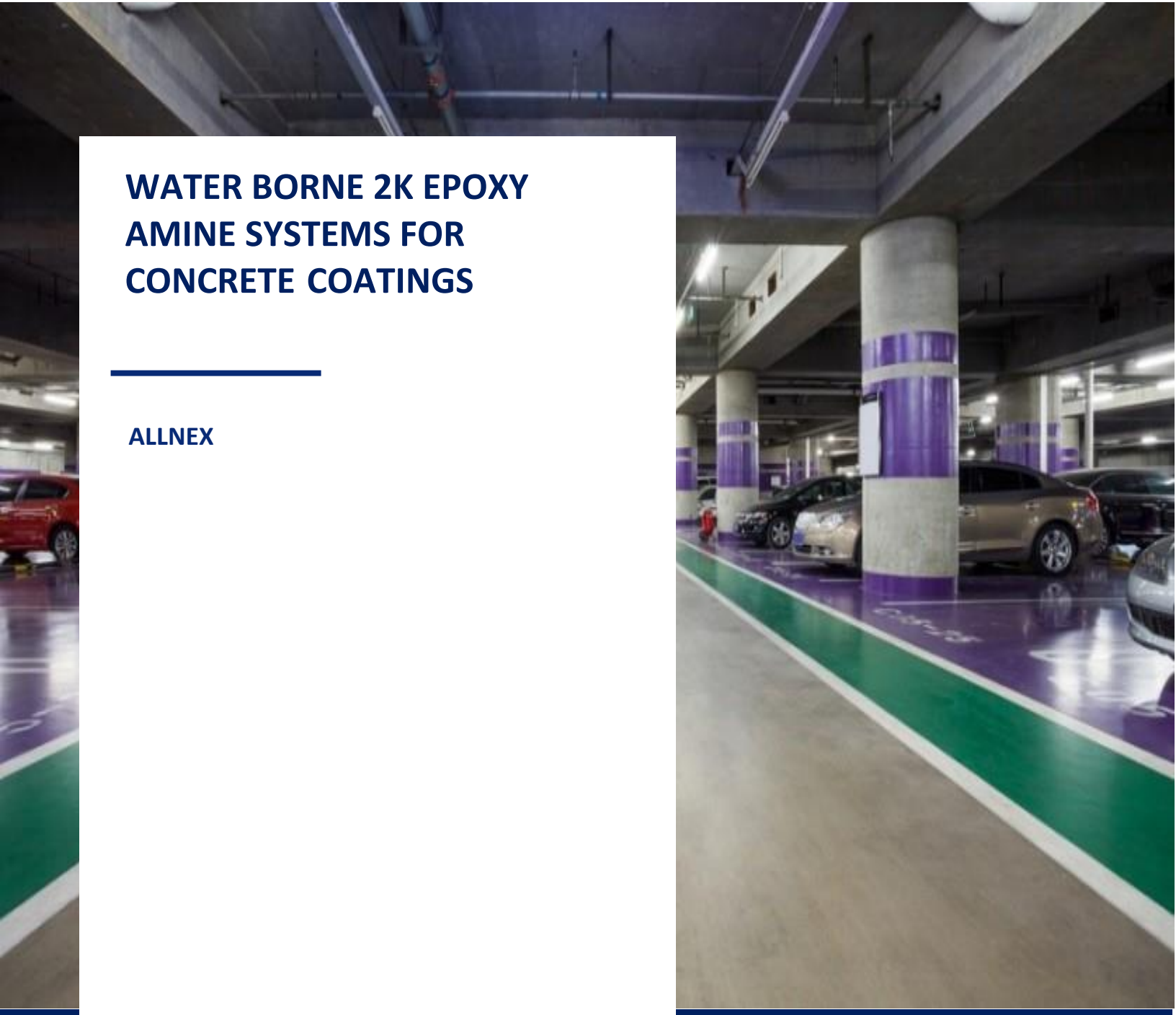

WATER BORNE 2K EPOXY AMINE SYSTEMS FOR CONCRETE COATINGS

ALLNEX

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allnex
The Coating Resins Company

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1. INTRODUCTION

Concrete is a key building material throughout the world for many structures. Even the best concrete has natural limitations, including dusty and weak surfaces, performance reduction over time due to reactions with materials in the environment, cracking, efflorescence and poor chemical resistance, to name but a few. Many of these limitations can be negated or at least improved through the use of a properly formulated coating. The most well-known coating technology for concrete is an epoxy-amine based, two component system, due to its inherent cross-linked chemical strength and compatibility with alkaline concrete. These systems seal in the dust, strengthen the surface, reduce cracking propagation, provide a chemical barrier to prevent degradation and staining and can also provide an aesthetically pleasing appearance.

Water content in the concrete tends to be a significant challenge for all epoxy-based systems. Too much water can cause poor initial adhesion or loss of adhesion over time in the form of osmotic blistering. Water borne systems are much more tolerant to water content in the substrate than solvent borne or 100% solids systems. They typically show less susceptibility to osmotic blistering, due to their open pore structure, and better adhesion to multiple types of concrete. Water borne systems are generally regarded as a more environmentally friendly option, with easier clean-up, reduced worker exposure hazards, lower odour and offering lower VOC (Volatile Organic Components) options.

