications for polyvinyl alcohol in compounding adhesives. For more detailed information on specific applications, the preparation of polyvinyl alcohol solutions, please refer to our other brochures, visit our website at www.selvol.com, or call our Product Information Center at +1-281-280-3460.

Environmental, Health, and Safety

Please refer to our Material Safety Data Sheets (MSDSs) or Safety Data Sheets (SDSs) 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.

TABLE 1:
Selvol Polyvinyl Alcohol Right-to-Know Information

Ingredient	CAS Number
Selvol Polyvinyl Alcohol • Super and Fully Hydrolyzed • Partially and Intermediate Hydrolyzed	 9002-89-5 25213-24-5
Water	7732-18-5
Methanol	67-56-1
Sodium Acetate	127-09-3

Selvol Polyvinyl Alcohol

Selvol Polyvinyl Alcohol is a white, granular, water-soluble resin manufactured by polymerizing vinyl acetate and hydrolyzing the resultant polymer to produce the alcohol (Figure 1).

Because PVOH is synthesized from polyvinyl acetate, a variety of different grades of Selvol Polyvinyl Alcohol is available that varies in molecular weight and hydrolysis level. These two factors are the major determinants of the performance properties of PVOH.

FIGURE 1:
General Structure of Polyvinyl Alcohol

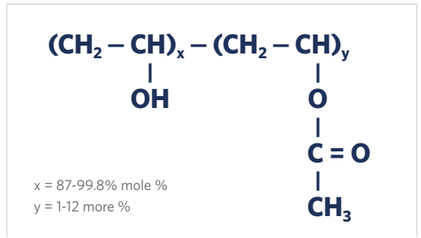
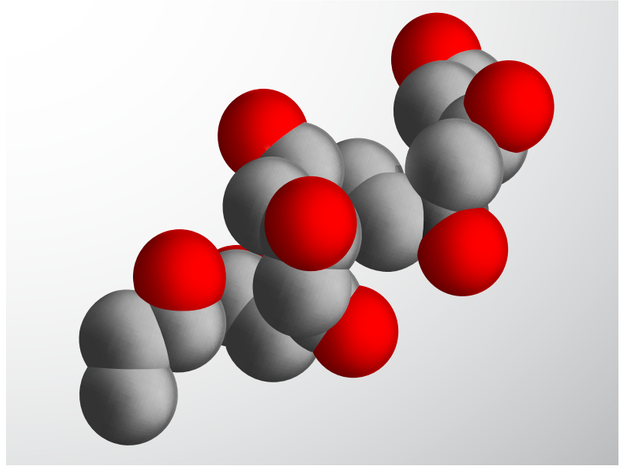


TABLE 2:
Selvol Polyvinyl Alcohol Molecular Weight

Viscosity[1] (cP)	Viscosity Type	Degree of Polymerization	Average Weight Molecular Weight Range	Number Average Molecular Weight Range
3-6	Low	150 - 650	13,000 - 50,000	7,000 - 23,000
22-30	Medium	1000 - 1500	85,000 - 124,000	44,000 - 65,000
45-72	High	1600 - 2200	146,000 - 186,000	70,000 - 101,000

1 4% aqueous solution viscosity.

Molecular weight is a measure of polymer chain length and is typically reported as a 4% aqueous solution viscosity (Table 2).



Molecular Structure PVOH

TABLE 3:
Description of the Different Hydrolysis Levels for PVOH

Grade	Hydrolysis Mole %
Super	99.3+
Fully	98.0-98.8
Intermediate	90.0-97.0
Partially	87.0-89.0

Hydrolysis level is a measure of the mole % hydroxyl functionality on the polymer. The hydrolysis level of PVOH is typically categorized as shown in Table 3.

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Selvol Polyvinyl Alcohol Product Line

The Sekisui Selvol Polyvinyl Alcohol product line, presented in Table 4, consists of 27 standard grades (including E-grades) and several specialty grades. The products are classified by hydrolysis as super, fully, intermediate and partial hydrolyzed. Each standard grade suitable for adhesive application has been portrayed graphically in Figure 2 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.

