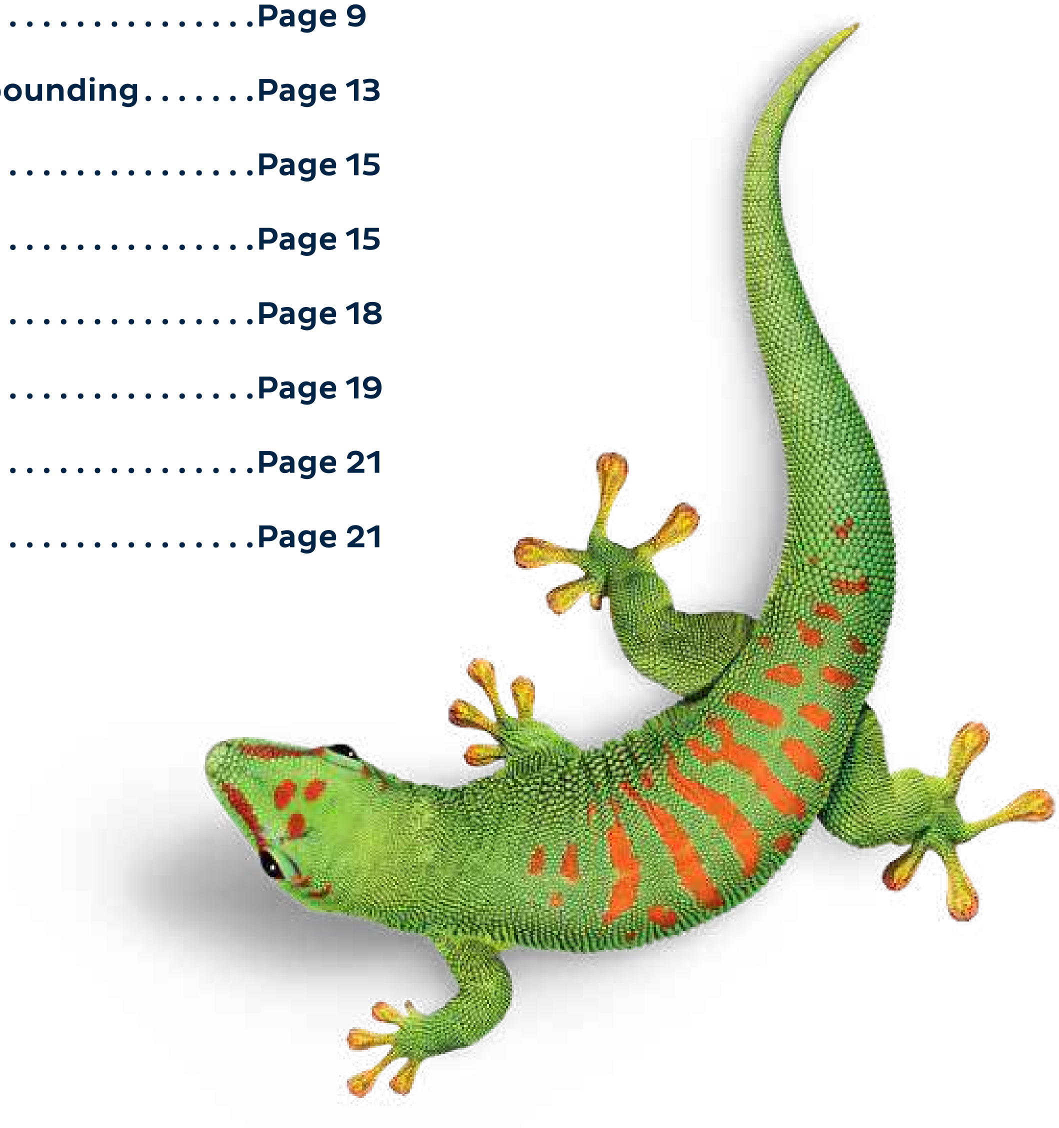
Bostik
smart adhesives

VITEL® RESINS TECHNICAL GUIDE

CONTENTS



INTRODUCTION

The VITEL® copolyester resins which make up the 1000, 2000, 3000 and 7000 series have been used for many years in the resolution of difficult coating and adhesion problems. Many of the VITEL resins are suitable for use in certain food contact applications. This established family of high performance, linear, saturated copolyesters is produced by condensation polymerization of mixtures of diols and dibasic organic acids or their simple esters. The products are generally classified as medium to high molecular weight, and as such have chemically reactive sites only at the ends of the polymer chains. This means they are essentially thermoplastic. However, they can be cured or cross linked. They also might be referred to as "oil-free alkyds".

VITEL resins have shown excellent performance properties in many other areas, as well. They exhibit high specific adhesion, good abrasion and chemical resistance, very good UV stability, and high pigment binding properties. Their ability to soften with increases in temperature, or "heat activate", is extremely important when these coatings are used as heat sealing or laminating adhesives.

VITEL copolyester resins have shown good adhesion characteristics and utility with a wide variety of substrates, such as:

- PET (polyethylene terephthalate) films
- Metals (aluminum, copper, and steel)
- Polyvinylchloride film
- Polystyrene film
- Polycarbonate film
- Polyamide film
- Corona-treated olefin films (Polyethylene, polypropylene)
- Polyimide/amide films

The composition of these resins is similar to the well known PET (polyethylene terephthalate) resins used to produce such films as Terphane®,Hostaphan®, Melinex®, and Mylar®. Because of their chemical similarity, most VITEL resins exhibit exceptionally good adhesion to PET films, which have found wide use in many industries, notably packaging (both food and non-food), electrical/electronic, graphic arts/office supplies, and label making. The commercial success of PET films, which are difficult to adhere to, would have been limited were it not for copolyester products such as the VITEL resins that have been used as primers, coatings, ink vehicles, and adhesives for those film products.

Strong adhesion to metal substrates makes VITEL resins well suited for laminating polyester films to copper or aluminum foils, rigid metal coatings, and coil coatings where sheet stock is subsequently formed into containers.

VITEL resins are extremely versatile, offering a good balance of properties when blended or used by themselves. They also offer a range of compatibility with other coating resins such as RS nitrocellulose and solution grade vinyl copolymers which may be used for property modification.

VITEL resins have been utilized as primer coatings providing intercoat or ink adhesion. They are also used as ink vehicles, providing adhesion to difficult substrates without the incorporation of priming steps.

This brochure describes the physical and chemical properties of the VITEL 1000, 2000, 3000 and 7000 series resins and presents data from extensive studies of coating and adhesive applications. It provides the basic technical information required for preliminary determination of the VITEL resin best suited for a particular application area. For resin samples or technical assistance on a specific VITEL application, please call Bostik's Technical Service Center at 1-800-7 Bostik.

GENERAL PROPERTIES

VITEL copolyester resins may be broken into three broad categories. The three classes are: 1) extrusion polymers with limited solubility, 2) hard resinous soluble polymers with Tgs above room temperature, and 3) soft flexible soluble polymers with medium to high elongation and Tgs below room temperature.

Extrusion Polymers With Limited Solubility

VITEL 1000 series extrusion resins were designed to have superior chemical and temperature resistance along with exceptional adhesion to untreated polyester surfaces. This category of VITEL resins can be formulated to provide abrasion or scuff resistance through a hard resinous backbone or greater flexibility and temperature resistance by incorporating aliphatic acids and thereby modifying the crystallinity. Table 1 shows some of the more pertinent properties of the VITEL 1000 series polymers.

The 1000 series resins are geared toward extrusion or coextrusion processes. Since polyester resins tend to hydrolyze in presence of moisture and heat, it is recommended they are dried in-line and fed to the extruder with a moisture level not exceeding 0.05%.

