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Epoxy Polysiloxane Coatings – Isocyanate-free Topcoats with Outstanding Weathering Stability

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Epoxy (Polysiloxane) Coatings in General

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## **Epoxy (Polysiloxane) Coatings in General**





## **Characteristics of Epoxy Coatings**



#### **Epoxy Coatings offer**

- Hardness and Abrasion resistance
- Room temperature curing
- Chemical resistance
- Excellent adhesion on metals
- Reduced weatherability

Epoxy coatings are two component coatings.



# Two-Component Epoxy Coatings Find Numerous Applications in Marine & Protective Coatings



#### Corrosion Protection and Maintenance Coatings for

- Oil & Gas, Chemicals (drilling, platforms, refinery, storage tanks)
- Infrastructure (bridges, commercial buildings)
- Transportation (pipelines, cranes)
- Power generation (conventional & renewable)



## Various Types of Epoxy Resins Are Being Used in the Coatings Industry

#### Epoxy Resins Used as a Binder for Coatings Include

- various Bisphenol A (R=CH<sub>3</sub>) or F (R=H) types (see graph)
- cycloaliphatic epoxy resins (better weatherability)
- diverse liquid (low molecular weight) epoxy compounds (reactive diluents)

#### Bisphenol A type Epoxy







### **Amine-Functional Curatives for Epoxy Coatings**



#### Typical RoomTemperature Curing Agents Include

- aliphatic (poly-)amines (1, 2)
- aromatic (poly-)amines
- polyether amines (3)
- cycloaliphatic amines (4)
- Mannich base (5)
- Polyamidoamine adducts (6)
- Amine adducts (prereacted epoxy resin)



## **Epoxy Coatings Suffer from Low Weatherability**

In outdoor applications, the UV component of sunlight damages the film and causes severe chalking

#### **Standard Solution:**

Apply an additional weather-resistant PUR topcoat on the epoxy coating



### **Standard Protective Coating Systems usually Consist of Three Coats**

#### **Every Coat Protects from a Single Impact**





In outdoor applications, the UV component of sunlight damages the film and causes severe chalking Standard Solution:

Apply an additional weather-resistant PUR topcoat on the epoxy coating

Advanced Solution:

Add unique weathering stability to the epoxy coating by using silicone resins/polysiloxanes

**WACKER** Epoxy Polysiloxane Coatings – Isocyanate-free Topcoats with Outstanding Weathering Stability 02/02/2022



#### Basic Idea: Incorporate Silicone Resin / Polysiloxane into the Binder System



#### **Epoxy Polysiloxane Coating**





## **Option 1: Avoid Use of Isocyanates**

Epoxy Polysiloxane Coatings can be Used as PUR Topcoat Replacement in very Corrosive Enviroments (C5)







## **Option 2: Combine Two Coatings into One Coating**

Epoxy Polysiloxane Coatings can Replace PUR and Epoxy Coats by a Single Coat in Less Corrosive Environment (C4 and below)





**Chemistry of Epoxy Polysiloxanes** 



# Conventional Silicone Resins Must be Cured by Baking at High Temperatures (> 200°C)



#### Typical Structure of a Standard Silicone Resin

- UV resistant inorganic backbone
- Heat curing resin type
- Polycondensation reaction of alkoxy/hydroxy groups
- Predominantely used for heat-resistant coatings
- Does not cure epoxy resins

#### New resin structure or technology needed



## Basic Principle of Two Component Epoxy Polysiloxane Coatings<sup>1</sup>



<sup>1</sup> US 5,804,616; US 5,618,860; US 5,275,645 (Ameron)



## Cure Mechanism of Silane-based Epoxy Polysiloxane Coatings<sup>1</sup>



<sup>1</sup> US 5,804,616, US 5,618,860, US 5,275,645 (Ameron)



## **Disadvantages of Silane-based Epoxypolysiloxanes**

#### **Complex reaction mechanism (three components)**

- Use of monomeric silanes
- Hydrolysis and condensation steps of Alkoxy sil(ox)anes
- Polyaddition of reactive organic groups
- Different reaction rates
- > Application conditions (Temperature/relative humidity) may have an impact on film formation