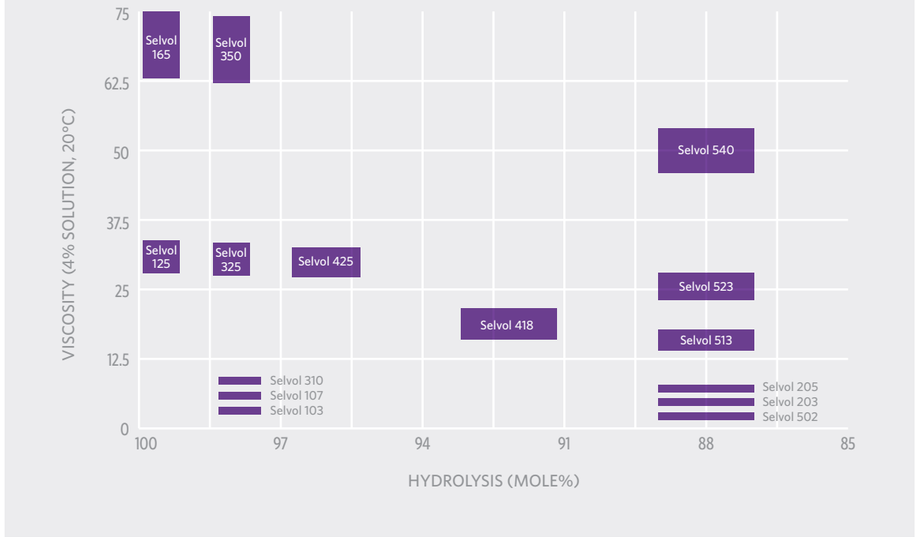

FIGURE 2: Sekisui Polyvinyl Alcohol Grades

TABLE 4:

STANDARD GRADES							
Grade	**Hydrolysis, %**	**Viscosity, cP[1]**	**pH[2]**	**Volatiles, % Max**		**Ash, % Max[5]**	**Methanol, wt % Max**
				Total [3]	VOC[4]		
Super Hydrolyzed							
Selvol PVOH 125	99.3+	28.0-32.0	5.5-7.5	5.0	1.0	1.2	0.9
Selvol PVOH 165	99.3+	62.0-72.0	5.5-7.5	5.0	1.0	1.2	0.9
Fully Hydrolyzed							
Selvol PVOH 103/E 103	98.0-98.8	3.5-4.5	5.0-7.0	5.0	1.0	1.2	0.9
Selvol PVOH 107/E 107	98.0-98.8	5.5-6.6	5.0-7.0	5.0	1.0	1.2	0.9
Selvol PVOH 310/E 310	98.0-98.8	9.0-11.0	5.0-7.0	5.0	1.0	1.2	0.9
Selvol PVOH 325/E 325	98.0-98.8	28.0-32.0	5.0-7.0	5.0	1.0	1.2	0.9
Selvol PVOH 350	98.0-98.8	62.0-72.0	5.0-7.0	5.0	1.0	1.2	0.9
Intermediate Hydrolyzed							
Selvol PVOH 418	91.0-93.0	14.5-19.5	4.5-7.0	5.0	1.0	0.9	0.9
Selvol PVOH 425	95.5-96.5	27.0-31.0	4.5-6.5	5.0	1.0	0.9	0.9
Selvol PVOH 443	92.0-94.0	53.0-63.0	4.5-6.5	5.0	1.0	0.9	0.9
Partially Hydrolyzed							
Selvol PVOH 502	87.0-89.0	3.0-3.7	4.5-6.5	5.0	1.0	0.9	0.9
Selvol PVOH 203/E 203	87.0-89.0	3.5-4.5	4.5-6.5	5.0	1.0	0.9	0.9
Selvol PVOH 504	87.0-89.0	4.0-5.0	4.5-6.5	5.0	1.0	0.7	0.9
Selvol PVOH 205/E 205	87.0-89.0	5.2-6.2	4.5-6.5	5.0	1.0	0.7	0.9
Selvol PVOH E 8/88	87.0-89.0	7.0-9.0	4.5-6.5	5.0	1.0	0.7	0.9
Selvol PVOH 508	87.0-89.0	7.5-9.5	4.5-6.6	5.0	1.0	0.7	0.9
Selvol PVOH 513	87.0-89.0	13.0-15.0	4.5-6.5	5.0	1.0	0.7	0.9
Selvol PVOH 518	87.0-89.0	17.5-20.5	4.5-6.5	5.0	1.0	0.7	0.9
Selvol PVOH 523/E 523	87.0-89.0	23.0-27.0	4.5-6.5	5.0	1.0	0.5	0.9
Selvol PVOH 540	87.0-89.0	45.0-55.0	4.5-6.5	5.0	1.0	0.5	0.9
Selvol PVOH E575							

TACKIFIED GRADES			
Grade	**Viscosity, cP[6]**	**pH[7]**	
Selvol PVOH MH-82	4200-5900	4.4-4.0	Derived from Fully Hydrolyzed Grades
Selvol PVOH MM-81	1300-1700	4.4-4.9	
Selvol PVOH MM-51	1100-1500	4.4-4.9	

[1] 4% aqueous solution, 20°C.
[2] 4% aqueous solution.
[3] Total volatiles incl. water.
[4] Volatile organic compound, primarily methanol. (max0.9%) with methyl acetate.
[5] As % Na_2O, corrected volatiles.
[6] 10% aqueous solution, 25°C.
[7] 10% aqueous solution.