These resins also have a very low solubility. They are not soluble in common solvents like methyl ethyl ketone, toluene, and ethyl acetate. They will, however, show some solubility at low levels (15 – 20% solids) in more aggressive solvents like 1,3 dioxolane, tetrahydrofuran, and methylene chloride.

Many VITEL 1000 series resins also hold a broad range of FDA compliances. One of which is 21 CFR 177.1630 designed for direct food contact applications. By incorporating an aliphatic acid portion to the backbone of some 1000 series polymers, the bond strength on polyester materials was designed to be peelable, which makes them ideal for some food packaging applications.

TABLE 1 - PERTINENT PROPERTIES OF VITEL EXTRUSION RESINS

Vitel Resin	Tensile Strength, psi	% Elongation	Melt Flow Index (g/10 Minutes)	Melt Point Ring & Ball °C	T_g °C
1200	11,000	5	8	150	70
1801	1,060	1,600	23	116	-20
1901NSB-P	800	60	27	143	-4
1902NSB-P	800	60	27	143	-4
1912NSB	NA	Flexible	30	145	-2
1916NSB	NA	Flexible	30	145	-2

* Melt Flow taken at 190°C, 2160 gram weight except 1901NSB-P and V1902NSB-P which were at 160°C

Hard Resinous Polymers

The hard, resinous, soluable polymers fit into the Vitel coating resins series. VITEL coating resins are abrasion, scuff, and chemical resistant resins exhibiting high tensile strength and low elongation properties.

The VITEL coating resins find specialized use either alone or modified in adhesive applications where high cohesive strengths are of prime importance. These polymers are used both as clear or pigmented coatings. Since they are compatible with a wide range of materials, high percentage modifications can be incorporated to obtain a wide range of properties.

The VITEL coating resins are all amorphous resins that are characterized by their excellent adhesion to PET films and their toughness. VITEL 2200 is the workhorse of the line with the broadest range of properties. Vitel 2700 offers better flow properties at lower temperatures on films. Bostik 7900 is a modifier for these resins to improve flexibility.

Some of the more pertinent properties of the hard resinous VITEL 2000 series resins are shown in Table 2.

TABLE 2 – PERTINENT PROPERTIES OF VITEL COATING RESINS

Vitel Resin	Tensile Strength, psi	% Elongation	Hardness, Shore D	Melt Point Ring & Ball °C	T_g °C
2200	9600	7	79	155	69
2700	6500	3	78	142	50
7900	3100	406	70	85	30

Soft Flexible Polymers

VITEL laminating resins are soft flexible soluble polymers. These resins are designed primarily for adhesive applications, although they are also used to modify hard resinous materials such as VITEL coating resins, nitrocellulose, vinyls, and others. When used as a coating modifier, the flexible VITEL polymers significantly improve adhesion to a variety of substrates. They also assist in obtaining other desired properties such as flexibility, improved pigment binding, electrical resistance, etc.

VITEL 3200 resin was designed primarily as an adhesive binder for attaching difficult-to-adhere flexible webs to a variety of substrates, such as polyester, PVC, or treated polypropylene to aluminum foil.

VITEL 3300 was developed to provide superior compatibility with other VITEL resins and long-term solution stability in aromatic or ketone solvent systems. We also offer a lighter color version of this resin in the form of Vitel 3350.

The amber colored VITEL 3550 has been the workhorse of this series of resins. VITEL 3650 is produced as a lower colored version of the VITEL 3550 resin and has been used in a few applications where resin color was of great importance. While the solid resins exhibit considerable color differences, in typical thin adhesive application the color is not noticeable. In addition, there are other subtle differences between these products. They are all however, highly flexible and permanently tacky.

The laminating resins 7908, 7915 and 7962 are semi-crystalline polymers. The crystallinity raises the activation temperature and improves the green strength of the adhesive when compared to amorphous polymers with the same T_g. Semi-crystalline resins will also result in a slightly hazier coating.

Some important properties of the soft, flexible VITEL 3000 and 7000 series resins are shown in Table 3.

TABLE 3 – PERTINENT PROPERTIES OF VITEL LAMINATING RESINS

Vitel Resin	Tensile Strength, psi	% Elongation	Hardness, Shore A	Hardness, Shore B	Melt Point Ring & Ball °C	T_g °C
3200	400	800	67	22	129	15
3300	500	800	67	25	125	16
3350	500	800	67	25	125	16
3550	30	>2000	25	--	99	-11
3650	30	>2000	29	--	99	-10
7962	2500	700	82		110	-5
7908	400	--	--		110	-12
7915	370	<1000	65A		85	

Detailed studies of all of the VITEL resins in various areas follow.

SOLUBILITY

Since the soluble grades of VITEL resins are most frequently applied from solution, solvation and solvent selection are important. Methyl ethyl ketone (MEK) is commonly used as a primary solvent. Among hydrocarbons, toluene is an effective solvent for these copolyester resins. The VITEL coating resins are highly swollen in toluene but require some portion of oxygenated solvent for solvation. Generally a blend of oxygenated solvent such as MEK and toluene is a stronger solvent system than either solvent alone. The solids-viscosity relationship for VITEL 2200 and 3200 in various toluene/MEK blends are shown in Figures 1 and 2.

FIGURE 1 – SOLUTION VISCOSITY VS. TOLUENE/ MEK BLEND FOR VITEL® 2200

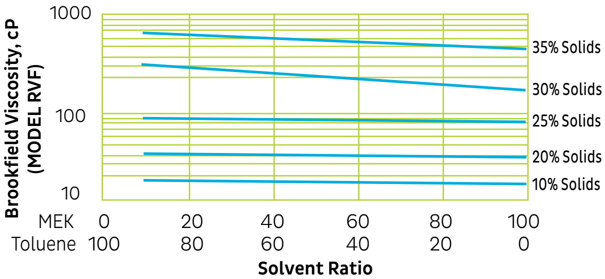
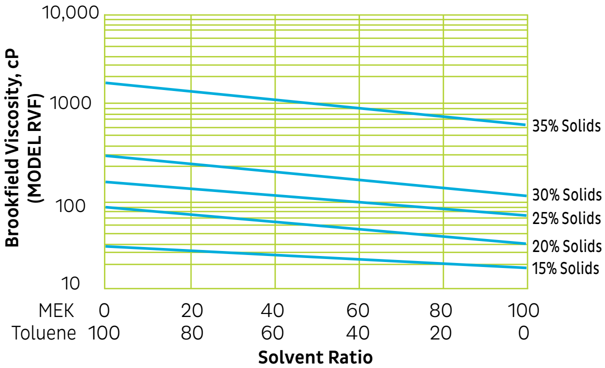


FIGURE 2 – SOLUTION VISCOSITY VS. TOLUENE/ MEK BLEND FOR VITEL® 3200



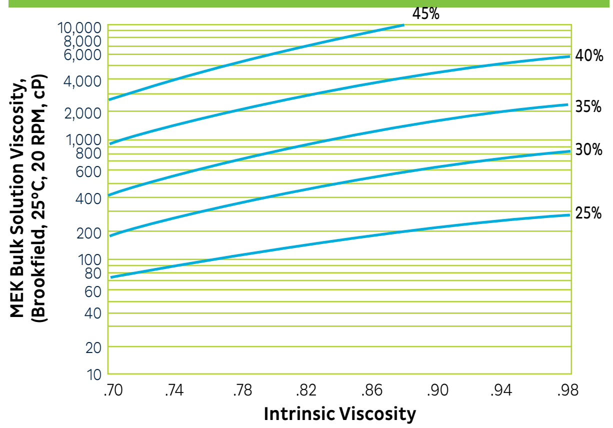
The solution viscosity of these resins will vary slightly depending on molecular weight (Intrinsic Viscosity). For purposes of comparison, the following viscosities were measured for 30% solids solutions in 50/50 toluene/MEK:

VITEL 2200 – 240 cP

VITEL 3200 – 295 cP

The relationship of MEK solution viscosity at various resin concentrations to the intrinsic viscosity (IV) of the VITEL 3300 copolyester adhesive resin is given in Figure 3.

