

## Polyurethane Specialty Products Group

# VERSALINK™

## Oligomeric Diamines in Two-Component Adhesives

Tables 3A-D show preliminary overlap shear data for unformulated systems processed with liquid MDI and MDI prepolymers. All metal surfaces were primed and the adhesive mixtures were prepared with 10% excess isocyanate. Bondlines for metal substrates were at 5 mils. All nonmetal substrates were bonded with adhesive mixtures prepared with 5% excess isocyanate. Bondlines for plastic substrates were at 10 mils. Wood and neoprene bondlines were at 0 mils.

As shown in Table 3A, the time to handle the substrates is reasonable in all cases. Working time varies depending on the particular combination of Versalink oligometric diamine and isocyanate, and with the specific isocyanates used. In Tables 3A-D, the working time varies from 2-75 minutes.

TABLE 3A -- VERSALINK/ISONATE® 2143L IN A TWO-PACK ADHESIVE OVERLAP SHEAR (PSI)			
	VERSALINK P-250	VERSALINK P-650	VERSALINK P-1000
Working Time @ Room Temp., min	2	15	25
Handling Time, min	2-3	35-40	25-30
Overlap Shear Strength, psi			
Aluminum	2900 (P)	2720 (A/P)	1790 (A/P)
Cold Rolled Steel	3440 (P)	2345 (A/P)	1430 (A/P)
Polycarbonate	—	660 (A)	705 (A)
PVC	—	460 (A)	420 (A)
Neoprene	—	> 200 (S)	> 200 (S)
Plywood	880 (A/S)	> 1000 (S)	900 (A/S)
Fiberglass	—	> 800 (S)	> 800 (S)
Glass	—	765 (A)	720 (A/S)
Epoxy-Graphite	—	1425 (A)	—
Polyethylene	—	95 (A)	95 (A)
Polypropylene	—	70 (A)	80 (A)

TABLE 3B -- VERSALINK/RUBINATE® LF-179 IN A TWO-PACK ADHESIVE OVERLAP SHEAR (PSI)			
	VERSALINK P-250	VERSALINK P-650	VERSALINK P-1000
Working Time @ Room Temp., min	2	15	25
Overlap Shear Strength, psi			
Aluminum	3900 (P)	3340 (A/P)	1910 (A/P)
Cold Rolled Steel	3290 (P)	2560 (A/P)	1500 (S)
Polycarbonate	—	520 (A)	620 (A)
PVC	—	545 (A)	445 (A)
Neoprene	—	> 200 (S)	> 200 (S)
Plywood	455 (A/S)	> 835 (S)	905 (A)
Fiberglass	—	> 800 (S)	> 800 (S)
Glass	—	> 1000 (S)	345 (A)
Epoxy-Graphite	—	1420 (A)	—
Polyethylene	—	100 (A)	100 (A)
Polypropylene	—	80 (A)	90 (A)

Overlap shear bonds were tested on inch-wide test specimens.

**Failure Mode**

S - Substrate Failure  
 A - Adhesive Failure  
 P - Primer Failure

In Tables 3A-D, the data for Versalink P-650 and P-100 oligomeric diamines is based on curing the adhesive at room temperature. To achieve optimum properties using Versalink P-250 oligomeric diamine, the adhesive system is mixed and set at room temperature followed by a two-hour post-cure at 93 °C.

The overlap shear for a particular substrate can be optimized by using blends of Versalink oligomeric diamines, by optimization of the primer, and by varying the system's stoichiometry.

In addition to the substrates that are listed, good adhesion has been achieved with ABS, polyester, acrylic, vinyl fabric and rubber.

TABLE 3C - VERSALINK/RUBINATE PBA-2234 IN A TWO-PACK ADHESIVE OVERLAP SHEAR (PSI)			
	VERSALINK P-250	VERSALINK P-650	VERSALINK P-1000
Working Time @ Room Temp., min	5	25	50
Overlap Shear Strength, psi			
Aluminum	4250 (A)	1260 (A/P)	1010 (A/P)
Cold Rolled Steel	3440 (S)	1545 (A/P)	1290 (A/P)
Polycarbonate	340 (A)	280 (A)	465 (A)
PVC	315 (A)	355 (A)	360 (A)
Neoprene	> 200 (S)	> 200 (S)	> 200 (S)
Plywood	825 (A/S)	600 (A)	485 (A)
Fiberglass	610 (A)	540 (A)	535 (A)
Glass	400 (S)	700 (A)	840 (A/S)
Epoxy-Graphite	—	660 (A)	—
Polyethylene	50 (A)	130 (A)	105 (A)
Polypropylene	80 (A)	90 (A)	80 (A)

TABLE 3D - VERSALINK/RUBINATE PBA-2257 IN A TWO-PACK ADHESIVE OVERLAP SHEAR (PSI)			
	VERSALINK P-250	VERSALINK P-650	VERSALINK P-1000
Working Time @ Room Temp., min	3	20	35
Overlap Shear Strength, psi			
Aluminum	2285 (P)	2145 (A/P)	1445 (A/P)
Cold Rolled Steel	3030 (P)	2310 (A/P)	1335 (A/P)
Polycarbonate	160 (A)	270 (A)	465 (A)
PVC	—	430 (A)	415 (A)
Neoprene	—	> 200 (S)	> 200 (S)
Plywood	680 (A/S)	> 1000 (S)	855 (A/S)
Fiberglass	495 (A)	> 800 (S)	> 800 (S)
Glass	—	830 (A)	385 (A)
Epoxy-Graphite	—	1120 (A)	—
Polyethylene	—	95 (A)	95 (A)
Polypropylene	—	70 (A)	80 (A)

Overlap shear bonds were tested on inch-wide test specimens.

