

INTRODUCTION

SCOPE

A starting point formulation based on Essential Industries' polymer R4370, a solvent-free, urethane/acrylic hybrid was used to evaluate the enhanced performance properties when used in a trimer 2K system and compared to the following commercially available polymers:

Hybridur 870 Polymer Dispersion - A NMP-free, low solvent, urethane/acrylic hybrid polymer dispersion.

Hybridur 878 – A NMP-free, low solvent, aliphatic, urethane/acrylic hybrid polymer dispersion.

Witcobond A-100 – A solvent-free polyurethane /polyacrylate alloy.

The starting point formulations used for the competitive set were as provided by the manufacturer.

Various performance properties were evaluated for each polymer in a 1K system versus a trimer 2K system. The tests performed were; chemical resistance, mar resistance, Konig hardness, Taber Abrasion, metal adhesion, wood adhesion, impact resistance, and MEK double rub.

PROPERTIES

Physical Properties of Polymers

Property	R4370	Hybridur 870	Hybridur 878	Witcobond A-100
Solids, Wt %	35	40	40	35
pH	7.5	7.5 - 9.0	7.5 -9.0	7.0 - 9.0
Viscosity (Brookfield), cps @ 25°C	<50	<150	<150	<100
VOC (g/L minus water)	51	30	24	33.5
Solvent Content	-	<0.2	<0.1	-
Acid Number	25	16	14.5	18
Tensile Strength	3900	2525	4400	7200
% Elongation	50	279	>32	140

Physical Properties of Starting Point Formulations

Property	R4370	Hybridur 870	Hybridur 878	Witcobond A-100
Solids, Wt %	28.0	36.3	30.9	28.8
VOC (g/L minus water)	238	220	301	242

STARTING POINT FORMULATION

4370

Raw Material	% by Weight	Process Instructions
R4370	82.02	
DPnB	2.36	Add very slowly to the polymer
Premix the Following:		
Water	12.98	
DPM	2.36	
Zonyl FSO	0.08	
BYK 028	0.1	Add premix slowly to blend
BYK 346	0.1	
Total	100	

SUPPLIERS FOR STARTING POINT FORMULATION

RAW MATERIAL	SUPPLIER	FUNCTION
BYK ®-028	BYK Chemie	Defoamer
Dowanol® DPM	The Dow Chemical Company	Co-solvent
Dowanol® DPnB	The Dow Chemical Company	Co-solvent
Zonyl® FSO	DuPont™	Wetting Agent

PERFORMANCE TESTING

All performance tests were run at 73°F +/-3°F and 28% +/-10% relative humidity. Tests were run on cross-linked and uncross-linked films cast from each of the polymer floor coating starting point formulations. The films were cross-linked at room temperature using a trimer. The trimer 2K system of each polymer system was prepared by adding 4.8g of trimer to 100g of coating product. The trimer is 90% aliphatic polyisocyanate and 10% DMM glycol diether. The films were allowed to cure for 7 days.

Cross-linking R4370 improves chemical resistance significantly, as shown in the included chemical resistance and methyl ethyl ketone (MEK) double rub test results. The chemical resistance test results show that by cross-linking the R4370, the alcohol stain and film resistance is greatly improved. Also noteworthy, is the improvement of the ammonia resistance of R4370 when cross-linked. Pencil hardness and film thickness of the R4370 2K system, after the MEK double rub, is equal to or better than that of the competitive set. Overall, the chemical resistance of the R4370 in a 2K system performs similarly or better

than the competitive set while maintaining a lower VOC level than two of the competitor's formulas tested.

Cross-linking also provides for additional benefits in improved abrasion resistance and better impact strength. Test results show that the abrasion resistance can be more than doubled when using a 2K system of R4370 and impact strength can be increased to the best rating. When comparing the R4370 2K system to the competitive set in Taber Abrasion, wood and metal adhesion and impact resistance combined; it outperforms the competitive set by obtaining the highest performance rating in every one of those tests.

Overall, the trimer 2K system of R4370 exhibits outstanding performance characteristics when compared to other polymers within the competitive set, with better abrasion resistance, Konig hardness, pencil hardness after MEK double rub, impact resistance, and metal and wood adhesion; and maintains comparable chemical resistance and mar resistance to the competitive set.

KONIG HARDNESS

Konig hardness was measured for uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on aluminum plates using a 28 gauge wire draw down bar producing a wet film thickness of 2.8 mils. Films were tested at the time intervals indicated, beginning directly after film application. A BYK Gardner Pendulum Hardness Tester was used and results are measured in seconds. A higher result indicates a harder film. Results show that a slightly softer film is typically developed when using a trimer 2K system.