FIGURE 3 – MEK BULK SOLUTION VISCOSITY VS. IV FOR VITEL® 3300



Although toluene/MEK solvent systems have been widely used, there are many applications where other solvents are more desirable. Solubility parameters have been recognized as useful tools in selecting solvent systems for a wide variety of coating application requirements. They provide a convenient method for determining, without exhaustive trial and error, the best solvent or solvent system for a particular polymer.

The solubility parameter is a numerical constant which is characteristic for each solvent. Table 4 lists the solubility parameters of common solvents. These values can be accurately calculated for each solvent from such measurable properties as molecular weight, density, and heat of vaporization. However, for polymers, since they are mixtures of a number of different molecular species, these values are not calculated but are determined experimentally and the parameter given as a range of values. When the value for a solvent falls within the parameter range of the resin, solubility will occur.

It is necessary to combine one other condition with solubility parameter to obtain an accurate prediction of solubility. The hydrogen bonding strength, or polarity, of the solvent must be considered. Solvents are grouped into three simple classes:

- Class I — Poor hydrogen bonding (This class includes aromatic, aliphatic, and chlorinated solvents.)
- Class II — Moderate hydrogen bonding (Esters, ethers, and ketones fall in this class.)
- Class III — Strong hydrogen bonding (Includes alcohols and amines.)

Solubility parameter theory provides a useful tool in solvent selection for the VITEL copolyester resins. However, it is important to note that there are exceptions to this concept. For instance, while the solubility parameter of ethyl acetate lies within the parameter range for VITEL 2200 resin, this solvent may not dissolve this selected VITEL resin into a 100% clear solution.

The solubility parameter ranges of the VITEL resins are listed in Table 5 and illustrated in the contour maps on page 8. Those solvents that are just outside the solubility parameter ranges are called latent solvents. While they will not produce complete solubility, they will cause the resin to swell or even give partial solubility. To determine the strongest solvent for the VITEL resins in a given solvent class, determine the average value or midpoint for the resin parameter range. For example, the VITEL 2200 midpoint value is about 10.1 for weakly hydrogen-bonded solvents, and therefore, the strongest solvent would be nitrobenzene or dichlorobenzene. These two solvents are not shown because they are not widely used in coating formulations. The chlorinated solvents, such as ethylene dichloride, would be the next strongest in solvency of VITEL 2200. The same principle is applied to the moderately hydrogen-bonded solvents. The midpoint value for VITEL 2200 is 9.3, therefore MEK will have the highest solvency for this resin. The list of solvent solubility parameters shown is by no means complete, but does list some of the more common solvents.

Some solvents will not dissolve the VITEL resins by themselves, but when used in specific ratios, provide complete resin solubility and are useful solvent blends in certain coating applications. Examples are given in Table 6. Essentially, solvents from Class I and Class III can be blended in specific ratios to provide a solvent parameter for a moderately hydrogen-bonded solvent. In the two specific examples given, the parameter value for MEK and benzene respectively is achieved by this principle of non-solvent blending. There is enough evidence to indicate that this theory is not universal for all solvents, but is effective when one of the non-solvents is a latent solvent. While this entire concept of solubility parameters must be used with discretion, it can prove to be a time saver and a useful technique in selecting solvents and solvent mixtures.

Solution stability is also an important consideration in selecting solvents for specific application needs. Table 7 offers an indication of the solution stability of VITEL 2200, 2700, and 3200 resins in commonly used solvents or solvent blends. The data was determined by measuring the viscosity change of a 30% solids solution during a four-week period at room temperature.

VITEL resins generally only tolerate highly polar alcohols in the solvent system when there is some nonpolar aromatic hydrocarbon such as toluene present. Additionally any significant portion of aliphatic hydrocarbon solvent very likely will result in inadequate solvent systems. Studies extending beyond one year have shown that only VITEL 3200 exhibits a tendency for solutions to become immobile reversible gels. There is a slight tendency toward gelation upon long-term aging with VITEL 3550 at greater than 40% non-volatiles.

Care should be taken when using ethyl acetate with VITEL resins. With prolonged storage at high temperatures, the ethyl acetate will generate ethanol which inhibits isocyanate cures. The solvent may also transesterify with the resin causing loss of functionality. Solutions of VITEL resins made with ethyl acetate should be stored below 90°F.

TABLE 4 – SOLUBILITY PARAMETERS OF SOLVENTS

Class I/Poorly H-Bonded[1]		Class II/Moderately H-Bonded[2]		Class III/Strongly H-Bonded[3]	
n-Heptane	7.4	DIBK	7.8	n-Butanol	11.4
Solvesso	8.5	Methyl Amyl Acetate	8.0	Isopropanol	11.5
Xylene	8.8	MIBK	8.4	n-Propanol	11.9
Toluene	8.9	n-Butyl Acetate	8.5	Ethanol	12.7
Benzene	9.2	Cellosolve Acetate®	8.7		
Monochlorabenzene	9.5	Ethyl Acetate	9.1		
Methylene Chloride	9.7	MEK	9.3		
2-Nitropropane	10.7	THF	9.8		
Nitroethane	11.1	Cyclohexanone	9.9		
		Dioxane	9.9		
		Acetone	10.0		
		Methyl Cellosolve	10.8		

1. This class includes aromatic, chlorinated, and nitrohydrocarbon solvents.
2. Esters, ethers, and ketones fall in this class.
3. Includes alcohols and amines.

TABLE 5 – SOLUBILITY PARAMETERS FOR VITEL® RESINS AND SELECTED SOLVENTS

Vitel Resin	Poorly H-Bonded Solvents	Moderately H-Bonded Solvents	Strongly H-Bonded Solvents
2200	9.2 – 11.1	8.7 – 9.9	0
3200	8.8 – 11.1	8.5 – 9.9	0
2700	8.9 – 11.1	8.5 – 9.9	0
3300	8.9 – 11.1	8.5 – 9.9	0
3550	8.9 – 12.7	8.5 – 9.9	0