Allnex provides water borne epoxy resins and amine hardeners that can be adapted to a variety of concrete coating applications. Emulsifiers are incorporated into the backbone of some of our polymers to prevent their migration from the coating, which could lead to adhesion problems and water or chemical sensitivity. This built in, self-emulsifying aspect allows for excellent compatibility in water and thus, easier mixing. The amine hardeners discussed here are capable of emulsifying liquid epoxies without the use of additional external emulsifiers.

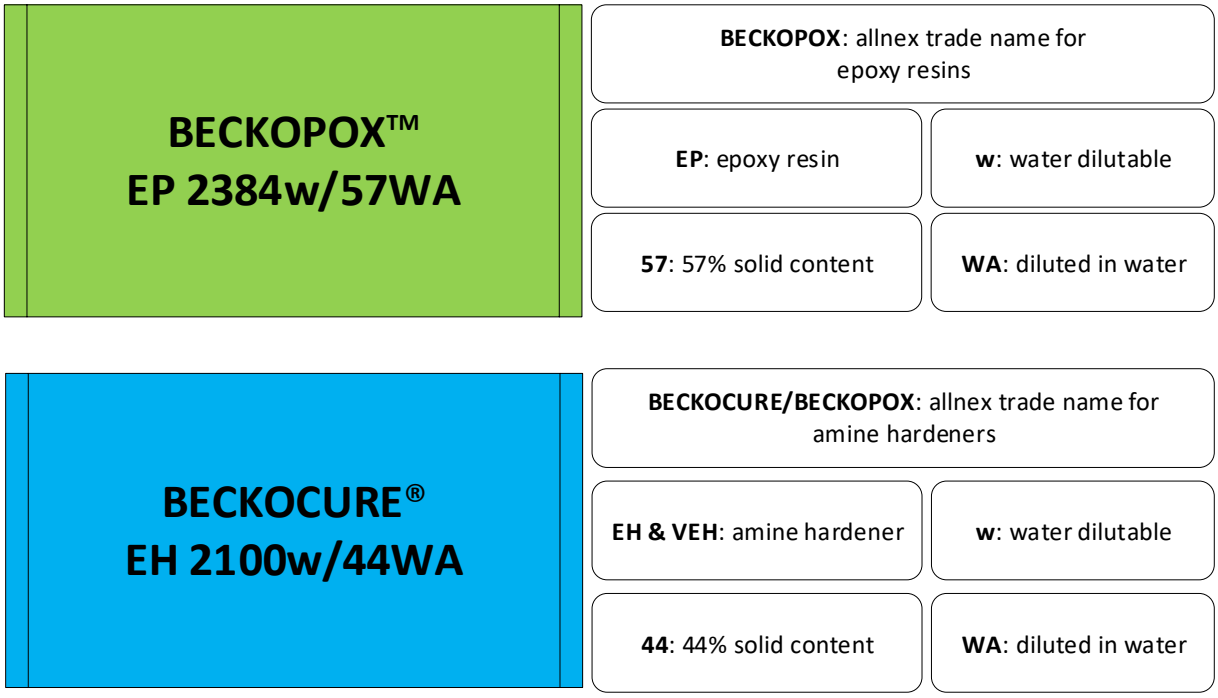
Allnex has developed a toolbox approach to our epoxy-amine systems. This allows formulators the ability to optimise performance properties needed for demanding concrete applications. This user's guide provides a comprehensive view of our portfolio of hardeners and resins. Included are examples to show how to calculate the cross-link density by stoichiometry, what to expect from water dilution and an understanding of the expected pot life, or useful working time of these two component systems. Further recommendations for useful solvents and additives are also included.

2. NOMENCLATURE

2K wb system based epoxy resins and amine hardeners

- 2K: Two component system, typically mixed prior to application
  - Consists of part A & part B
- wb: Water borne