#### **Options to Reduce the Number of Components**





#### **Options to Reduce the Number of Components: Silicone Epoxy Hybrid**







#### **Options to Reduce the Number of Components: Amino Polysiloxane**





## **Typical Chemical Structure of Amino Polysiloxanes**

#### Aminofunctional Silicone Resin (= Amino Polysiloxane)

- Aminofunctional groups react with epoxide groups at room temperature
- Silicone backbone provides resistance to the UV component in sunlight





# Basic Principle of Two Component Epoxy Polysiloxane Coatings with Amino Polysiloxanes





## **Correct Ratio of Resin to Curing Agent is Important**

#### **Epoxy Resin**

- Epoxy equivalent weight (EEW)
  - How many grams of epoxy resin contain 1 mol of epoxide groups

#### Amine Curing Agent (= Hardener)

Amine Hydrogen Equivalent Weight (AHEW)

How many grams of amine hardener contain one mol of N-H groups

Calculated addition level is just a theoretical guideline, over- or undercured coatings in the range of 10 – 20% are possible



#### How to Calculate the correct AHEW for such Aminopolysiloxanes?



▶ 2 N atoms (= AN), but one Nitrogen can react twice with epoxy and the other one only once.





## Formulation of Epoxy Polysiloxane Coatings with Amino Polysiloxanes



## **Basic Formulation**

#### Epoxy Polysiloxane Coating Components

- Cycloaliphatic epoxy resin (e. g. EEW 220 g/mol)
- Pigments
- Extenders/Fillers
- Additives
- Aminofunctional Polysiloxane (e. g. AHEW 247 g/mol)

#### **Test Formulation**

Component A: Paint Base	Weight%	
Cycloaliphatic epoxy resin	33	
Pigment, e.g. Titanium dioxide	30	
Mix and disperse thoroughly (Dissolver or bead		
mill)		

Component	<b>B</b> :	Curing	Agent
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Aminofunctional Polysiloxane

37

Add and mix Comp A with B prior to use; Potlife 4 – 5 h



### **Exemplary Coating Performance Data**



## Significant Improvement of the Gloss Retention of a White Epoxy Coating

QUV-B Accelerated Weathering Test of a White Epoxy Coating Cured either

- > with a commercial cycloaliphatic curing agent (reddish-brown curve) or
- with an aminofunctional polysiloxane (orange curve)





## Gloss Retention Eight-times Better after 6,000 h in the Xenon Test Compared to an Aliphatic PUR Coating

Xenon Accelerated Weathering Test, Gloss Retention of a White

- Epoxy-polysiloxane coating (orange curve) compared with an
- Aliphatic HDI-Isocyanurate based PUR topcoat (dark red curve)





## Epoxy Polysiloxane Coating Showed Better Long-Term Gloss Retention than Aliphatic PUR Coatings

QUV-B Accelerated Weathering Test of White Coatings

- Epoxy Polysiloxane Coatings (orange curve) outperforms various
- PUR Coatings (Hydroxyfunctional Acrylic resin/HDI-Isocyanurate)





### **Chemical Resistance is Good**

#### Test method: droplet on coating, covered with watch glass, 24 h, visual inspection

Binder Chemistry	Cycloaliphatic Epoxy Resin + Aminofunctional Polysiloxane
Solvent (MEK), 200 DR	No change
Hydrochloric Acid, 37%	No change
Phosphoric Acid, 85%	No change
Sulfuric Acid, 98%	Strong defect
Conc. Acetic Acid	Strong defect
NaOH 50%	No change (slight decrease in gloss*)
Ammonium hydroxide, conc.	No change

\*Remark: Dipping a coated panel into 20% NaOH solution for 72h caused a decrease in gloss from 91 to 71 units (60°)



## **Comparison of WACKER's Aminofunctional Polysiloxanes**





## Comparison of SILRES® HP 2000 and 2020 (1)

#### **Product properties**

Name	SILRES <sup>®</sup> HP 2000	SILRES <sup>®</sup> HP 2020
Amine type and value	identical	identical
Moisture sensitive (self-condensation)	yes	yes
Additional Solvent content	10 w% Xylene	none
Typical Viscosity [mm <sup>2</sup> /s]	100 - 400	50 - 250
Methoxy group content (SiOMe)	lower	higher
Storage stability	Average (min. 6 months)	Longer (min 12 months)
Cost	Higher	Lower