FIGURE 4 – SOLUBILITY CONTOUR FOR VITEL® 2200 AND 2700

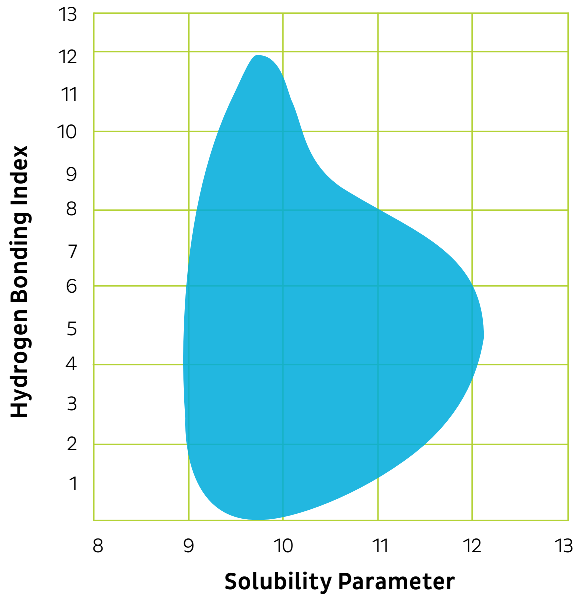


FIGURE 6 – SOLUBILITY CONTOUR FOR VITEL® 3550

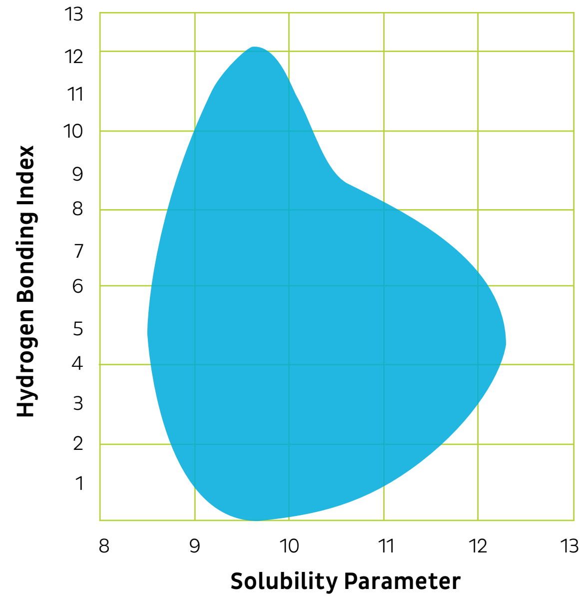


FIGURE 5 – SOLUBILITY CONTOUR FOR VITEL® 3200 AND 3300

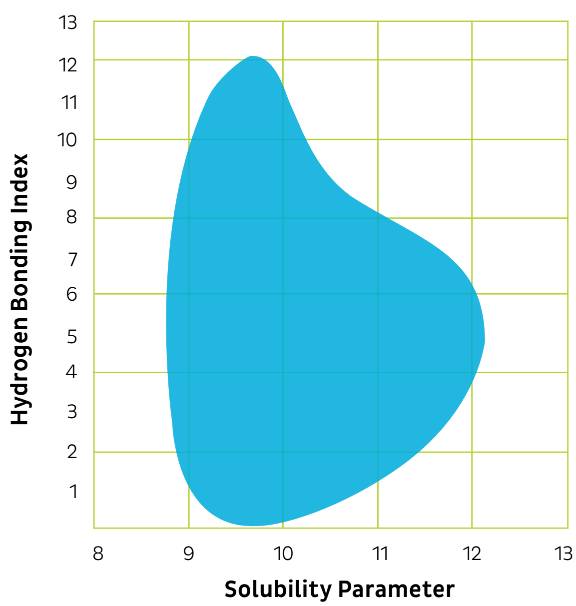


TABLE 6 – EXAMPLES SHOWING USE OF SOLUBILITY PARAMETERS

VITEL 2200 + Toluene	No solution	(8.9)
VITEL 2200 + Isopropanol	No solution	(11.5)

However, VITEL 2200 will dissolve in a blend* of 85/15 toluene/isopropanol.

The reason can be shown as follows:

Toluene	8.9 x 0.85 = 7.6
Isopropanol	11.5 x 0.15 = 1.7
	9.3

The solubility parameter for the blend is 9.3, which is similar to the parameter for MEK.

VITEL 2200 + Methyl Cellosolve	No solution	(10.8)
VITEL 2200 + Isopropanol	No solution	(8.8)

VITEL 2200 will dissolve in 80/20 blend of Toluene/Methyl Cellosolve.

Methyl Cellosolve	10.8 x 0.2 = 2.2
Xylene	8.8 x 0.8 = 7.0
	9.2

The solubility parameter for the blend is similar to the parameter for benzene.

* Determined on a volume basis.

TABLE 7 - ROOM TEMPERATURE VISCOSITY STABILITY OF VITEL® RESIN SOLUTIONS @ 30% SOLIDS					
	Initial Reading	**1 Week**	**2 Weeks**	**3 Weeks**	**4 Weeks**
2200 in:					
MEK	130	130	134	142	147
80/20 Toluene MEK	252	250	246	270	278
50/50 Toluene MEK	192	192	196	204	222
20/80 Toluene MEK	134	132	138	152	152
Monochlorobenzene	976	950	932	968	962
2-nitropropane	684	650	634	690	690
2700 in:					
MEK	229	285	290	296	296
80/20 Toluene MEK	409	480	490	496	492
50/50 Toluene MEK	312	360	384	398	398
20/80 Toluene MEK	249	292	302	298	315
Monochlorobenzene	1840	1895	1970	1985	1985
2-nitropropane	1480	1268	1275	1290	1310
3200 in:					
Toluene	936	938	942	950	950
MEK	378	380	380	380	380
80/20 Toluene MEK	718	712	720	724	730
50/50 Toluene MEK	560	556	556	560	560
20/80 Toluene MEK	440	446	446	450	450
Monochlorobenzene	2775	2760	2780	2780	2800
2-nitropropane	1705	1705	1735	1754	1735
Ethyl Acetate	770	774	780	790	800

*All viscosities were run with a Brookfield Viscometer (model RVF) at 20 RPM in units of cP.

VITEL resins are available for purchase in various solvent solutions.

COMPATIBILITY

It is unusual for a single resin to offer both optimum performance and economy. Therefore, modification with other resins must often be considered. The VITEL resins, by themselves, offer extreme versatility in balancing performance properties. VITEL 2200 and 2700 resins provide hard abrasion resistant coatings which can be modified with VITEL 3200, 3300, or 3550 to increase flexibility and enhance coating adhesion. On the other hand VITEL 3200, 3300, or 3550 can be modified with VITEL 2200 or 2700 to reduce blocking and increase cohesive strength.

Despite the versatility of VITEL resins, there are many applications where modification with other types of resins is desirable. VITEL resins are compatible with vinyl chloride/vinyl acetate copolymers nitrocellulose, epoxy resins, sucrose benzoate, polyketones, and many other types of resin modifiers. They are generally incompatible with acrylic and alkyd resins. Table 8 lists the advantages and disadvantages of some of the more common types of polymers used to modify VITEL resins. A general list of resin modifiers is included in Table 9.

TABLE 8 - GENERAL MODIFIER SELECTION

Modifier Type	Typical Advantages	Typical Disadvantages
Nitrocellulose	Improves solvent release, maintains mar resistance, improves spray leveling, improves heat resistance.	Poor UV aging, low solids
Sucrose Benzoate	Water white extender, good UV properties, increases spray solids, imparts leveling, improves heat resistance	Impairs flexibility and mar resistance
Epoxies	Improve adhesion	Impairs flexibility
Vinyl Chloride/Vinyl Acetate Copolymers	Heat sealability, improves chemical resistance and perchloroethylene resistance, improves adhesion to vinyl substrates.	Poor aging, poor spraying qualities, reduce adhesion to polyester film
Isocyanate Resin	Cross-linking agents, increase hardness and solvent resistance and increase adhesion	Short-term pot life, poor color stability with non-aliphatic isocyanates
Polyketone Resins	Adhesion	Poorer water resistance and flexibility
Chlorinated Rubber	Improves solvent release, improves spray solids and leveling, improves heat resistance, good chemical resistance.	Poor aging, brittle, impairs adhesion
Glycerol Tribenzoate	Improves adhesion, reduces zipper effect and lowers heat activation temperature	Poor compatibility, and loss of film strength at excessive levels of modification