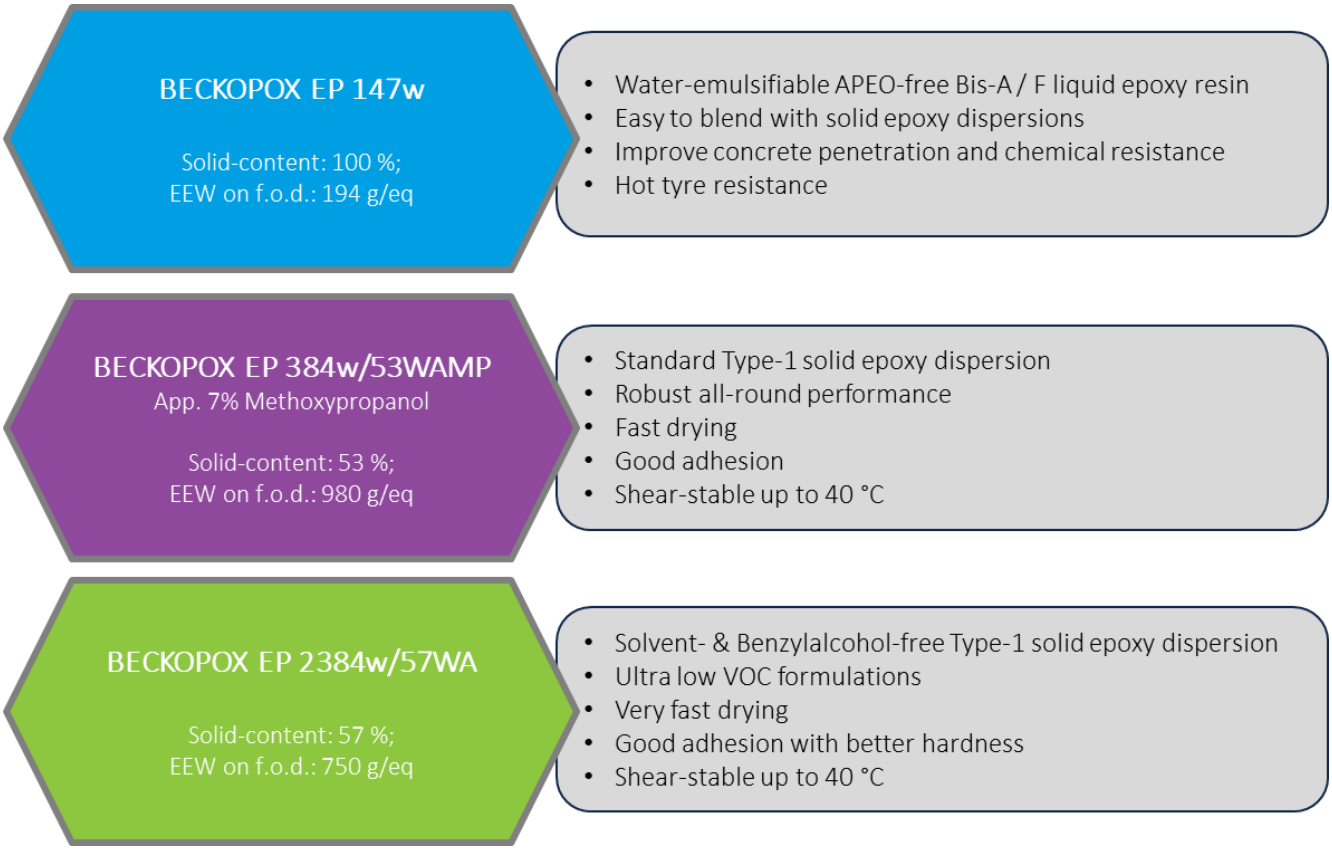
Example for Epoxy resin and Amine hardener



Bis-A: Bisphenol-A epoxy (most common class of liquid epoxy sometimes referred to instead of the common term liquid epoxy)
Bis-F: Bisphenol-F epoxy (liquid epoxy has lower viscosity and better chemical resistance than Bis-A)
Type 1 solid epoxy resin: epoxy with equivalent weight of ~500 on non-volatiles
Type 2-9 solid epoxy resins: increase in equivalent weight with ~4000 for Type 9

3. BECKOPOX™ AMINE HARDENERS

4. BECKOPOX™ EPOXY RESINS



Liquid Epoxy Water Dilution:

Standard Bis-A based liquid epoxy and reactive diluents require external emulsifiers to be emulsified in water. BECKOPOX EP 147w can easily be emulsify in water for improved application consistency.

Blending Recommendation for BECKOPOX EP 147w:

Start at 50% BECKOPOX EP 147w and 50% solid epoxy dispersion (BECKOPOX™ EP 2384w or BECKOPOX EP 384w) based on stoichiometry for improved air dry speed.

Stoichiometric recommendations for epoxy to amine:

- Best crosslink density for hardness and chemical resistance: 1:1 ratio of epoxy resin to amine hardener
- To improve water resistance, reduce the amine hardener slightly: 1:0.8 epoxy to amine

5. STARTING RECOMMENDATIONS

	Chemical Resistance (e.g. Containment Structures, Grocery Store Flooring)	Concrete Penetration (e.g. Primer Sealer)	Hot Tire Pick-up (e.g. Garages)	Early Hardness Development (Fast Return to Service)	End Hardness (e.g. Warehouses)	Pot-life (Working Time)	Low VOC Content (VOC Regulations)	Time to return to service
Amine Hardeners								
BECKOPOX™ EH 623w/80WA	Good	Better	Good	Good	Better	Best	Best	Good
BECKOPOX VEH 2106w/80WA	Best	Best	Best	Best	Best	Good	Best	Better
BECKOPOX VEH 2177w/80WA	Good	Better	Good	Better	Better	Better	Best	Better
BECKOCURE® EH 2100w/44WA	Good	Good	Best	Best	Good	Better	Best	Best
Epoxy Resins								
BECKOPOX EP 147w	Best	Best	Best	Good	Best	Best	Best	Good
BECKOPOX EP 2384w	Good	Good	Good	Best	Best	Good	Best	Best
BECKOPOX EP 147w : EP 2384w Blend	Better	Better	Better	Better	Better	Better	Best	Better
BECKOPOX EP 147w : EP 384w Blend	Better	Better	Better	Better	Better	Better	Good	Better

While our products offer a high level of latitude for the formulator to develop coatings for exact needs, we offer the above recommendations as an initial starting point based on our experiences. However, the outcome may vary slightly as formulation practices are also highly influential on performance and applicability.

Please contact us for more specific recommendations or starting point formulations.