**Failure Mode**  
 S - Substrate Failure  
 A - Adhesive Failure  
 P - Primer Failure

Table 3E provides preliminary information on the peel strengths obtainable in Versalink oligomeric diamine-based adhesives. Both TDI and MDI system properties are shown for a number of different substrates. The results illustrate that Versalink oligomeric diamine adhesives give excellent peel strengths, and in some cases, the adhesive outperformed the substrate.

## Cured Polyurethane-to-Metal Adhesives

Excellent polyurethane-to-metal bonds can be obtained when liquid polyurethane is molded directly onto metal and cured at elevated temperatures. However, in some cases where field repair or room-temperature processing is required, it may be necessary to bond already cured polyurethane to metal. Air Products has found that a Versalink oligomeric diamine/MDI system produces an adhesive that is ideal for this type of situation. Table 3F exhibits the utility of Versalink oligomeric diamine/liquid MDI adhesives for fastening cured polyurethane elastomers to metal.

The data in Table 3F shows the peel strengths of both stiff (Shore 70D) and pliable (Shore 80A) elastomers bonded to cold, rolled steel. To determine the peel strengths, strips of MOCA-cured polyurethane were adhered at right angles to a 1" x 3" strip of metal. The cold, rolled steel was grit blasted, immersed in TCE, and then primed with Chemlok 213 before use. For the polyurethane elastomers, care was taken to insure that all traces of mold release had been removed. The Versalink oligomeric diamine/Isonate 2143L adhesives were formulated at room temperature and were applied to the primed metal coupon at a bondline of 10 mils. Peel strengths were taken after the specimens were cured for 1 week at 21 °C and 50% RH.

	VERSALINK P-250/ AIRETHANE® PET-75D	VERSALINK P-650/ ISONATE 2143L	VERSALINK P-1000/ ISONATE 2143L
Working Life, min	2-5	15	25
Cure Temp.	21 °C (70 °F)	21 °C (70 °F)	21 °C (70 °F)
<b>Substrates</b>			
Rubber	21-30 (A)	28-32 (S)	24-31 (S)
Aluminum	12-15 (A)	20-30 (A)	19-26 (A)
Neoprene	20-36 (S)	17-35 (S)	18-23 (S)
SBR	19-26 (S)	21-26 (S)	19-23 (S)
Glass	7-10 (A)	1 (A)	1 (A)
Etched Steel	—	24-34 (A)	31-40 (A)
Polycarbonate	—	> 40 (S)	> 50 (S)
Polyester Fiberglass	—	5-14 (A/P)	7-12 (A/P)

	HARDNESS	POLYURETHANE TYPE	VERSALINK P-650	VERSALINK P-1000
Working Life, min			15	25
Gel Time, min			25	40
<b>Peel Strength (PLI)</b>				
Airthane PET-70D Prepolymer	70D	Polyether	50 (P)	52 (P)
Airthane PET-80A Prepolymer	80A	Polyether	36 (S/P)	48 (P/S)
Versathane™ A-8 Prepolymer	80A	Polyester	49 (A)	52 (A)
Versathane D-7 Prepolymer	70D	Polyester	65 (P)	33 (P)

**Failure Mode**  
S - Substrate Failure  
A - Adhesive Failure  
P - Primer Failure

(PLI) - Pounds per linear inch

The predominant mode of failure with the stiff polyurethanes (Airthane PET-70D and Versathane D-7 prepolymers) occurred at the primer-metal interface, suggesting that primer optimization could possibly lead to even higher peel strengths. The soft polyether-based elastomers (Airthane PET-80A prepolymer) produced substrate failures while the soft polyester materials (Versathane A-8 prepolymer) gave adhesive failure at the polyurethane-Versalink oligomeric diamine interface. Where multiple failure modes were observed, the modes are reported in order of prevalence, with the most common mode reported first.

The best overall performance for the room-temperature-cured adhesives was obtained with a Versalink P-650 or a Versalink-1000 oligomeric diamine-based adhesive.

Table 3G provides data for Versalink oligomeric diamine/MDI adhesives that underwent a high-temperature cure. In order to speed up the curing process, these specimens were cured at 100 °C for 4 hours. The general effect of this high-temperature cure was to reduce peel strengths.

Overall, when cured under the appropriate conditions, the Versalink oligomeric diamine/MDI adhesives produced good-to-excellent peel strengths between properly cleaned and prepared substrates.