TABLE 9 – MODIFER COMPATIBILITY WITH VITEL® POLYESTER RESINS

Modifier	Chemical Type	2200				2700				3200				3300				3550				Supplier
		% Modification by Weight																				
		10	20	50	75	10	20	50	75	10	20	50	75	10	20	50	75	10	20	50	75	
Cellolyn® 21	Abitol alcohol ester	SH	SH	I	I	C	SH	I	I	C	C	C	I	C	C	C	SH	C	C	SH	I	Eastman Chemical
Cymel® 301	Melamine	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	--	C	C	C	--	Cytec Ind.
EPON® 828	Epoxy	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	--	C	C	C	--	Resolution Performance
EPON® 1001	Epoxy	C	C	C	SH	C	C	C	SH	C	C	C	C	C	C	C	C	C	C	C	C	Resolution Performance
EPON® 1007	Epoxy	SH	I	I	I	SH	I	I	I	SH	I	I	I	C	C	I	I	C	C	C	C	Resolution Performance
Foral® 105	Rosin ester	SH	I	I	I	C	C	I	I	C	C	SH	I	C	C	SH	I	C	C	SH	C	Hercules
Krumbhaar® K-1717B	Polyketone	C	C	SH	I	C	C	SH	I	C	C	C	C	C	C	C	C	C	C	C	I	Eastman Chemical
Mondur® CB-75	Isocynate	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	--	C	C	C	--	Bayer
Nitrocellulose® RS 1/4 sec.	Cellulose nitrate	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	Aqualon
QR-336®	Triazine formaldehyde	C	SH	I	I	C	SH	I	I	C	C	SH	I	C	C	SH	I	C	C	SH	C	ICI America
SR-82M®	Silicone resin	C	C	I	I	C	C	I	I	C	C	I	I									General Electric
Sucrose Benzoate		C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	Velsicol Chemical
Vinylite® VAGH	Vinyl chloride-copolymer	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	Dow Chemical
Vinylite® VMCH; VMCC	Vinyl chloride-copolymer	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	Dow Chemical
Vinylite® VYHH	Vinyl chloride-copolymer	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	Dow Chemical
Benzoflex® S-404	Trimethylolethane tribenzoate	C	C	C	--	C	C	C	--	C	C	C	--	C	C	C	--	C	C	C	--	Velsicol Chemical
Acryloid® B-66	Acrylic	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Rohm & Haas
Butvar® B-90	Polyvinyl butyral	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Solutia
Ethyl® Cellulose N-7		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Aqualon
Half Second Butyrate	Cellulose acetate butyrate	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	SH	I	I	I	Eastman Chemical
Hypalon® 20	Chlorosulfonated rubber	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Du Pont
Pliolite® S-5	Styrene butadiene	SH	I	I	I	SH	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Goodyear Chemicals
Pliolite® AC	Styrene acrylate	SH	SH	I	I	SH	I	I	I	SH	I	I	I	I	I	I	I	I	I	I	I	Goodyear Chemicals
Polyvinyl/ Acetate AYAT		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Talas
Versamid® 940	Polyamide	I	I	I	I	I	I	I	I	SH	SH	I	I	I	I	I	I	I	I	I	I	Cognis
Wing Tack® 95	Hydrocarbon	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	Goodyear Chemicals

C: Compatible I: Incompatible SH: Slightly Hazy

Although VITEL 3200, 3300, and 3550 resins may be used as plasticizers for VITEL 2200 and 2700, there are many instances where more economical plasticizers are desirable. A few plasticizers and their level of compatibility with VITEL 2200 and 2700 resins are listed in Table 10. In general, commercial polymeric PVC type plasticizers are not compatible with VITEL resins.

TABLE 10 – PLASTICIZER COMPATIBILITY FOR VITEL® 2200 AND 2700

Trade Name	Chemical Name	% Modification				Supplier
		10	20	30	40	
Dibutyl Phthalate	- - -	C	C	C	C	Eastman Chemical
Dibutyl Sebacate	- - -	C	I	I	I	Eastman Chemical
Ketjenflex 8	n-Ethyl o-p-Toluene Sulfonamide	C	C	C	C	Akzo Chemical
Santicizer 154	Paratertiary Butyl Phenyl Diphenyl Phosphate	C	C	C	C	Ferro
Santicizer 141	Alkyl Aryl Phosphate	C	C	C	C	Ferro
Santicizer 160	Butyl Benzyl Phthalate	C	C	C	C	Ferro
Tricresyl Phosphate	- - -	C	C	C	C	Ferro
CP-40®	Chlorinated paraffin	C	C	I	I	Diamond Alkali
Dioctyl Phthalate	- - -	C	I	I	I	Eastman Chemical
NP-12®	Neopentyl Glycol Derivative	I	I	I	I	Eastman Chemical
Paraplex® G-60	Polymeric	I	I	I	I	C. P. Hall Co.
Paraplex® G-62	Polymeric	I	I	I	I	C. P. Hall Co.

C: Compatible   I: Incompatible

FORMULATING AND COMPOUNDING

Since this handbook deals principally with property performances of the VITEL solution grade copolyester resins, specific formulations for individual applications will not be covered. However, compounding techniques developed by our Technical Resource Group are worthy of mention. It is felt that these recommendations help alleviate some of the problems associated with saturated polyester compositions deposited from solvent systems.

1. Accelerating Solvent Release

Generally a coating formulator will choose a primary solvent to achieve resin solubility. Diluents are often added to control speed and reduce cost of the system. Primary solvents have a distinct disadvantage in that the polymer will often have some difficulty releasing the last fragments of this solvent. Tack or poor block resistance results. Where conditions permit, it is recommended that the formulator investigate the use of non-solvent blends to achieve resin solubility. Typically, blends of toluene/isopropanol (as outlined in Table 6) or xylene/ethylene glycol monomethyl ether will effect faster drying speed than systems based on comparable primary solvents.

Resinous modifications found useful to overcome solvent release problems with the VITEL copolyester resins include nitrocellulose, chlorinated rubber and compatible low molecular weight resins with high thermal softening points. It is felt that these modifiers are less influenced by small percentage of residual solvents and therefore mask this influence.

2. Reducing Coating Tack

Where insufficient block resistance is not the result of retained solvent, several tools are available to the compounder to over come this deficiency. Exclusive of printing application methods where small increases in viscosity are not tolerable, isocyanate modification of the VITEL polymers is the preferred method to achieve higher softening point of the coating. This is demonstrated by the data in Table 11 where the flow melt temperature for a very soft polyester is dramatically increased through the use of Mondur® CB-75. Generally, 5-8% isocyanate is recommended, however, where small changes in polymeric thermal properties are required, lower levels should be considered. If cross-linking is undesirable, then use of nitrocellulose, chlorinated rubber or high softening point resin derivatives at low levels (10% or less) will aid in improving the coating's upper-tack point. Care should be exercised to fully determine what effects these additives have on the final adhesion of the coating particularly where PET film is employed.

TABLE 11 – VITEL® 3550 SOFTENING POINT VS. ISOCYANATE MODIFICATION

% Mondur CB-75	Softening Point °F
0	205
4	Discolors 405; very soft 420
8	Discolors 415
12	Discolors 420
16	Discolors 415-420

3. Improving Adhesion

While the VITEL copolyester resins as a family demonstrate very good adhesion to most plastic and metal surfaces, certain additional benefits can be realized with specific additives. In gravure printing systems based on VITEL 2200 or 2700 where high pigmentation is necessary for hiding color strength, the high molecular weights of these resins detract from pigment wetting and good adhesion development. Plasticizing resins or modifying polymers (such as Vitel 3300 and 3550) have been found suitable in overcoming these deficiencies.

When VITEL copolyester resins are used in metal decoration, the coating formulator will find modification with an epoxy Novolac resin (e.g. EPON DPS 155) extremely beneficial for thermoplastic systems. If thermosetting coatings are desired, then appropriate modification of the VITEL copolyester component with aliphatic or cycloaliphatic epoxy and Cymel 303 will yield a tough coating with good draw characteristics. Because VITEL resins are high in molecular weight, terminal hydroxyl curing sites are quite low. Therefore curing agents that self-condense or react with moisture are the most effective in producing thermoset or "cured" properties.

