Epoxy Curing Agents and Modifiers

ANCAMIDE® 2353 Curing Agent

DESCRIPTION

Ancamide 2353 curing agent is a high-performance modified polyamide intended for use with epoxy resins in two-part ambient cure coatings. Special features of this product include fast dry, good cure at low temperatures and good resistance to solvents.

BENEFITS

- Fast dry time
- Good cure at 40°F
- High solvent resistance
- Good corrosion resistance
- High gloss finish
- Excellent development of hardness
- DOT noncorrosive
- Zero induction time at ambient temperature
- Good adhesion to damp concrete
- Moderate viscosity

APPLICATIONS

- High-solids marine and maintenance coatings
- Concrete primers, coatings and bonding agents
- Adhesives

SHELF LIFE

At least 24 months from the date of manufacture in the original sealed container at ambient temperature. Store away from excessive heat and humidity in tightly closed containers.

STORAGE AND HANDLING

Refer to the Safety Data Sheet for Ancamide 2353 curing agent.

TYPICAL CURE SCHEDULE

2-7 days at ambient temperature.

TABLE 1: TYPICAL PROPERTIES

Appearance	Slightly Turbid Amber Liquid
Color[1] (Gardner)	9
Viscosity[2] @ 77°F (cP)	3,000
Amine Value[3] (mg KOH/g)	330
Specific Gravity[4] @ 77°F	1.01
Density[4] (lb/gal)	8.45
Flash Point[5] (°F)	>200
Equivalent Wt/{H}	114
Recommended Use Level, phr	
(EEW=190)	60
(EEW=500)	23

TABLE 2: TYPICAL HANDLING PROPERTIES*

Mixed Viscosity[2] (cP)	5,800
Gel Time[6] (150 g mix) (min)	65
Thin Film Set Time[7] @ 77°F (h)	4.5
Thin Film Set Time[7] @ 40°F (h)	20
Peak Exotherm[8] (100 g mass) °F	300
Peak Exotherm Time[8] (min)	65

TABLE 3: TYPICAL PERFORMANCE*

Glass Transition Temp[9] (°F)	131
Compressive Strength[10] @ Yield (psi)	14,300
Compressive Modulus[10] (thousand psi)	388
Tensile Strength[11] (psi)	9,800
Tensile Modulus[11] (thousand psi)	403
Tensile Elongation[11] (%)	6.7
Flexural Strength[12] (psi)	16,300
Flexural Modulus[12] (thousand psi)	516
Hardness[13] (Shore D)	80
Adhesion to Damp Concrete[14] (psi):	
7 DAY CURE @ 72°F	300
7 DAY CURE @ 40°F	250

* Ancamide 2353 curing agent formulated with standard Bisphenol-A based (DGEBA, EEW=190) epoxy resin.

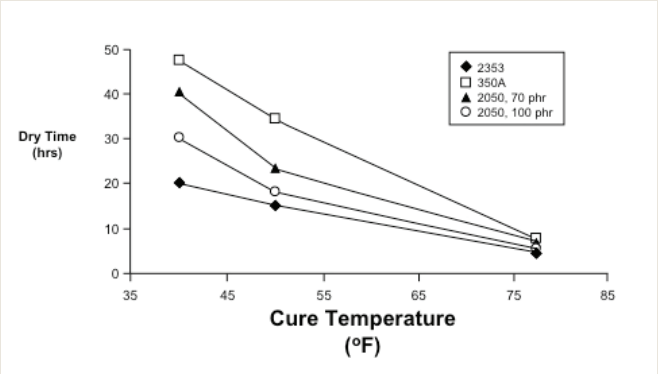
NOTE: Please see last page for footnotes

SUPPLEMENTARY DATA

FAST DRY TIME: As shown in Figure 1, the thin film dry time of Ancamide 2353 curing agent with liquid epoxy resin is significantly faster than Ancamide 2050 and Ancamide 350A (a conventional polyamide) curing agents. In dry time tests at room temperature, the thin film set time was reduced to 4.5 hours from 7 hours and 11 hours, respectively. At 40°F, the thin film set time was reduced from 46 hours for Ancamide 350A and 30-40 hours for Ancamide 2050, depending on use level, to 20 hours for Ancamide 2353. Ancamide 2353-based coatings can be recoated after overnight cure at 40°F.