## Adhesives for Bonding Rubber to Rubber

Tables 3H and 3I exhibit the peel strengths obtainable between rubber substrates for Versalink oligomeric diamine/MDI-based adhesives. The data was obtained using various grades of Versalink oligomeric diamine formulated at a 90% stoichiometry with liquid MDI.

Before determining peel strengths, the rubber surfaces were washed with methanol to remove oil and organic contaminants. The clean parts were then placed in an oven at 100 °C for 15 minutes to dry. When they were dry, the parts were submerged in a solution of deionized water (97 pbw), bleach (3 pbw) and HCl (0.3 pbw) for a period of 3 minutes. The parts were brushed to remove surface bubbles and to wet all undercuts. They were then dried for 1 hour at 50 °C and were used immediately afterwards.

TABLE 3G - VERSALINK/ISONATE 2143L IN A TWO-COMPONENT ADHESIVE POLYURETHANE ELASTOMER BONDED TO STEEL HIGH-TEMPERATURE CURE (100 °C)				
	HARDNESS	POLYURETHANE TYPE	VERSALINK P-650	VERSALINK P-1000
Working Life, min			15	25
Gel Time, min			25	40
<b>Peel Strength (PLI)</b>				
Airthane PET-70D Prepolymer	70D	Polyether	48 (P)	43 (P)
Airthane PET-80A Prepolymer	80A	Polyether	26 (A/S/P)	23 (P/S)
Versathane A-8 Prepolymer	80A	Polyester	25 (A)	33 (A/P)
Versathane D-7 Prepolymer	70D	Polyester	48 (P/A)	54 (P)

Substrate Primer - Chemlok 213 (Lord Corp.)

TABLE 3H - VERSALINK/ISONATE 2143L IN A TWO-COMPONENT ADHESIVE RUBBER BONDED TO RUBBER ROOM-TEMPERATURE CURE (21 °C)		
	VERSALINK P-650	VERSALINK P-1000
Working Life, min	15	25
Gel Time, min	25	40
<b>Peel Strength (PLI)</b>		
Maximum	134	134
Average	97	97
Failure Mode	(S)	(A/S)

Failure Mode  
A - Adhesive Failure  
P - Primer Failure  
S - Substrate Failure

(PLI) - Pounds per linear inch

To adhere the substrates, an 8" x 8" rubber plaque was placed on a flat surface and a 4" x 8" area was masked by stapling a sheet of polyethylene to the plaque. The Versalink-based adhesive was then applied to the unmasked area and was covered with the second rubber plaque. To insure proper contact between the two substrates, a piece of plate glass (or another flat, rigid material), followed by two 750-gram weights placed at the corners, was added. The weights and the glass were removed after one hour. The specimens were then subjected to an ambient or high-temperature cure.

The peel strengths obtained for the specimens that were post-cured at 21 °C for one week are displayed in Table 3H. The adhesives were based on either Versalink P-650 or Versalink P-1000 oligomeric diamine and Isonate 2143L, which is pure, liquid MDI. The predominant mode of failure found in both cases occurred in or at the substrate, thus illustrating the excellent adhesion properties of Versalink oligomeric diamines.

For the high-temperature-cured systems, the specimens were post-cured at 100 °C for 16 hours and were not flexed or cut for another 8 hours. The results provided in Table 3I suggest that the Versalink P-650 oligomeric diamine-based adhesive offers the best properties in high-temperature-cured systems.

In general, the Versalink oligomeric diamine/MDI adhesives produced excellent peel strengths between rubber substrates, especially for room-temperature-processed systems. In fact, at ambient temperature, the majority of failures occurred in the substrate, showing that the adhesive's strength exceeds that of the rubber. Through the addition of fillers and by optimizing surface preparation, it may be possible to improve peel strengths even further.

## Effect of Filler Content

The effect of filler content on Versalink oligomeric diamine/MDI adhesives is illustrated in Table 3J. The systems were filled with either calcium carbonate or talc ranging from 10-25% by weight. In all the systems investigated, lap shear strengths improved when compared with the unfilled system.

	VERSALINK P-650	VERSALINK P-1000
Working Life, min	15	25
Gel Time, min	25	40
<b>Peel Strength (PLI)</b>		
Maximum	82	70
Average	72	49
Failure Mode	(A/S)	(A)

**Failure Mode**  
 S - Substrate Failure  
 A - Adhesive Failure  
 C - Cohesive Failure

(PLI) - Pounds per linear inch

	VERSALINK P-650/ ISONATE 2143I	VERSALINK P-650/ RUBINATE PBA-2234	VERSALINK P-1000/ ISONATE 2143L
Substrate	Aluminum	Aluminum	Polycarbonate
Unfilled	1020	650	720
10% CaCO <sub>3</sub>	1220	680	810
25% CaCO <sub>3</sub>	1360	820	760
10% Talc	1300	650	760
25% Talc	1140	680	980

## Safety and Handling Information

For all safety and handling information, please refer to the Versalink oligomeric diamine Material Safety Data Sheets, available upon request from Air Products.

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