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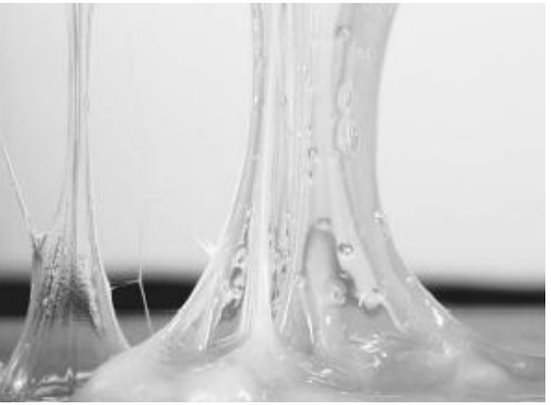
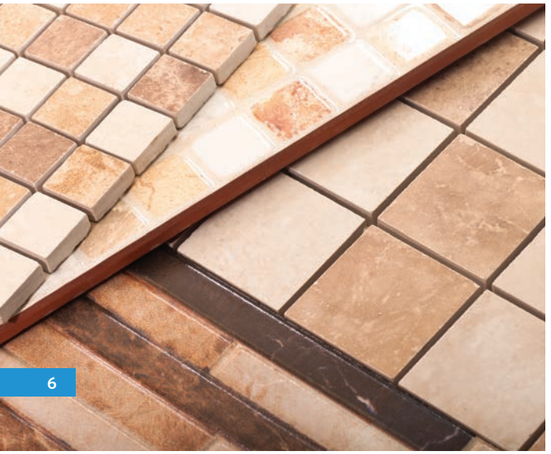




Polyvinyl Alcohol Business

Important end-use markets for these polymer products include textiles, paper, adhesives, building products, and specialty applications.

Selvol Polyvinyl Alcohol resins perform well as textile sizing agents, pigment binders, emulsifying agents, and in adhesive and protective film applications. Special properties may be imparted by blending grades or compounding with other ingredients.

For a full list of Adhesive Applications please refer to Table 5.

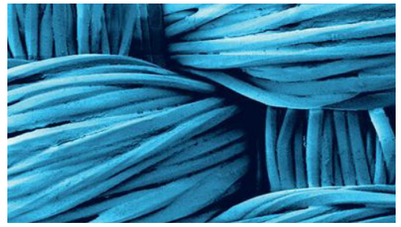


TABLE 5:

	COMPOUNDING ADDITIVE												SOLE ADHESIVES			
	Remoistenable Adhesive	Envelope - Side Seam	Wood - General Assembly	Padding	Bookbinding	Cup Forming	Case Sealing	Paper Laminating	Bag Seams	Labels	Carton Sealing	Bag Bottom Paste	Solid Fiber Laminating	Tube and Core Winding	Wood-High Performance	Consumer/Craft Glue
STANDARD GRADES																
Super Hydrolyzed																
Selvol PVOH 125													◆	◆		
Selvol PVOH 165													◆	◆		
Fully Hydrolyzed																
Selvol PVOH 103/E 103	◇	◆	❖	◆	◆	◆	◆	◆	◆		◆		◆	◆	❖	
Selvol PVOH 107/E 107	◇	◆	❖	◆	◆	◆	◆	◆	◆		◆		◆	◆	❖	
Selvol PVOH 310/E 310	◇	◆	❖	◆	◆	◆	◆	◆	◆		◆		◆	◆	❖	
Selvol PVOH 325/E 325	◇	◆	❖	◆	◆	◆	◆	◆	◆		◆		◆	◆	❖	
Selvol PVOH 350	◇	◆	❖	◆	◆	◆	◆	◆	◆		◆		◆	◆	❖	
Intermediate Hydrolyzed																
Selvol PVOH 418	❖	◆	❖	◆	◆	◆	◆		◆		◆		❖	❖	❖	
Selvol PVOH 425	❖	◆	❖	◆	◆	◆	◆		◆		◆		❖	❖	❖	
Selvol PVOH 443	❖	◆	❖	◆	◆	◆	◆		◆		◆		❖	❖	❖	
Partially Hydrolyzed																
Selvol PVOH 502	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 203/E 203	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 504	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 205/E 205	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH E 8/88	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 508	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 513	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 518	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 523/E 523	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH 540	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
Selvol PVOH E575	◆	◆	◆	◆	◆		❖		❖	◆	◆	◆			◆	◆
TACKIFIED GRADES																
Fine Particle (S-Grade)																
Selvol PVOH MH-82			❖						◆				◆	◆	❖	
Selvol PVOH MM-81			❖						◆				◆	◆	❖	
Selvol PVOH MM-51			❖						◆				◆	◆	❖	