Tables 9, 10, 11 and 12 contain preliminary formulations based on Ancamide 2353 curing agent for an anti-corrosive primer, an aluminized mastic and two white gloss enamels (one low-VOC formulation with liquid resin and one fast-dry formulation with solid resin). The dry-to-touch times for these formulations were all under 4.5 hours, with the primer formulation being only 1 hour.

FIGURE 1:
COMPARATIVE DRY TIMES

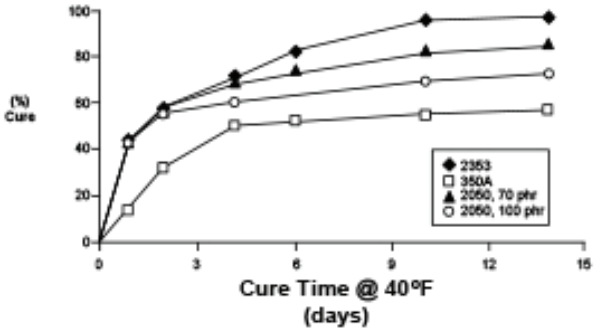


NOTE: Set to touch times were measured by a BK dry time recorder.

LOW TEMPERATURE PERFORMANCE: Ancamide 2353 curing agent is designed to cure at temperatures as low as 40°F when used with liquid epoxy resins. It produces hard, high-gloss coatings which are highly resistant to amine blush even when cured at low temperature and high humidity.

Figure 2 compares the cure development of Ancamide 2353, Ancamide 2050 and Ancamide 350A curing agents at 40°F. Both Ancamide 2353 and Ancamide 2050 curing agents have a faster and more complete cure than the conventional polyamide, even when the conventional polyamide is accelerated with Ancamine K54 curative. The superior cure is most evident in the first 3 days of cure at 40°F, when rapid property development is needed most. Although Ancamide 2353 and Ancamide 2050 curing agents both show very good cure rate and degree of cure at 40°F, Ancamide 2353 possesses the best balance of degree of cure and glass transition temperature, which is necessary for good coating performance.

FIGURE 2:
40°F CURE TIMES



NOTE: % Cure was measured by DSC.

CORROSION RESISTANCE: Formulations developed for an aluminized epoxy mastic and an inhibitive metal primer based on Ancamide 2353 are detailed in Tables 9 and 10. These formulations were evaluated for salt spray resistance after 1000 hours of exposure, and the results are shown in Table 1. Both formulations showed very good performance.

TABLE 1:
SALT SPRAY RESISTANCE – ANCAMIDE 2353

	General Corrosion	Scribe Corrosion	Field Blistering	Blister Size
Aluminum Mastic	10	6-7	8	8
Red Primer	10	8-9	8-9	7-8

NOTE: 5% salt spray, cabinet temperature 95°F — ASTM B-117, film thickness 2.5 mils. Rating: 10 = Best, 0 = Worst.

ADHESION

STEEL SUBSTRATE: The Ancamide 2353-based primer and aluminum mastic formulations were evaluated per ASTM D-4541, Pull-Off Adhesion Test, for adhesion to heavy, hot rolled steel. Panels were blasted to an SSPC-SP 5 white metal quality with a mil profile of 3.0 mils. Greater than 450 psi was required for each formulation to cause failure, and all failures occurred in the adhesive. No cohesive failure in the coatings nor adhesive failure at any interface was observed. Both formulations showed good results.