## Comparison of SILRES® HP 2000 and 2020 (2)

Cured Coating (Binder system: Cycloaliphatic epoxy resin (e. g. IPOX® ER 15) + SILRES<sup>®</sup> HP20X0)

SILRES®	HP 2000 to HP 2020
Cure time	Similar (4 – 5 h)
Accelerated weathering tests (gloss retention)	
Xenon test	Similar
QUV-A	Better
QUV-B	Much better
Mechanical tests	
Pencil hardness	Comparable (5H – 6H)
Adhesion / Cross hatch	Slightly Better
Mandrel bend test	Little bit more flexible



## Summary



## The Advantages of SILRES<sup>®</sup> HP 2000 and HP 2020

#### Epoxy Polysiloxane Coatings based on SILRES® HP 2000 / 2020

- offer excellent long-term gloss retention and weathering resistance
- outstanding solvent resistance (easy-to-clean, removal of Grafitti)
- very high hardness
- Iow VOC values (high solids, 100 250 g/l depending on desired viscosity)
- b do not contain harmful isocyanates or urethane groups

SILRES<sup>®</sup> HP 2000 / 2020 enable the formulation of coatings that combine the advantages of conventional epoxy coatings with the known weathering stability of PUR topcoats in a single coating



## Further Documents for SILRES<sup>®</sup> HP 2000/2020 at www.wacker.com

#### **Documents**

- General SILRES<sup>®</sup> **Coatings brochure**
- ▶ SILRES<sup>®</sup> HP 2000 Infosheet (media library)

TDS and SDS (product search)





#### SILRES® HP 2000:

#### Epoxy Coatings with Unparalleled Weathering Stability

Epoxy coatings combine excellent adhesion-strength and chemical resistance with outstanding corrosionprotection. However, their resistance to sunlight has been inadequate so far. In outdoor applications, the UV component of sunlight damages the film and causes severe chalking. But now a solution is available: SILRES<sup>®</sup> HP 2000 imparts unique weathering stability to epoxy coatings.

Conventional silicone resins must be cured by baking at high temperatures, such as about 200 °C for 1 hour. This causes the silanol groups to undergo polycondensa tion. However, for a number of reasons there are many coatings that cannot be haked

#### SILRES® HP 2000 Cures Even at

SILBES® HP 2000 is an amino-functional silicone resin (see figure 1). The amino groups linked to the silicone resin via silicon-carbon bonds both catalyze the condensation of silicon-alkoxy groups and act as reactive curing groups. Even SILRES® HP 2000: The Principle at room temperature, they react with the SILRES® HP 2000 replaces the organic epaxide groups of epaxy resins to form curing agent (e.g. polyamine) in twoa high-molecular coating film. The cured component epoxy coatings, Cycloaliphatic coating is completely resistant to strong epoxy resins are particularly suitable solvents such as 2-butanone (methyl ethyl as epoxy components of the pigmented ketone. MEK) which proves the high decoating base. Pigments (Inorganic or gree of crosslinking that can be achieved organic types), extenders, additives, by using SILRES® HP 2000. solvents should be added to the paint base. The products are known as epoxy-



ILRES <sup>®</sup> HP 2000: Typical Formulation	
aint base (component 1)	Weight %
yckaliphatic epoxy resin	33.2
Igment, titanium dioxide	30.0
lixing and dispersion (high-speed mixer or bead mill)	
uring agent (component 2)	
ILRES® HP 2000 (AHEW 247 g/eq)	36.8

Mk/ng with component 1 directly before application; pot life approx. 4h; drying time approx. 4 – 5 h (50% r.h., 23 °C)

hybrid coating in general).

SILBES<sup>®</sup> HP 2000: The Advanta

Epoxy-polysiloxane coatings based on SILRES® HP 2000 are characterized by verv high hardness, excellent long-term gloss stability, excellent solvent resistance and low VOC values1. Depending on the desired viscosity, typical coating formula tions contain only 100 - 250 g VOC/liter. They combine the advantages of conventional epoxy coatings with the known polyslloxane coatings (or organo silicone weathering stability of isocyanate-curing PUR top coats<sup>2</sup> in a one-coat lacquer.

SILRES<sup>®</sup> is a registered to Wacker Chemie AG.

VOC: Volatile Organic Cor PUR: Polyurethane



## **Thank You for Your Attention**