High peel strength laminating adhesives are generally based on VITEL 3550 resin, particularly when PET, PVC, treated polyolefin film or aluminum foil are to be joined. Superior adhesion is developed to most substrates because of the resin's ability to completely wet the film's surface. This is directly related to polymeric composition which utilizes a high content of aliphatic acid. However, this component also internally plasticizes the resin to a high degree thus lowering its shear strength, creep resistance and thermal properties. Isocyanate modification is useful in offsetting these aspects. It may be advantageous in certain instances to start with an adhesive resin with higher modulus properties. VITEL 3300 would be the resin of choice for these applications. Lamination studies with VITEL 3300, however, indicate lower peel strength values which in almost all cases evaluated are related to the polymer's zipper type release under load. An improvement in peel values can be realized when VITEL 3300 resin is appropriately modified with Vitel 3550.

Isocyanate modification is beneficial in developing the ultimate bond strength when treated polypropylene is joined to another flexible substrate. Although this mechanism is not entirely understood, some form of chemical bonding may occur between the treated surface and isocyanate modifier.

4. Varying Adhesive Activation

By appropriate blending of VITEL resins with large differences in glass transition temperature, a formulator has the tools available to him to control the heat seal temperature of a coating or adhesive. With the addition of VITEL 3550 to the product, extremely low temperature activating systems are possible. This technique is possible because of the high inter-family compatibility of Bostik's VITEL copolyester resins. (See Table 12) Careful consideration of these compounding techniques will prove extremely useful if application problems with VITEL copolyester resins arise.

TABLE 12 – COMPATIBILITY OF VITEL® RESINS WITH EACH OTHER

Modifier	Chemical Type	2200				2700				3200				3300				3550			
		% Modification by Weight																			
		10	20	50	75	10	20	50	75	10	20	50	75	10	20	50	75	10	20	50	75
2200	Copolyester	--	--	--	--	C	C	C	C	C	C	I	C	C	C	C	C	C	C	C	C
2700	Copolyester	C	C	C	C	--	--	--	--	C	C	C	C	C	C	C	C	C	C	C	C
3200	Copolyester	C	C	I	C	C	C	C	C	--	--	--	--	C	C	C	C	C	C	C	C
3300	Copolyester	C	C	C	C	C	C	C	C	C	C	C	C	--	--	--	--	C	C	C	C
3550	Copolyester	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	--	--	--	--

C: Compatible I: Incompatible

ADHESION

Whether a resin is used as a coating or an adhesive, to function properly and provide long-term performance, it is necessary to obtain a strong bond with the substrate to which it is being applied. VITEL copolyester resins exhibit superior adhesion to a variety of substrates such as Mylar, Melinex, and Hostaphan polyester films, polyethersulfone films, aluminum and copper foils, vinyl, metals, nylon, cellulose acetate, ABS films, polycarbonate and treated polypropylene.

The selection of a particular VITEL resin depends upon the type of substrate, the degree of adhesion and abrasion resistance desired, and the blocking requirements, if any. The more resinous polymers, VITEL 2200 and 2700 resins, are used primarily in coating applications where superior abrasion and block resistance and adequate adhesion are required. Although these resins have inherently high cohesive strength, their ability to sufficiently wet solvent insensitive substrates, such as polyester films, is limited by their resinous nature. Adhesion under these conditions can be significantly improved by plasticizing the VITEL 2000 series based coatings with VITEL 3200, 3300, or 3550 to enhance their wetting properties.

The inherent tack and good wetting properties of VITEL 3200, 3300, 3350, 3550, and 3650 resins are extremely important when compounding an adhesive for laminating applications. It is often desirable to modify these five resins with VITEL 2700 or an isocyanate to enhance cohesive strength, and increase chemical and block-resistant properties. It is evident that the VITEL resins offer a high degree of versatility in optimizing abrasion, block, and chemical resistance with adhesion for ultimate coating and adhesive performance.

The VITEL copolyester resins are designed to solve a variety of adhesion and coating problems. A common method of forming laminates with the VITEL resins is to first coat the substrates, evaporate the solvent, and then produce a bond by heat reactivation. The heat must be accompanied by pressure for a short period of time. Lower activation temperatures may be used if VITEL 3550 or 3650 is used as the adhesive rather than the other VITEL resins.

Adhesion is one of the most difficult properties to accurately quantify. In coating applications, empirical tests such as “Scotch” tape pull and substrate flexing are used to determine the relative degree of coating adhesion. In adhesion applications, peel and lap shear strengths can be measured to evaluate adhesion under a given set of conditions. In general, VITEL 3200, 3300, 3350, 3550, and 3650 resins are recommended for adhesive applications; however, where high cohesive strengths are desirable, such as laminating vinyl to vinyl, VITEL 2200 or 2700 may be more suitable. The more crystalline polymers, 7962 and 7908, are used where chemical resistance and toughness are required.

CURING

Although the VITEL resins are completely saturated linear polymers with very low hydroxyl numbers (2.0-6.0 mg KOH/g of VITEL), cross-linking or curing with an isocyanate is possible. Significant improvement in hardness, solvent and chemical resistance, as well as heat resistance, will occur with isocyanate modification. There is a slight sacrifice in flexibility. The level of isocyanate modification used depends upon the degree of cure required.

The weight average molecular weights are 18M-33M, which makes the equivalent number average equal to 9M-16M. At this equivalent weight only about 2.2 pphr of Mondur CB-75 or 2.4 pphr of Boscodur 21 is required for complete reaction with the available OH groups. Mondur CB-75 is a triisocyanate with an NCO equivalent weight of 311. Boscodur 21 is a trifunctional isocyanate with an equivalent weight of

385. The aforementioned curatives are polyisocyanates which have beneficial crosslinking effects, yielding a more thermoset characteristic.

Most customers use 3–10 pphr of the triisocyanate (active basis) in high performance laminating adhesives. This results in a moisture cure urethane reaction in which the NCO in excess of the stoichiometric quantity reacts first with moisture in the air, and then with the products of the moisture reaction, yielding a cured, substituted urea network.

The moisture cure reaction with triisocyanates normally requires several days at normal temperature and relative humidity to go to completion. The rate of the crosslink reaction is highly dependent upon the percent relative humidity in which the laminate (in roll form) is stored shortly after the laminate is produced. Quality assurance testing before the completion of the moisture cure reaction will often yield less than expected properties. The VITEL resins will normally absorb about 0.3% moisture at ambient temperature and 50% Relative Humidity (RH). For normal resin storage this much moisture is carried into the adhesive/coating system at the time of dissolving. This moisture and the variables inherent in the process can cause the reaction after the second adhesive component (reactive polyisocyante) is added, which results in viscosity drift and eventual gelation.

Figure 7 show the effect of adding an isocyanate curative (PAPI 2027) to VITEL 3200. As the amount of curative increases, the elongation at break decreases and the tensile strength increases. Figure 8 shows the effect of different levels of Boscodur 21 curative on the ultimate tensile strength of VITEL 3200. Obviously the level used is important. However, one can also see that it requires about a week to reach the ultimate cure strength.