TABLE 2:
HUMIDITY EXPOSURE – ANCAMIDE 2353

	General Corrosion	Blistering Degree	Blister Size
Aluminum Mastic	10	10	10
Red Primer	10	10	10

NOTE: Continuous 100% Humidity Exposure — ASTM D-2247, cabinet temperature 122°F, film thickness 2.5 mils. Rating: 10 = Best, 0 = Worst

CONCRETE: Ancamide 2353 curing agent was tested for adhesion to damp concrete using dolly pull-off tests in accordance with ASTM D-4541. Samples were prepared by immersing blocks of ASTM C109 cement mortar in water for 24 hours. The blocks were then removed from the water, the excess water was wiped from the surface, and formulated epoxy was applied immediately.

As shown in Table 3, Ancamide 2353 curing agent provides excellent adhesion to damp concrete even when used in conjunction with a diluted epoxy resin at 40°F. By comparison, Ancamide 350A curing agent exhibits poor adhesion to concrete when cured at low temperatures or when used with diluted epoxy resin. Ancamine K54 curing agent is ineffective at improving the adhesion of Ancamide 350A to damp concrete.

TABLE 3:
ADHESION TO DAMP CONCRETE

Curing Agent	Epoxy Resin	Tensile Pull Off (psi) 72°F Cure	Failure Mode	Tensile Pull Off (psi) 40°F Cure	Failure Mode
Ancamide 2353	DGEBA*	300	Surface	250	Surface
	90% DGEBA* 10% Epodil® 748*	290	Mortar	Mortar	Mortar
Ancamide 350A	DGEBA*	210	Cohesive	60	Cohesive
	90% DGEBA* 10% Epodil 748*	60	Cohesive	50	Cohesive
95% Ancamide 350A 5% Ancamine K54	DGEBA*	200	Cohesive	60	Cohesive
	90% DGEBA* 10% Epodil 748*	40	Cohesive	40	Cohesive

DGEBA: Diglycidyl Ether of Bisphenol-A (EEW=190) Epodil 748: C12–14 Alkyl Glycidyl Ether

Surface Failure: Bond failure in the upper 10% of the mortar specimen
Mortar Failure: Bond failure in the lower 90% of the mortar sample
Cohesive Failure: Bond failure in the epoxy bond line

HANDLING PROPERTIES: Table 4 compares the handling properties of Ancamide 2353, Ancamide 2050 and Ancamide 350A curing agents. Ancamide 2353 has the lowest viscosity and zero induction time, resulting in easier handling than a conventional polyamide such as Ancamide 350A. Equivalent loading compared with Ancamide 350A allows Ancamide 2353 curing agent to be substituted into existing formulations with minimal modifications.

TABLE 4:
HANDLING PROPERTIES

	Ancamide 2353	Ancamide 350A	Ancamide 2050
Viscosity (cP)	3,000	11,000	4,000
Mixed Viscosity*	5,800	12,000	6,400
Pot Life (min)*	60	200	100
Tack-Free (h @ 72°F)*	4.5	11	7
Tack-Free (h @ 40°F)*	20	46	40

*Curing agents were mixed with liquid bis-A epoxy (EEW=190) at 60 phr for Ancamide 2353 and Ancamide 350A, and 70 phr for Ancamide 2050.

FILM PROPERTIES: Table 5 shows that the direct and reverse impact resistance levels for Ancamide 2353 are comparable to Ancamide 350A curing agent. Gloss is superior, while VOC content in a formulated paint can be at least maintained at the same level. Table 11 shows a white gloss enamel preliminary formulation based on liquid epoxy resin and Ancamide 2353 where the VOC has been reduced to 1.6 lb/gal.

TABLE 5:
FILM PROPERTIES

	Ancamide 2353	Ancamide 350A
VOC (LB/GAL)	2.3	2.3
Direct Impact (in/lb)	192	208
Reverse Impact (in/lb)	10	12
Gloss, 60°	100	90

NOTE: Pigmented formulations based on solid epoxy resin (EEW=325) were mixed with each curing agent, applied to cold rolled steel panels (S) (5 mil DFT) and cured for 7 days @ 72°F before testing.