◆ Typically Used ❖ Sometimes Used ◇ Can Be Used

SELVOL™ POLYVINYL ALCOHOL

ADHESIVE APPLICATIONS

Sole or Primary Adhesives

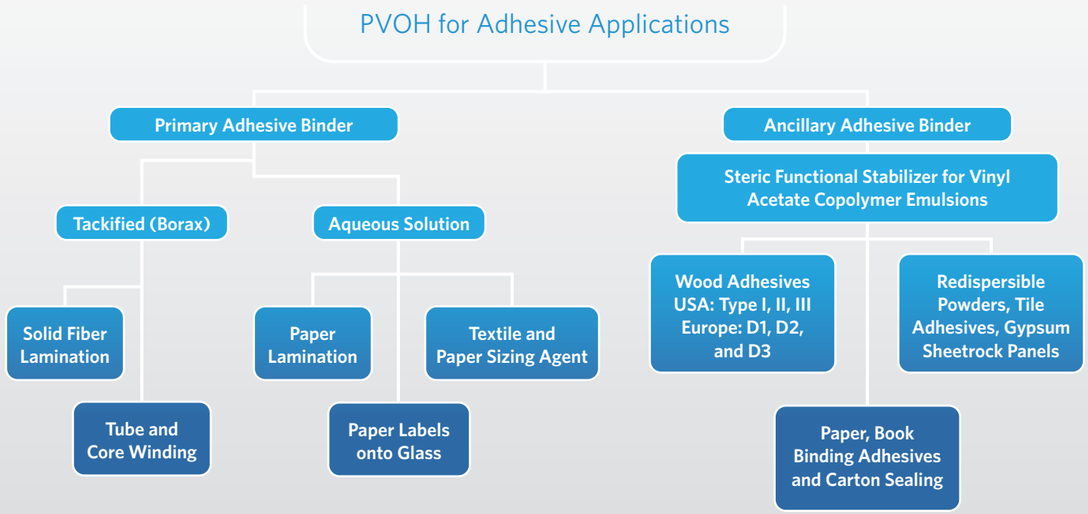
In these applications, Selvol Polyvinyl Alcohol is used as the sole or primary binder in the adhesive.

SOLID FIBER LAMINATING AND TUBE CORE WINDING

Tackified Selvol 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 Selvol Polyvinyl Alcohol allows high levels of extender, such as clay, to be added to the formulation. Tackified Selvol PVOH grades derived from fully hydrolyzed polyvinyl alcohols (see Tables 2 and 3) provide a combination of good pot life and good water resistance.

WOOD—HIGH PERFORMANCE

PVOH is mostly used for PVAc and VAE wood adhesives as steric stabilizer during the emulsion polymerization and/or additional formulation additive to impart additional adhesion strength. 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, water resistance and adhesion strength.



REMOISTENABLE ADHESIVES

Partially hydrolyzed polyvinyl alcohol grades increase the water sensitivity of adhesive films, making them useful for formulating remoistenable adhesives. Selvol Polyvinyl Alcohol 203/E 203 is especially useful in remoistenable adhesives due to its low viscosity. The 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 adhesion strength of these adhesives. Low molecular-weight grades, such as Selvol Polyvinyl Alcohol 205/E 205 will allow greater polyvinyl alcohol incorporation into the adhesive, while a grade such as Selvol Polyvinyl Alcohol 540 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 AND CASE SEALING

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

CONSUMER/CRAFT GLUE

Adding partially hydrolyzed grades like Selvol Polyvinyl Alcohol 523/E 523 will increase fiber tear and improve the wash off.

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.

BAG SEAMS AND CARTON SEALING

Fully hydrolyzed polyvinyl alcohol compounding improves heat and water resistance.