FIGURE 7 – EFFECT OF ISOCYANATE CURE WITH VITEL® 3200

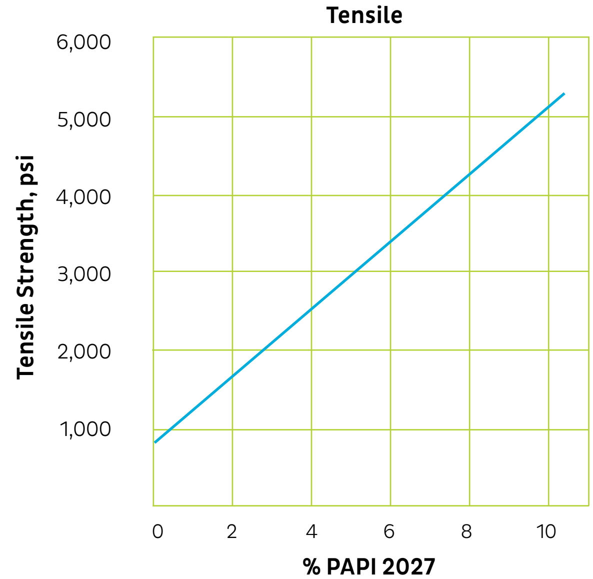
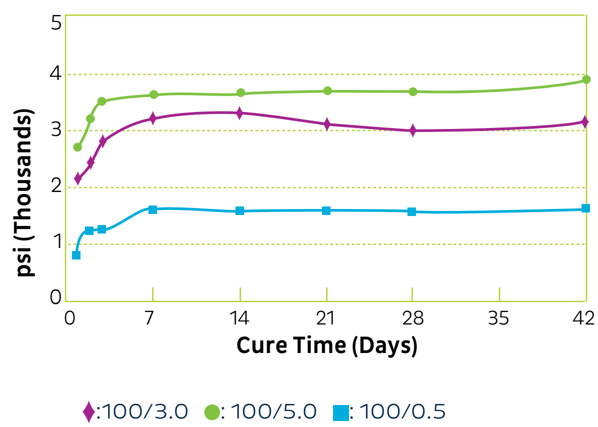


FIGURE 8 – TENSILE AT BREAK OF VITEL® 3200 (WITH BOSCODUR 21)



In general, difunctional isocyanates do not produce the crosslinked network and bond strength in polyester copolymer resins provided by the triisocyanates. Instead, the diisocyanates primarily only produce chain extension.

Selection of the proper isocyanates depends on the balance of properties desired. Table 13 lists curatives provided by Bostik and their properties. Moreover, a formula is provided under Table 13 to calculate the amount of isocyanate to add to the Vitel system. The formula will calculate amounts based on a 1:1 NCO:OH ratio. For most applications, it is recommended to increase the NCO:OH ratio slightly to account for moisture in the adhesive system.

In general, urethane grade solvents should be specified in any formula containing crosslinking agents. Moisture in the finished adhesive should be controlled.

In the previous section on formulating and compounding VITEL resins, the use of isocyanates was recommended when high softening point coatings are necessary. Table 11 demonstrates this concept specifically for VITEL 3550 resin and Mondur CB-75. The solvent resistance of VITEL resins can be enhanced by curing with isocyanate. This technique has been particularly useful in applications where dry cleanability or resistance to perchloroethylene are important. The effect of isocyanate curing of VITEL 2700 and 3200 resin coatings with various levels of isocyanates is demonstrated in Tables 14 and 15. One mil dry films were applied to phosphated steel Q panels, allowed to air dry for one hour, and then baked at 300°F for five minutes. The panels were then immersed in toluene and perchloroethylene baths.

TABLE 13 – COREACTANTS FOR VITEL® RESINS

Crosslinker Correctant	% Solids	Spec. Grav.	Solvent	NCO Type	% NCO	UV Stability	Cure Rate	FDA 175.105
Boscodur 21	70	1.13	Ethyl Acetate	MDI	10.9	Poor	Fast	Listed
Boscodur 16	70	1.07	Ethyl Acetate	IPDI	12.0	Excellent	Very Slow	Listed
Boscodur 1621	70	1.1	Ethyl Acetate	MDI/IPDI	11.5	Medium	Medium	Listed

Grams of Isocyanate per 100 grams of adhesive for 1:1 Molecular Ratio NCO/OH

$$\frac{\text{GMS(solid) Polymer x Functionality (Aced+Hydroxyl) x Molecular Wt. NCO(42)}}{\text{56100(Equivalents of KOH) x \% NCO Content in Boscodur Coreactant}}$$

TABLE 14 – SOLVENT RESISTANCE OF VITEL® 2700 AND 3200 FILMS WITH VARIOUS LEVELS OF ISOCYANATE CURES

Resistance to Toluene:	2700					3200				
	Hours Immersed					Hours Immersed				
Isocyanate Modification	**0.5**	**1**	**2**	**5**	**24**	**0.5**	**1**	**2**	**5**	**24**
Control	0	--	--	--	--	0	--	--	--	--
1% Mondur CB-75	1	1	0	--	--	0	--	--	--	--
3% Mondur CB-75	1	1	1	0	--	1	1	1	1	1
5% Mondur CB-75	1	1	1	1	0	2	2	2	2	2
1% PAPI 2027	1	1	0	--	--	1	1	0	--	--
3% PAPI 2027	2	1	1	0	--	3	3	3	3	3
5% PAPI 2027	2	2	1	1	1	4	4	4	4	4

Rating Code
5 Excellent – no apparent physical effect on coating
4 Good – slight softening of coating
3 Fair Good – perceptible solvent attack
2 Fair – moderate solvent damage to film
1 Poor – excessive solvent damage to film
0 Coating removed – dissolved

TABLE 15 - RESISTANCE TO PERCHLOROETHYLENE										
Resistance to Toluene:	**2700**					**3200**				
	Hours Immersed					**Hours Immersed**				
Isocyanate Modification	**0.5**	**1**	**2**	**5**	**24**	**0.5**	**1**	**2**	**5**	**24**
Control	2	2	2	1-2	1-2	1	1	1	1	0-1
1% Mondur CB-75	2	2	2	1-2	1-2	2	2	2	1	0-1
3% Mondur CB-75	3	3	3	2	2	3	3	3	3	2-3
5% Mondur CB-75	4	4	4	3	3	4	4	4	4	3
1% PAPI 2027	3	2	2	1-2	1-2	3	3	2	2	1
3% PAPI 2027	4	4	3	3	3	4	4	3	3	2
5% PAPI 2027	4	4	4	4	4	4	4	4	4	3

Rating Code
5 Excellent – no apparent physical effect on coating
4 Good – slight softening of coating
3 Fair Good – perceptible solvent attack
2 Fair – moderate solvent damage to film
1 Poor – excessive solvent damage to film
0 Coating removed – dissolved

HOT MELT PROPERTIES

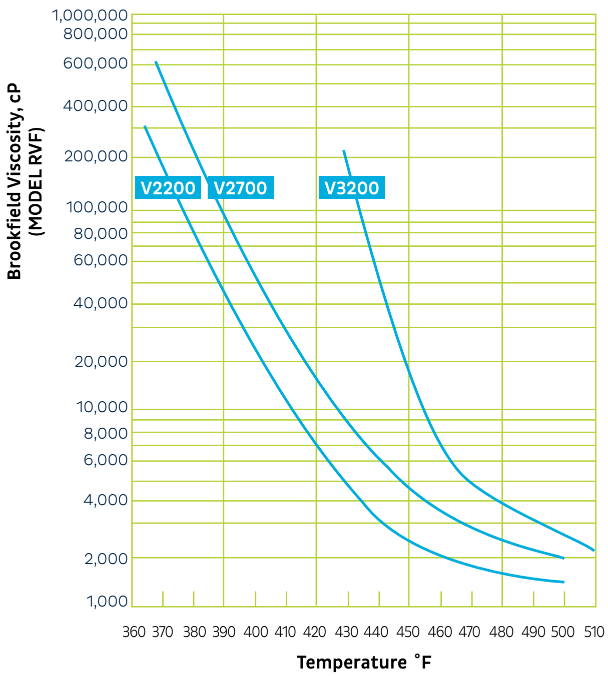
Although designed for solution use, the VITEL resins are also used in hot melt systems as the principal adhesive or in combination with other ingredients for a wide range of applications. These would include laminating operations, packaging, metal and plastic construction, and fabric bonding. Melt viscosities obtained for the resins without stabilization, indicate that the effective operating range is 400 to 500 °F.