Table 6 compares the hardness development of Ancamide 2353 and Ancamide 2050 curing agents with liquid bis-A resin at ambient temperature. Also shown are film appearance results under various conditions for both curing agents. Ancamide 2353-based films harden much more rapidly than those based on Ancamide 2050, and the Ancamide 2353-based films develop greater ultimate hardness.

TABLE 6:
HARDNESS DEVELOPMENT AND FILM APPEARANCE

	Ancamide 2353	Ancamide 2050
Hardness Development (pendulum)		
1 day	98	5
7 days	137	60
14 days	140	112
Film Appearance		
1 day, 77˚F, 50% RH	clear, tack-free	clear, tack-free
1 day, 50˚F, 90% RH	slight haze, tacky	haze, tacky
1 day, 40˚F, 80% RH	clear, tacky	clear, very tacky
7 days, 50˚F, 90% RH	slight haze, tacky	haze, tack-free
7 days, 40˚F, 80% RH	clear, tacky	clear, tacky

NOTE: Clear formulations with liquid epoxy resin (EEW=190)

Film appearance also favors Ancamide 2353 in low temperature/high humidity conditions. Both curing agents give clear, tack-free film appearance at ambient temperature and moderate humidity.

PHYSICAL PROPERTIES: Table 7 shows the superior physical properties of Ancamide 2353 curing agent compared with Ancamide 350A. The high tensile strength, flexural strength and Shore D hardness show that Ancamide 2353 curing agent produces harder, tougher, more resilient epoxy formulations than the conventional polyamide.

TABLE 7:
PHYSICAL PROPERTIES

	Ancamide 2353	Ancamide 350A
Tensile Strength (psi)	9,770	5,700
Flexural Strength (psi)	16,300	13,900
Compressive Strength (psi)	14,270	13,100
Shore D Hardness	80	75

NOTE: Curing agents were mixed with liquid epoxy (EEW-190) at 60 phr and cured for 7 days at 72°F before testing.

CHEMICAL RESISTANCE: Comparative chemical resistance levels for Ancamide 2353 and Ancamide 350A curing agents are shown in Table 8. Ancamide 2353 curing agent imparts significantly higher chemical resistance than Ancamide 350A curing agent, particularly to toluene. The conventional polyamide is destroyed after 3 days' immersion in toluene, while Ancamide 2353 curing agent is virtually unaffected after 28 days' immersion in toluene.

Ancamide 2353-based systems have higher resistance to ethanol, 10% acetic acid and 70% sulfuric acid, particularly as the immersion time increases. Resistance to 50% NaOH is comparable to the conventional polyamide.

TABLE 8:
COMPARATIVE CHEMICAL RESISTANCE[15]

		Weight Gain (%)	
Reagent	**Immesion Time (days)**	**Ancamide 2353**	**Ancamide 350A**
Toluene	1	0.0	13.7
	3	0.1	26.3
	7	0.3	Destroyed
	28	1.8	Destroyed
Ethanol	1	1.7	3.3
	3	3.0	4.7
	7	4.4	6.1
	28	8.5	10.4
10% HA_c	1	5.6	7.6
	3	9.7	13.9
	7	14.1	20.7
	28	25.1	36.8
70% H_2SO_4	1	0.2	0.3
	3	0.4	0.7
	7	0.7	1.6
	28	2.4	10.3
50% NaOH	1	0.0	0.0
	3	0.0	0.0
	7	0.0	0.0
	28	0.0	0.0

NOTE: Curing agents were mixed with liquid epoxy resin (EEW=190) at 60 phr and cured for 7 days at 72°F before immersion.