6. STOCHIOMETRIC-CALCULATION

Epoxy-Amine systems

Epoxy Equivalent Weight $$EEW = \frac{Molecular\ Weight}{\#\ of\ Epoxy\ Groups}$$

Hardener Equivalent Weight $$HEW = \frac{Molecular\ Weight}{\#\ of\ Amine\ Groups}$$

Calculation for stochiometric crosslinking

$$\frac{Hardener\ Equivalent\ Weight\ (HEW)\ [\frac{g}{mol}]}{Epoxy\ Equivalent\ Weight\ (EEW)\ [\frac{g}{mol}]} \times 100 = \cdots g\ amine\ for\ 100g\ epoxy\ resin$$

Example for 100% crosslinking

Epoxy resin:	BECKOPOX EP 384w	EEW: 750 g/mol (f.o.d.)
Amine hardener:	BECKOPOX EH 623w	HEW: 200 g/mol (f.o.d.)

$$\frac{200\ [\frac{g}{mol}]}{750\ [\frac{g}{mol}]} \times 100 = \mathbf{26,7}g\ EH\ 623w\ for\ 100g\ EP\ 384w$$

Mixture of different epoxy dispersions

If different epoxy dispersions or liquid epoxy resins are to be used in a blend, a new EEW-value needs to be calculated. This will then be used for the calculation of the needed amine hardener.

$$\frac{Total\ amount\ of\ the\ used\ epoxy\ dispersions}{\frac{Amount\ epoxy\ resin\ I}{EEW\ of\ epoxy\ resin\ I} + \frac{Amount\ of\ epoxy\ resin\ II}{EEW\ of\ epoxy\ resin\ II}} = \cdots \frac{g}{mol}\ (new\ EEW\ for\ the\ epoxy\ mixture)$$

Example for BECKOPOX EP 384w/57WAMP and BECKOPOX EP 147w

EP 384w:	86 parts	EEW: 980 g/mol
EP 147:	14 parts	EEW: 194 g/mol
Total:	100 parts of the mixture	

$$\frac{100\ parts}{\frac{86\ parts\ EP\ 384w}{980\ \frac{g}{mol}} + \frac{14\ parts\ EP\ 147w}{194\ \frac{g}{mol}}} = 625\ \frac{g}{mol}\ (new\ EEW\ for\ mixture\ of\ EP\ 384w\ \&\ EP\ 147w)$$

Mixture of different amine hardeners

If different amine hardeners are to be blended and used, a new HEW-value needs to be calculated. This will then be used for the calculation of the needed amount of the corresponding epoxy dispersion.

$$\frac{\boldsymbol{Total\ amount\ of\ the\ used\ amine\ hardeners}}{\frac{\boldsymbol{Amount\ amine\ hardener\ I}}{\boldsymbol{EEW\ of\ amine\ hardener\ I}} + \frac{\boldsymbol{Amount\ of\ amine\ hardener\ II}}{\boldsymbol{EEW\ of\ amine\ hardener\ II}}} = \cdots \frac{\boldsymbol{g}}{\boldsymbol{mol}} (\boldsymbol{new\ HEW\ for\ the\ amine\ hardener\ mixture})$$

EEW & HEW of BECKOPOX™ / BECKOCURE® products mentioned in this technical bulletin

Amine hardener	HEW (f.o.d.) [g/mol]	Epoxy resin	EEW (f.o.d.) [g/mol]
BECKOPOX EH 623w/80WA	200	BECKOPOX EP 147w	194
BECKOPOX VEH 2106w/80WA	145	BECKOPOX EP 2384w/57WA	750
BECKOPOX VEH 2177w/80WA	175	BECKOPOX EP 384w/53WAMP	980
BECKOCURE EH 2100w/44WA	570	BECKOPOX EP 384w & EP 147w (86:14)	625

Calculation for different combinations of epoxy resins and amine hardeners

	X g of amine hardener			
	BECKOPOX EH 623w/80WA	BECKOPOX VEH 2106w/80WA	BECKOPOX VEH 2177w/80WA	BECKOCURE EH 2100w/44WA
100g of epoxy resin	**100% crosslinking**			
BECKOPOX EP 147w	**103,1 g**	**74,7 g**	**90,2 g**	**293,8 g**
BECKOPOX EP 2384w/57WA	**26,7 g**	**19,3 g**	**23,3 g**	**76,0 g**
BECKOPOX EP 384w/53WAMP	**20,4 g**	**14,8 g**	**17,9 g**	**58,2 g**
BECKOPOX EP 384w & EP 147w (86:14)	**32,0 g**	**23,3 g**	**28,0 g**	**91,2 g**

7. CALCULATION TOOL

For easier calculation of the stochiometric crosslinking we developed a simple Excel calculation tool. If it was not provided with this technical bulletin, please contact one of our Technical Service & Business Development Managers.

Below a screenshot of the tool, to give a short insight into the tool

Calculation if only one Epoxy dispersion is used					
BECKOPOX EP 384w/53WAMP	**980**	*EEW f.o.d*			
BECKOPOX EH 623w/80WA	**200**	*HEW f.o.d*			
Degree of Crosslinking:	100%				
For 100g	BECKOPOX EP 384w/53WAMP		**20,4**	g of	BECKOPOX EH 623w/80WA

Calculation if two epoxy dispersions are used							
Epoxy Resin 1	*EEW f.o.d*		***Epoxy Resin 2***	*EEW f.o.d*			
BECKOPOX EP 384w/53WAMP	**980**		BECKOPOX EP 147w	**194**			
Parts Epoxy Resin 1	60,00		Parts Epoxy Resin 2	40,00			
					Total parts	*100*	
New EEW from mixture of	***EP 384w***	***EP 147w***	**374**	g/mol			
	HEW f.o.d						
BECKOPOX VEH 2177w/80WA	**175**						
Degree of Crosslinking:	100%						
For 100g of mixture	EP 384w	&	EP 147w	**46,8**	g of	BECKOPOX VEH 2177w/80WA	

GUIDELINES

The blue fields indicate that this field can be changed or adjusted depending on the preferred choice of epoxy dispersion and amine hardeners.