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.

LABELS

Partially hydrolyzed polyvinyl alcohol is used to formulate wash off removable adhesives for glass wine bottles.

SELVOL™ POLYVINYL ALCOHOL

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 3 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.

Post-Add Compatibility with Emulsions

Partially hydrolyzed polyvinyl alcohol (Selvol Polyvinyl Alcohol 203/E 203, 205/E 205, 523/E 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. PVOH can be used together with either anionic or cationic surfactants to stabilize emulsions. Intermediate hydrolyzed polyvinyl alcohol (Selvol Polyvinyl Alcohol 418 and 425 resins) shows some compatibility while fully hydrolyzed polyvinyl alcohol (Selvol Polyvinyl Alcohol 103/E 103,107/E 107, 310/E 310, 325/E 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. There are commercial emulsions available that are compatible with both partially and fully hydrolyzed polyvinyl alcohol that can be used to avoid this problem.

FIGURE 3: Adhesive Properties as a Function of PVOH Molecular Weight and Hydrolysis Level

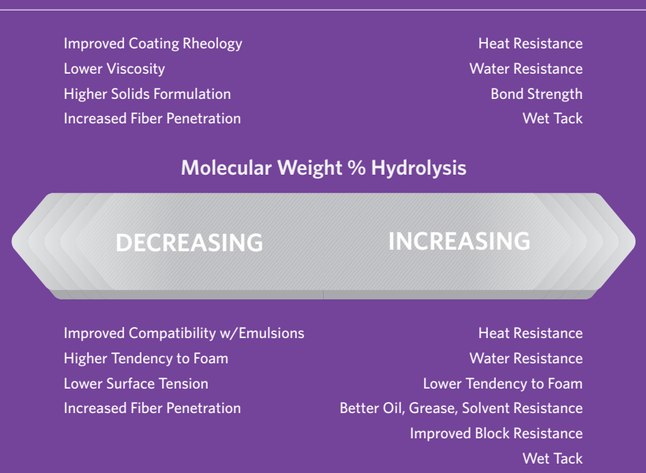


TABLE 6:
Recommended Defoamers for Selvol Polyvinyl Alcohol

Brand or Generic Name	Manufacturer	Level Use
Foam-a-Tac 407	ESP Enterprises	< 1% d/d
Antifoam 116	Harcros	< 1% d/d
FC 402**	ESP Enterprises	< 1% d/d

Foaming

Generally, the higher the hydrolysis, the less the tendency to foam (see Figure 4). Fully and super hydrolyzed grades are generally used without defoamers, whereas intermediate and partially hydrolyzed grades nearly always require a defoamer. Grades in Selvol's 800 specialty series usually have less foaming issues than other standard grades. See Table 6 for recommended defoamers. If Sekisui guidelines for PVOH cooking are met; foaming is unlikely to occur (Check dissolution procedures at www.selvol.com).

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 5. Partially hydrolyzed polyvinyl alcohol wets surfaces better than the fully or super hydrolyzed grades and, as a result, works well in adhesives for low energy surface substrates. The super hydrolyzed grades have surface tension close to that of water; a property which can help the adhesive formulators to tailor physical properties. 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.

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 Polyvinyl Alcohol 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 Polyvinyl Alcohol 325/E325 and 523/E 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 adhesion strength 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 or PVOH crosslinker.

FIGURE 4:
Foaming Characteristics of Selvol Polyvinyl Alcohol

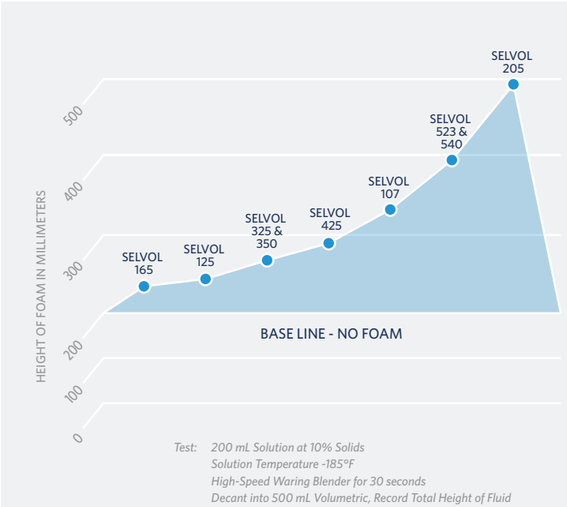
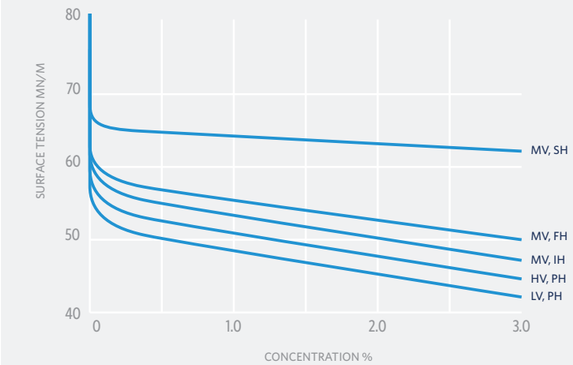