ANCAMIDE 2353 STARTING FORMULATIONS

TABLE 9: ANTICORROSIVE PRIMER PRELIMINARY FORMULATION

PART A	lb	gal
Liquid Epoxy Resin (Dow, Resolution)	233.7	24.093
MPA-1078 (Rheox)	4.0	0.541
Mix Well, Then Add At High Speed:		
Tipure R-900 (Dupont)	25.0	0.751
10 Wollastokup As (NYCO)	370.0	15.289
Disperse To 5 Hegman And 125°F. Reduce Speed And Add:		
Xylene	45.0	6.207
Totals	**677.7**	**46.860**
PART B	**lb**	**gal**
Ancamide 2353 (Evonik)	125.54	15.212
MPA-1078 (Rheox)	4.0	0.541
Beetle 216-8 (Cytec)	15.0	1.724
Mix Well At High Speed, Then Add:		
Red Iron Oxide J-3100 (Mineral Tech)	60.0	1.4411
Beaverwhite 325 (Cyprus)	96.7	4.204
Phosplus J-0866 (Mineral Tech)	141.4	5.065
Disperse to 5 Hegman and 125°F. Reduce speed and add:		
Diacetone Alcohol (Union Carbide)	31.3	3.997
Super High Flash Naphtha	106.8	14.691
Totals	**583.74**	**46.877**
Properties		
Volume Solids	71.8%	
PVC	39.7%	
CPVC	54.6%	
PVC/CPVC	.725	
Weight/gallon, Part A	14.45	
Weight/gallon, Part B	12.45	
Weight/gallon	13.45	
VOC	2.1 lb/gal	
Mixing Ratio	1:1 by Volume	
Pot Life, h	3	
Dry to Touch, h	1	
Dry Through, h	6	

TABLE 10: ALUMINUM MASTIC PRELIMINARY FORMULATION

PART A	lb	gal
Liquid Epoxy Resin	307.0	31.7
MPA-1078 (Rheox)	8.0	1.0
10 Wollastokup AS (NYCO)	250.0	10.3
Disperse to 6 Hegman and 130°F.		
Epodil LV5 (Evonik)	35.0	4.0
High Flash Naphtha	120.0	16.5
Beetle 216-8 (Cytec)	25.0	2.8
Lansford L243 (Silberline)	125.0	10.2
Diacetone Alcohol	24.0	3.0
Cabosil TS 720 (Cabot)	10.0	0.4
Totals	**904.0**	**80.0**
PART B	**lb**	**gal**
Ancamide 2353 (Evonik)	**169.0**	**20.0**
Properties		
Volume Solids	71.9%	
PVC	20.0%	
CPVC	47.1%	
PVC/CPVC	.426	
Weight/gallon, Part A	11.29	
Weight/gallon, Part B	8.45	
Weight/gallon	10.73	
VOC	< 2.5 lb/gal	
Mixing Ratio	4:1 by Volume	
Pot Life, h	5	
Dry to Touch, h	3	
Dry Through, h	7	

ANCAMIDE 2353 STARTING FORMULATIONS

TABLE 11: LOW-VOC WHITE GLOSS ENAMEL

PART A	lb	gal
Grind Base		
Liquid Epoxy Resin (Dow, Resolution)	352.76	36.43
Nuosperse 657 (Hüls America)	3.88	0.46
Byk 307 (BYK Chemie)	1.76	0.25
PM Solvent	48.68	6.32
TiPure R-960 (DuPont)	388.04	11.92
Let Down		
High Flash Naphtha	67.73	9.22
Methyl Propyl Ketone	14.11	2.09
Totals	**876.97**	**66.70**
PART B	**lb**	**gal**
Ancamide 2353 (Evonik)	212.03	23.96
n-Butanol	63.14	9.34
Totals	**275.17**	**33.30**
Properties		
Part A Viscosity	73 KU	
Part B Viscosity	64 KU	
Mixed Viscosity	70 KU	
PVC	17%	
Volume Solids	70%	
VOC, @ 70 KU	< 2.2 lb/gal	
Mix Ratio	2:1 by Volume	
Induction Time	0	
Pot Life, hr	2	
Dry Times		
Set to Touch, h	5	
Dust-Free, h	7	
Hard Dry	Overnight	
60º Gloss	102	