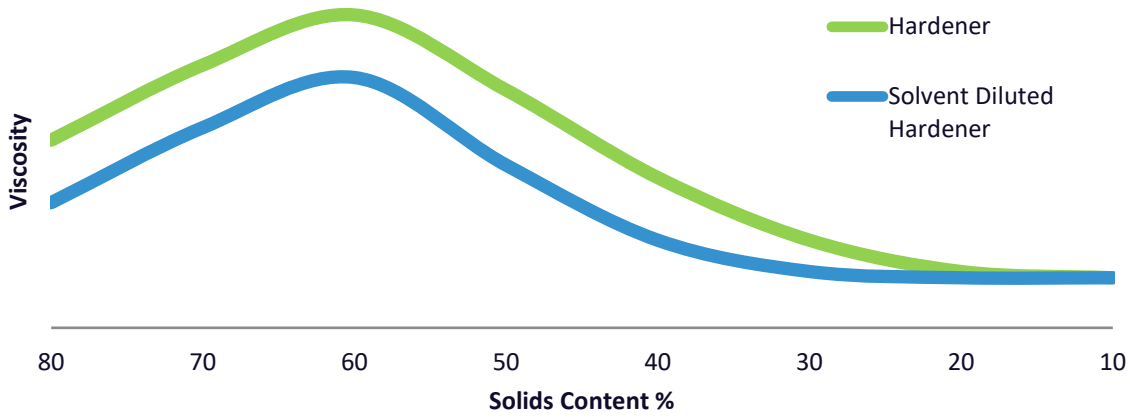
There is a drop down menu where all epoxy dispersions or amine hardeners mentioned in this technical bulletin can be chosen. Automatically, the correct epoxy- or amine-equivalent-weight is shown in the grey field.

The degree of crosslinking can be also adjusted by yourself. Important is that you enter a valid number in this field.

As soon as all three blue fields are filled with the needed input, the hardener amount for 100g of the chosen epoxy dispersion will be calculated and displayed in the green field.

8. WATER DILUTION

Behavior of an amine hardener during water dilution



- Amine hardeners increase in viscosity with the addition of water, up to a point, then decrease. It is recommended to add (co-) solvent to amine hardeners prior to water incorporation to reduce this initial viscosity and viscosity peak.
    - Best incorporation of extra water into the system is with slow steps, allowing emulsification into the water, followed by dilution.
        - At high solids the hardeners have more the characteristics of a solvent borne system, than a dispersion.
- For best stability, it is recommended to formulate the amine hardener side at 40% solids or higher.
    - Below 20% solids these amine hardeners tend to be less stable, which is more prevalent at elevated temperatures.

Epoxy Water Dilution

- Standard liquid epoxy can be diluted with water using external emulsifier surfactants. It is recommended to do this dilution just prior to application, as this will only have short-term stability. Addition of surfactants will typically reduce the water resistance properties of the coating.
    - BECKOPOX™ EP 147w is internally emulsified and can be easily diluted with water for short term stability.
        - The internal emulsifier does not cause water resistance issues.
- Solid epoxy dispersions can be further diluted with water.
    - Blends of solid epoxy dispersions with BECKOPOX EP 147w can be further diluted with water.
        - For best stability, it is recommended to formulate the solid epoxy dispersion side at 40% solids or higher.
        - For best incorporation dilute with water then add BECKOPOX EP 147w.
        - It is important to understand that solid epoxy dispersions have a tendency for syneresis (settling) after long storage. However, this can easily be reversed by stirring.

It is always recommended to check formulation stability.
Water content, solvent, pigments and additives all factor into total formulation

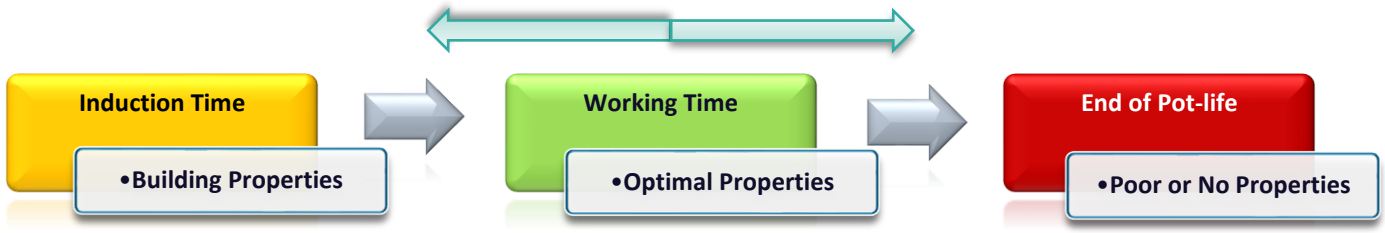
9. INDUCTION TIME, POT-LIFE & SOLVENTS

Induction Time

- Epoxy-amine systems require some time for the two components to become fully compatible and begin chemically reacting. Prior to this time frame, film formation tends to be poor, resulting in poorer application properties. This is commonly referred to as induction or sweat-in time. The induction time can be influenced by temperature, humidity, incorporation of the two components, and reactivity of the system.
    - BECKOPOX™ EH 623w systems tend to have a 15-30 min induction time at 23°C, 50% humidity
    - Systems with the faster reacting hardeners or blends tend to have a shorter induction time