The heat stability of VITEL copolyester resins 2200, 2700, and 3200 is quite good without the addition of stabilizer. This property allows adequate time for processing through constant feed hot melt equipment without evidence of degradation. However, a recycle system employing a high temperature reservoir necessitates the use of stabilizer with these resins.

Agerite Geltrol® (an organic phosphite) is recommended at a level of 0.1 phr polyester. Agerite Geltrol is effective in preventing hydrolytic degradation of polyesters, due to the heat used and presence of moisture— both in the air and in trace quantities in the polyester itself. However, polyesters may also degrade by oxidation at elevated temperatures. The use of 0.1 phr of a hindered phenol stabilizer antioxidant is indicated to help prevent this oxidative degradation. Optimum results are obtained when the organic phosphite and hindered phenol are used together. Melt viscosities for the VITEL resins are shown in Figure 9.

For optimum results it is recommended that the VITEL coating resins be applied through an extrusion coating or coextrusion method similar to the VITEL 1000 series. This includes drying in-line and feeding the resin with moisture levels not exceeding 0.05%. High moisture levels will facilitate the degradation of the polymer at the high temperatures and disrupt their final application performance.

FIGURE 9 – MELT VISCOSITY OF VITEL® 2200, 2700, 3200 AND 3350



ELECTRICAL PROPERTIES

Polyesters as a class are well known for their dielectric strength. VITEL resins exhibit this desired property to a high degree. Because of their superior ratings in this area, the VITEL copolyester resins find use in electrical applications such as coatings for magnetic wire and as laminating adhesives to bond PET films to copper in printed circuits and other sophisticated electrical insulation composites. Figure 10 demonstrates the electrical properties of VITEL 3200.

FIGURE 10 – VITEL® 3200 ELECTRICAL PROPERTIES

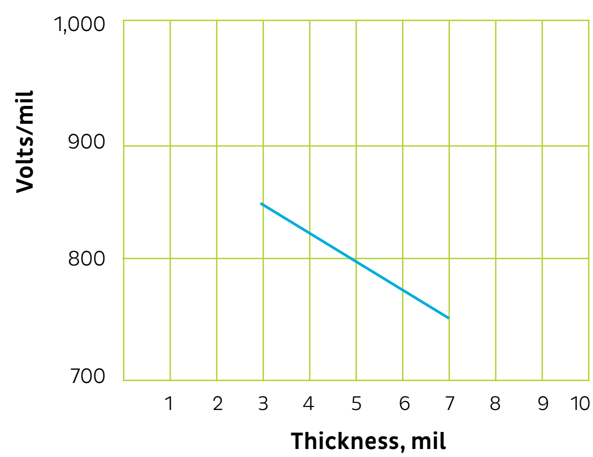


TABLE 16 – VITEL SELECTORY GUIDE

	Morphology	Glass Transition, Tg (°C)	Melt Flow (°C)	Melt Point, Tm (°C)	Intrinsic Viscosity (dl/g)	Acid Number	Hydroxyl Number	Shore Hardness	Tensile Strength (psi)	Elongation (%)	Refractrive Index	CIElab L* (min)	CIElab b* (max)	Specific Gravity	Molecular Weight, Mw	Acetates [1]	Ketones [2]	Aromatics [3]	Specialty Solvents [4]	Graphic Arts/Ink Binders	Heat Seal Films	Electrical Laminations	Can Coatings	Over Lacquer	Primer Coatings	Food Contact Compliant*	Film Adhesion
Extrusion Resins																											
V1200B	A	70	150	NA	0.59	1-3	3-6	80D	11,000	5	1.57	90	5		43,000				⊙	✓	✓	✓				✓	a,c
V1801	SC	-20	112	NA	0.98	0-2	1-3	25D	1,060	1,600		90	10	1.22	96,000	●	◗		⊙		✓	✓				✓	a, b, c, d
V1901NSB	SC	-4	143	150	0.92	0-2	1-3	35D	800	60		90	10	1.23	79,000				⊙		✓	✓				✓	a, c
V1912NSB	SC	-2	145	150	0.84	0-2	1-3					90	12	1.23	72,000				⊙		✓					✓	a, c
V1916NSB	SC	-2	145	150	0.84	0-2	1-3					70	20	1.30	72,000				⊙		✓					✓	a, c
Coating Resins																											
V2100B	A	66	150	NA	0.59	1-3	3-5					92	38	1.27			●	●		✓	✓			✓	✓		a, b
V2200B	A	69	155	NA	0.59	1-3	3-5	79D	9,600	7	1.55	95	10	1.27	47,500	●	●	●		✓	✓		✓	✓	✓	✓	a, b
V2700B	A	50	142	NA	0.74	1-2	2-5	78D	6,500	3	1.56	90	15	1.25	67,000	●	●	●		✓	✓			✓	✓	✓	a, b, c
V2700BLMW	A	50		NA	0.58	1-2	2-5	78D				90	15	1.25	50,000	●	●	●		✓	✓			✓	✓	✓	a, b, c
Laminating Resins																											
V3200B	A	15	129	NA	0.78	0-2	3-6	67A	400	800		95	25	1.16	63,500	●	●	●	●				✓			✓	a, b, c, d
V3300B	A	16	125	NA	0.80	0-2	3-6	67A	500	800	1.54	95	30	1.22	63,000	●	●	●	●				✓				a, b, c, d
V3350B	A	16	125	NA	0.80	0-2	3-6				1.54	95	30	1.22		●	●	●	●				✓				a, b, c, d
V3550B	A	-11	99	NA	0.85	0-2	3-6	25A	30	2,000	1.53	95	30	1.22	75,000	●	●	●	●								a, b, c, d
KP7915	SC	-15	100	85	0.72	<2.3	3-6	65A	370	<1,000				1.21	44,000		●	●	●								a, b, c
KP7962	SC	-5	110	100	0.77	1-2	2-6	82A	2,500	700				1.24	55,000		◗	◗	●			✓					a, b, c, d
Modifying Resin																											
V5833B	A	48	99	--	0.17	0-2	37-55						10	1.18	9,800	●	●	●	●								a, b, c

● - Soluble up to 40% solids
◗ - Requires cosolvent MEK: Toluene 50:50 up to 21% solids
⊙ - Soluble at low solids (~15-20%)
* - Regulations vary by substrate and contry; extraction limits may apply
A - Amorphous
SC - Semi-crystalline

1 - Ethyl acetate, butyl acetate
2 - Acetone, methyl ethyl ketone, methyl propyl ketone
3 - Toluene, xylene
4 - Tetrahydrofuran, 1,3 dioxolane, formaldehyde

a - PET
b - Vinyl Adhesion (PVC, PVF)
c - Metal Adhesion (Aluminum, Copper, SS)
d - Olefin Adhesion (Treated <38 dynes)

INDEX OF TABLES

INDEX OF FIGURES

Notes:

Smart help:
1-800-726-7845

Bostik, Inc.
11320 W Watertown Plank Road, Wauwatosa, WI 53226
800-7-BOSTIK
www.bostik-us.com

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