Konig Hardness Development of Polymer 1K Systems vs. Trimer 2K Systems

Time Elapsed	R4370 Uncross-linked	R4370 Cross-linked	Hybridur 870	Hybridur 870 Cross-linked	Hybridur 878	Hybridur 878 Cross-linked	Witcobond A-100	Witcobond A-100 Cross-linked
1 Hour	41	40	35	27	33	24	31	24
2 Hours	53	52	46	31	38	27	42	30
3 Hours	73	66	51	37	45	37	47	37
4 Hours	76	73	59	39	58	44	56	44
5 Hours	76	77	60	40	73	52	63	46
1 Day	105	107	81	65	116	112	112	102
2 Days	105	108	83	72	115	115	118	108
3 Days	107	119	86	84	118	115	114	114
1 Week	107	115	86	94	112	111	122	114

CHEMICAL RESISTANCE

Chemical resistance was tested on the uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on birch wood panels using three coats of finish, applied with a lamb's wool applicator. The films were allowed to cure for 7 days. The first set of results indicates the level of staining and the second set shows finish softening. A higher score indicates greater damage to the film.

Chemical Resistance of 1K Systems vs. 2K Systems

Chemical	R4370 Uncross- linked	R4370 Cross- Linked	870 Uncross- linked	870 Cross- linked	878 Uncross- linked	878 Cross- linked	A-100 Uncross- linked	A-100 Cross- linked
50% Ethanol	2,5	0,2	3,5	2,3	1,5	1,1	3,4	1,2
70% IPA	1,5	1,3	0,5	2,4	2,5	1,1	1,4	1,1
Formula 409	3,4	1,1	2,1	1,2	1,0	0,0	2,3	1,0
10% Ammonia	3,2	3,0	5,3	3,2	4,1	2,0	4,2	3,0
10% HCL	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0
10% NaOH	0,0	0,0	1,1	0,1	0,0	0,1	0,0	0,0
10% Sulfuric Acid	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5% Bleach	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0
Vinegar	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Insect Repellent (100% DEET)	0,4	0,2	0,4	0,5	0,4	0,0	0,4	0,1
Yellow Mustard	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Sun Block SPF 45	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Subtotals	10,20	7,8	13,20	9,18	9,15	5,3	11,17	7,4
Total	30	15	33	27	24	8	28	11

Scale: 0 = Best, No Effect, 5 = Worst, Coating Destroyed

MAR RESISTANCE

Mar resistance was tested on the uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on birch wood panels using three coats of finish, applied with a lamb's wool applicator. The films were allowed to cure for 7 days. The panels were then attached to a modified Snell Capsule filled with leather blocks for 4 hours. The panels were inspected for degree of marring and rated in poor, fair, good, or excellent condition. The cross-linked films prove to have superior mar resistance to the uncross-linked films.

Mar Resistance of 1K Systems vs. Trimer 2K Systems

System	Mar Resistance
R4370 Uncross-linked	Poor
R4370 Cross-linked w/Trimer	Excellent
Hybridur 870 Uncross-linked	Poor
Hybridur 870 Cross-linked w/Trimer	Excellent
Hybridur 878 Uncross-linked	Excellent
Hybridur 878 Cross-linked w/Trimer	Excellent
Witcobond A-100 Uncross-linked	Poor
Witcobond A-100 Cross-linked w/Trimer	Excellent

TABER ABRASION

Taber Abrasion was measured for uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on aluminum plates using a 28 gauge wire draw down bar producing a wet film thickness of 2.8 mils. Films were allowed to cure for 7 days. Taber Abrasion was tested on each film using ASTM method D 4060. Calibrase abrasive wheels No. CS-17 were used with 1000g load on the wheels for 500 cycles. Abrasion is reported in the loss in weight in milligrams. Abrasion is dramatically reduced when cross-linked with trimer.

Taber Abrasion of 1K Systems vs. Trimer 2K Systems

System	Taber Abrasion (mg loss)
R4370 Uncross-linked	18.0
R4370 Cross-linked w/Trimer	8.4
Hybridur 870 Uncross-linked	21.7
Hybridur 870 Cross-linked w/Trimer	14.2
Hybridur 878 Uncross-linked	11.9
Hybridur 878 Cross-linked w/Trimer	11.7
Witcobond A-100 Uncross-linked	14.1
Witcobond A-100 Cross-linked w/Trimer	10.0

METAL ADHESION

Metal adhesion was tested on the uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on aluminum plates using a 28 gauge wire draw down bar producing a wet film thickness of 2.8 mils. The films were allowed to cure for 7 days. The metal adhesion test was performed using ASTM method D 3359.