Pot-life

- 2K epoxy systems are reactive once mixed and have a usable working time referred to as pot-life. For solvent borne systems pot-life tends to refer to the time taken for the viscosity of the system to double in value. Besides systems utilizing BECKOPOX EH 2106w for visible end of pot-life, most of the water borne hardeners tend not to build viscosity as time progresses. The end of the pot-life can only be determined by measuring loss of performance properties. Typically, this is demonstrated by lower gloss, loss of adhesion, and/or reduction of chemical resistance. This is due to reduction in film integrity. Pot-life is typically influenced by temperature, humidity, coalescent, and reactivity of the system. When using water borne epoxy systems, extra care must be taken to adherer to pot-life recommendations by the supplier of the system.
    - Hardener blends can optimize pot-life and performance properties
    - Coalescent solvents tend to extend the pot-life
    - Acetic acid can be used to extend the pot-life. These are pH 9-11 systems, acidic materials tend to influence other performance properties



Solvents

- The use of solvents is recommended for optimizing handling viscosity, film formation, compatibility, and pot-life. Extremely low VOC systems are possible; however, they typically have difficulty with handling viscosity, application performance, and short pot-life. Solvents can be used in combinations to optimize properties and compatibility.
    - Recommended for best viscosity adjustment and dry time
        - Faster evaporating:
            - Propylene Glycol Monomethyl Ether (PM)
            - Propylene Glycol n-Propyl Ether (PnP)
    - Recommended for improving film integrity, compatibility, temperature tolerance, and pot-life
        - Slower evaporating coupling/coalescing:
            - Ethylene Glycol Monopropyl Ether (EP)
            - Dipropylene Glycol Methyl Ether (DPM)
    - Recommended for improving gloss, film integrity, temperature tolerance, and pot-life
        - Slow evaporating primarily coalescing solvent:
          Dipropylene Glycol n-Butyl Ether (DPnB)

10. ADDITIVES

The below shown additives are highly recommended for the use in water borne 2K epoxy systems. The selected additives are market proven and are also included in several of our 2K epoxy formulations either for concrete or metal applications.

Rheology Modifiers

For optimal application rheology and shelf stability, it is recommended to use a combination of low to medium shear and high shear rheology modifiers. These are easy to incorporate in WB epoxy systems.

Application area	Products	Description
Low to Medium Shear	**ADDITOL® VXW 6388**	Our masterpiece rheology Additive for spray applied high film build WB coatings; improves storage stability, sagging and settling
High Shear	**ADDITOL VXW 6360**	Improves rheology profile for roller & brush application – reduces roller spattering, reflow and leveling

Defoamers

For preventing and breaking foam during paint manufacturing and application, it is important to make the perfect choice for foam control additives.

Application area	Products	Description
Highly compatible	**ADDITOL VXW 6393** **ADDITOL VXW 4926** **ADDITOL XW 6544**	Easy incorporation in any stage of paint production Can be added at any stage of paint production The recommended addition ranges from 0.1-1.0% on total formulation

Substrate wetting/Flow and Leveling

To prevent or reduce surface defects such as poor leveling, orange peel or cratering, it is recommended to use a combination of substrate wetting & flow and leveling additives.

Application area	Products	Description
Substrate Wetting	**ADDITOL XW 6580**	Silicone based with reduced foam stabilization and no recoat-ability issues
Flow and Leveling	MODAFLOW® AQ 3025	Acrylic flow promotor (silicone free) for improved DOI and gloss

Pigment Dispersing

Special dispersing additives support grinding of all pigment types, for direct grinds and concentrates (hardener & resin dispersion). Non-ionic and low ion migration (LIM) technology based dispersants allow improved storage stability, anti-corrosion performance and chemical resistance in highly reactive systems e.g. epoxy dispersions. It is recommended to keep the temperature of the dispersion below 40 °C when processing.

Application area	Products	Description
Dispersants	**ADDITOL VXW 6208** **ADDITOL VXW 6208/60** **ADDITOL VXW 6394**	Non-ionic technology based pigment dispersing Additives strongly improve corrosion and humidity performance Optimum dosage levels from 3-10% for inorganic pigments & fillers and 15-50% for organic pigments

ADDITIVE INNOVATIONS suitable for water borne 2K epoxy amine systems

Following additives were developed in the last years with the intention to improve application properties. All are suitable for water borne 2K epoxy amine systems, we are currently working on new 2K epoxy formulations which includes the new additives.