TABLE 12: FAST-DRYING WHITE GLOSS ENAMEL

PART A	lb	gal
Grind Base		
DER 660X80 (Dow)	472.55	51.47
Nuosperse 657 (Hüls America)	3.54	0.42
Beetle 216-8 (Cytec)	2.84	0.34
PM Solvent	47.26	6.20
TiPure R-960 (DuPont)	307.16	9.44
Let Down		
High Flash Naphtha	73.72	10.03
Methyl Propyl Ketone	14.18	2.10
Totals	**921.25**	**80.00**
PART B	**lb**	**gal**
Ancamide 2353 (Evonik)	131.44	14.86
n-Butanol	34.75	5.14
Totals	**166.22**	**20.00**
Properties		
Part A Viscosity	86 KU	
Part B Viscosity	64 KU	
Mixed Viscosity	80 KU	
PVC	15.2%	
Volume Solids	62.2%	
VOC, @ 70 KU	< 2.8 lb/gal	
Mix Ratio	4:1 by Volume	
Induction Time	0	
Pot Life, hr	3	
Dry Times		
Set to Touch, h	50	
Dust-Free, h	75	
Hard Dry	Overnight	
60º Gloss	104	

Footnotes:
(1) ASTM D 1544-80
(2) ASTM D 445-83, Brookfield, RVTD, Spindle 4
(3) Perchotic Acid Titration
(4) ASTM D 1475-85
(5) Seta Flash Closed Cup
(6) Techne GT-4 Gelation Timer
(7) BK Drying Recorder
(8) ASTM D 2471-71
(9) ASTM D3418-82
(10) ASTM D 695-85
(11) ASTM D 638-86
(12) ASTM D 790-86
(13) ASTM D 2240-86
(14) ASTM D 4547
(15) ASTM D 543-84

ANCAMIDE 2353 STARTING FORMULATIONS

TABLE 11: LOW-VOC WHITE GLOSS ENAMEL

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Byk 307 (BYK Chemie)	1.76	0.25
PM Solvent	48.68	6.32
TiPure R-960 (DuPont)	388.04	11.92
Let Down		
High Flash Naphtha	67.73	9.22
Methyl Propyl Ketone	14.11	2.09
Totals	**876.97**	**66.70**
PART B	**lb**	**gal**
Ancamide 2353 (Air Products)	212.03	23.96
n-Butanol	63.14	9.34
Totals	**275.17**	**33.30**
Properties		
Part A Viscosity	73 KU	
Part B Viscosity	64 KU	
Mixed Viscosity	70 KU	
PVC	17%	
Volume Solids	70%	
VOC, @ 70 KU	< 2.2 lb/gal	
Mix Ratio	2:1 by Volume	
Induction Time	0	
Pot Life, hr	2	
Dry Times		
Set to Touch, hr	5	
Dust-Free, hr	7	
Hard Dry	Overnight	
60º Gloss	102	

TABLE 12: FAST-DRYING WHITE GLOSS ENAMEL

PART A	lb	gal
Grind Base		
DER 660X80 (Dow)	472.55	51.47
Nuosperse 657 (Hüls America)	3.54	0.42
Beetle 216-8 (Cytec)	2.84	0.34
PM Solvent	47.26	6.20
TiPure R-960 (DuPont)	307.16	9.44
Let Down		
High Flash Naphtha	73.72	10.03
Methyl Propyl Ketone	14.18	2.10
Totals	**921.25**	**80.00**
PART B	**lb**	**gal**
Ancamide 2353 (Air Products)	131.44	14.86
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Totals	**166.22**	**20.00**
Properties		
Part A Viscosity	86 KU	
Part B Viscosity	64 KU	
Mixed Viscosity	80 KU	
PVC	15.2%	
Volume Solids	62.2%	
VOC, @ 70 KU	< 2.8 lb/gal	
Mix Ratio	4:1 by Volume	
Induction Time	0	
Pot Life, hr	3	
Dry Times		
Set to Touch, hr	50	
Dust-Free, hr	75	
Hard Dry	Overnight	
60º Gloss	104	

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