Metal Adhesion of 1K Systems vs. Trimer 2K Systems

System	Adhesion Rating
R4370 Uncross-linked	5B
R4370 Cross-linked w/Trimer	5B
Hybridur 870 Uncross-linked	5B
Hybridur 870 Cross-linked w/Trimer	5B
Hybridur 878 Uncross-linked	4B
Hybridur 878 Cross-linked w/Trimer	3B
Witcobond A-100 Uncross-linked	5B
Witcobond A-100 Cross-linked w/Trimer	5B

Scale: 5B = Best, No Film Removal, 0B = Worst, Complete Film Removal

WOOD ADHESION

Wood adhesion was tested on the uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on birch wood panels using three coats of finish, applied with a lamb's wool applicator. The films were allowed to cure for 7 days. The wood adhesion test was performed using ASTM method D 3359.

Wood Adhesion of 1K Systems vs. Trimer 2K Systems

System	Adhesion Rating
R4370 Uncross-linked	5B
R4370 Cross-linked w/Trimer	5B
Hybridur 870 Uncross-linked	5B
Hybridur 870 Cross-linked w/Trimer	5B
Hybridur 878 Uncross-linked	3B
Hybridur 878 Cross-linked w/Trimer	4B
Witcobond A-100 Uncross-linked	5B
Witcobond A-100 Cross-linked w/Trimer	4B

Scale: 5B = Best, No Film Removal, 0B = Worst, Complete Film Removal

IMPACT RESISTANCE

Impact resistance was tested on the uncross-linked systems and their corresponding trimer cross-linked systems. Films were cast on aluminum plates using a 28 gauge wire draw down bar producing a wet film thickness of 2.8 mils. The films were allowed to cure for 7 days. The reverse impact (film side down) was measured for each film using a Gardner Impact Tester. Impact forces of 160 inch-lbs, 140 inch-lbs, 120 inch-lbs, 100 inch-lbs, 80 inch-lbs, 60 inch-lbs, 40 inch-lbs, 20 inch-lbs were tested on each panel. The impact force result indicates the force by which the film maintained its integrity.

Impact Resistance of 1K Systems vs. Trimer 2K Systems

System	Reverse Impact Resistance Rating
R4370 Uncross-linked	20
R4370 Cross-Linked w/Trimer	160
Hybridur 870 Uncross-linked	160
Hybridur 870 Cross-linked w/Trimer	160
Hybridur 878 Uncross-linked	80*
Hybridur 878 Cross-linked w/Trimer	80*
Witcobond A-100 Uncross-linked	0
Witcobond A-100 Cross-linked w/Trimer	80

*** Film showed signs of stress by becoming discolored. The film maintained structural integrity up to 80 inch-lbs of force but discoloration was detected at every level of impact force from 160 inch-lbs down to 20 inch-lbs.**

MEK DOUBLE RUB

MEK Double Rub was tested on the uncross-linked systems and their corresponding trimer cross-linked systems to show the film resistance to a strong solvent. Films were cast on aluminum plates using a 28 gauge wire draw down bar producing a wet film thickness of 2.8 mils. The films were allowed to cure for 7 days. The MEK Double Rub test was performed using ASTM method D 5402 with 25 double rubs performed.

MEK Double Rub on 1K Systems vs. Trimer 2K Systems

System	Film Thickness Prior to Rub (mils)	Film Thickness After Rub	Gloss Reading Prior to Rub	Gloss Reading After Rub	Pencil Hardness Prior to Rub	Pencil Hardness After Rub
R4370 Uncross-linked	0.38	0.01	255	322	6H	No Film
R4370 Cross-linked	0.36	0.38	253	265	4H	B
Hybridur 870 Uncross-linked	0.52	0.50	260	260	B	3B
Hybridur 870 Cross-linked	0.49	0.45	279	292	B	3B
Hybridur 878 Uncross-linked	0.38	0.49	224	225	6H	B
Hybridur 878 Cross-linked	0.40	0.43	251	271	B	3B
Witcobond A-100 Uncross-linked	0.45	0.29	258	200	2H	B
Witcobond A-100 Cross-linked	0.33	0.32	276	277	4H	B

* Film thickness has an error in measurement of +/-1% of the reading + 0.16mils.

** Gloss of an uncoated metal panel is 495, thus higher gloss rating after rub is resultant of complete film removal and lower gloss rating after rub is indicative of the white film residue left behind as film is being removed.

*** Pencil hardness scale, as tested, from softer to harder is: 6B-5B-4B-3B-B-2H-3H-4H-5H-6H.