Application area	Products	Description
Defoamers	**ADDITOL XW 6584** **ADDITOL XW 6585**	**Zero VOC**, Silicone-based, emulsifier-free, with no negative impact on paint rheology profile Recommended to be incorporated at higher shear forces The recommended addition ranges from 0.05-0.5% on total formulation
Flow and Leveling	**ADDITOL XW 6586**	**Zero VOC**, 100% silicone based leveling agent for improved substrate wetting, gloss and appearance. Not influence on recoat-ability and foam stabilization
Dispersants	**ADDITOL XW 6588** **ADDITOL XL 6592**	Non-ionic technology based pigment dispersing Additives strongly improve corrosion and humidity performance. Optimum dosage levels from 3-10% for inorganic pigments & fillers and 15-50% for organic pigments

11.FORMULATION EXAMPLE

	Weight	Function	Supplier
Part A			
ADDITOL® VXW 6208	4.50	dispersing additive	*allnex*
Deionized water	5.40		
Acticide MBS	0.10	biocide	Thor
ADDITOL VXW 6393	0.50	defoamer	*allnex*
Kronos 2059	34.10	pigment	Kronos
Aerosil R 972	0.40	rheology control	Evonik
Grind and then add:			
BECKOCURE® EH 2100w/44WA	47.60	amine resin	*allnex*
Rheolate FX 1070 (1 : 1 in water)	2.20	rheology control	Elementis Specialties
ADDITOL VXW 4926	0.40	air release additive	*allnex*
Deionized water	4.80		
	100.00		
Part B			
BECKOPOX™ EP 2384w/57WA	64.30	epoxy hardener	*allnex*

Part A

This is the part that contains pigments and fillers, which means that part A will be always grinded, by dissolver or pearl mill.

Possible grinding set ups:

- Grind in a slurry which only contains a dispersing additive.
- Grind in the amine resin with additional dispersing additive.
- Grind in the epoxy resin with additional dispersing additive

Part B

This contains the second part of the 2K epoxy-amine system. It can contain an amine or an epoxy resin, depending on the binder that is used in Part A.

Part B can contain some water to adjust viscosity and/or some defoamer.

Part B is mixed with part A just before application.

Dispersing additive

A dispersing additive is needed to disperse and grind all the needed fillers and pigments.

Very important : the dispersing additive needs to be NON IONIC, if any ionic structure is part of the epoxy system it will react with the epoxy groups and lose performance over storage time.

Biocide

A biocide is added to prevent micro-biological deterioration of the system.

Defoamer

A defoamer is needed to reduce the foam which is created during the dispersing step and reduce air bubbles in the applied surface. In some cases, a second amount of defoamer could be added after the dispersing phase, if most of the defoamer is consumed in the dispersing step.

Rheology control

Rheological control additive is used to adjust the needed application viscosity and help to stabilize the dispersed pigments and fillers. Either polyurethane or acrylate thickeners can be used. Rheological additives might have a very high viscosity. In a 1:1 water mixture the viscosity is reduced and the dosing and homogenization in the paint is easier.

Air release additive

An air release additive is added after dispersing step to provide good air release in the applied surface.

Deionized water

The use of deionized water is very important as standard tap water contains a lot of ionic compounds which react with the functional groups of the epoxy system, which will lead to performance and storage issues.

Please read our Do´s and Don´ts on the next page as they contain very helpful information for the preparation of an epoxy-amine system.

12.DO'S AND DON'TS

- Water borne epoxy dispersions and amine resins must be protected from frost.
  At low temperatures they must be stored under frost proof conditions.

- As a result of the high solid content and the solid resin character of water borne epoxy dispersions, they tend to form a tiny skin upon foaming and temperature changes during storage. Therefore, filtration of the product (without heating) before application by the end user is recommended.

- It is recommended to dilute water borne amine based hardeners with a solids content of 80% down to 40% with water before further processing.

- When reducing water borne amine hardeners with water, it should be ensured that the solids concentration does not go below 20 – 30 % (please see technical data sheet). this potentially has an effect on stability of the resin, especially at storage temperatures above room temperature. Exceptions are the BECKOCURE® amine resins, those have an unlimited dilutability.

- When pigments and fillers are being dispersed in water borne amine resins or epoxy dispersions, the mill base temperature **must not be allowed to rise above 40 °C**.

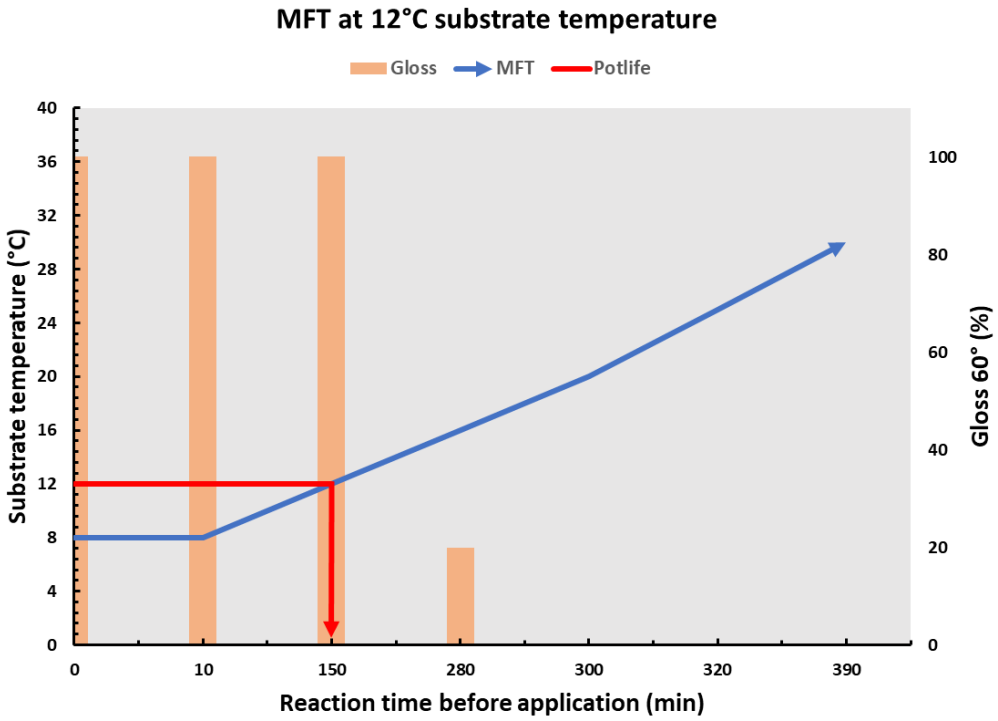
- **Pigments**, **fillers**, **additives** and **solvents** should be chosen carefully and should be tested for their applicability in water borne epoxy dispersions or water borne amine resins. They should not contain functional groups capable of reacting with epoxy or amine groups. Storage stability of pigment pastes should be tested.