FIGURE 5:
Surface Tension of Selvol Solutions



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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 wash off 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 hydroscopic 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, gluteraldehyde, melamineformaldehyde or certain salts (see Table 7 — Crosslinkers for Selvol Polyvinyl Alcohol).

Results of crosslinking on a paper substrate are shown in Figure 6.

TABLE 7: Insolubilizers for Selvol Polyvinyl Alcohol

Category	Insolubilizer	Supplier	Recommended Amount of Insolubilizer (wt% Actives based on PVOH)
Dialdehyde[1]	Glyoxal * Gluteraldehyde	BAFS, Clariant BASF, DOW	10 10
Melamine-Formaldehyde[1]	Cymel 303	Cytec	10-30
Urea-Formaldehyde	Cymel U-65 Urecoll	Cytec BASF	10-30 10-30
Polyamide-epichlorohydrin	Polycup 172	Ashland Water technologies	5
Inorganic Salts	Chromic Nitrate Dichromate salts [2,3] Ammonium Zirconium Carbonate, (Baycote 20)	MEL Chemicals	1-10 2-30 1-10
Cyclic Amide	Sunrez 700	Omnova Solutions	1-4
Organic Titanates	Tyzor-TE	Dorf Ketal	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 dichromate.
[3] Ultraviolet light is required to complete insolubilization. * Most preferred insolubilizer.

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 7, 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 filler, such as corn starch or clay, can also increases the shear strength of wood glues subjected to high temperatures.

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 temperature. 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

Adding appropriate concentration of Borax to PVOH or Emulsion containing PVOH is the easiest way to enhance the wet tack or increase the tensile strength of the dried film. Higher Borax concentration will lead to complete system coagulation.

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.

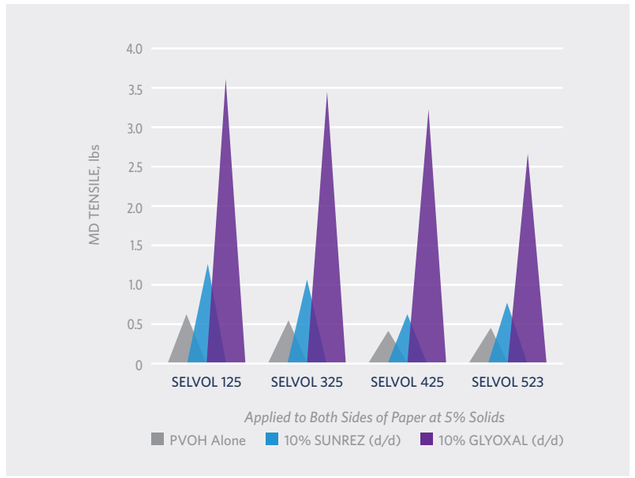

FIGURE 6: Wet Tensile Strength (3 minute Immersion in Water)

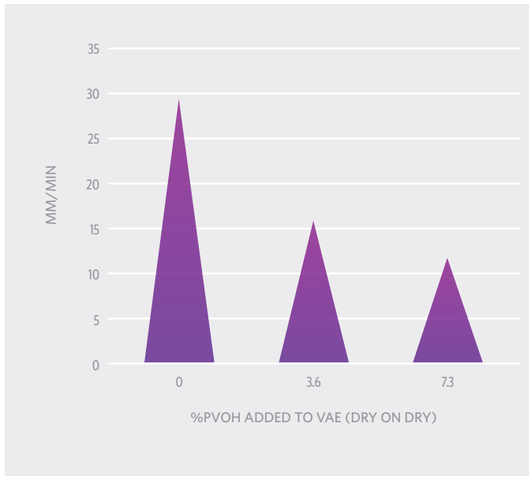

FIGURE 7: Creep Resistance at 158°

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