- Dilute slowly in order to avoid dilution shocks.

- For **concrete** applications, the amine to epoxy cross-linking ratio should be **100 %**.
  For **metal** applications the best results are obtained with an amine to epoxy cross-linking ratio of **50 – 80 %** (depending on the amine resin).

- It is essential to apply the paint within the time stated for pot life. This is because the end of pot life of water borne 2K epoxy - amine systems cannot normally be detected from an increase in viscosity by gelation of the product.

In the graphs below, the behavior of the minimum film building temperature (MFT) and gloss during the pot life of a water borne 2K epoxy system is shown. For both graphs the same water borne 2K epoxy combination is used.

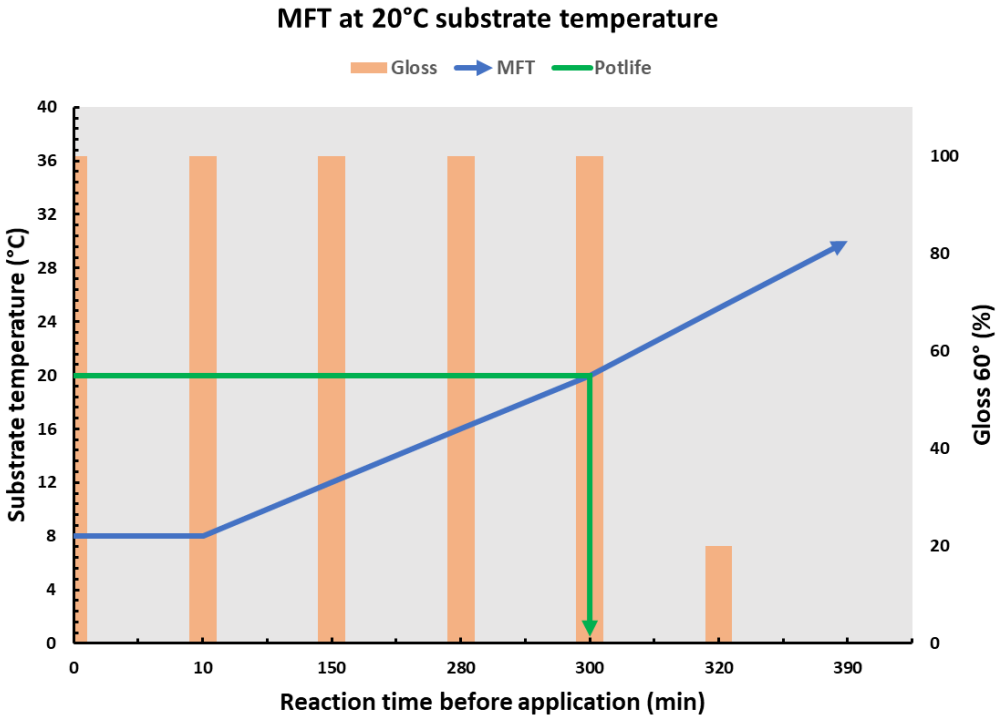


First, we take a look at the red line. This s indicates a substrate temperature of 12°C. As soon as we mix the 2K epoxy system, after the induction time the crosslinking and pot life starts. For detailed explanation of **induction time** see page 12.

For this example, the MFT of the 2K epoxy systems starts at 8°C. Over the pot life you can see that the blue line is increasing. This is indicating the increase in MFT as crosslinking of the system, takes place. As long as good film formation can take place (temperature of the coating MFT remains below the substrate temperature) then the sample is good to continue to use.

At a time of approximately 150 minutes, the MFT of the 2K epoxy systems reaches the same temperature of the substrate (12°C), which means this is the end of the working pot life for this system. Further application of the epoxy-amine coating will no longer produce a properly formed film.

This will result in a lower gloss and reduced performance of the final coating.



In the second case, the green line, the substrate temperature is now 20°C. If we us the same water borne 2K epoxy system as before, with an MFT starting at 8 °C, to reach 20 °C the system now takes approximately 300 minutes. This is the end of the pot life at this temperature.
Application of the water borne 2K epoxy system after the 300 minutes will result in poor film forming, low gloss and no performance properties.

This means the pot life first depends on the chosen combination of epoxy dispersions and amine hardeners, the final formulation, but also depends on the substrate temperature you will apply the water borne 2K epoxy system on.

As already mentioned, the end of pot life will not be indicated by an increase of viscosity.
Identification of pot life for your chosen system and final formulation needs always to be tested.

13.CONTACT INFORMATION

If you have any other questions or sample requests, please visit following page:
https://epoxy-resins-hardeners.com/

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