ANGUS® CHEMICAL COMPANY

Key Performance Advantages

- Controls problems associated with moisture in isocyanate-based (polyurethane and polyurea) coatings, sealants and elastomers
- Prevents downglossing, bubbles, pinholes and hazing
- Fast-acting, safe and effective

Paints and Coatings

ZOLDINE® MS-PLUS

ZOLDINE® MS-PLUS Oxazolidine Moisture Scavenger for Urethane Systems
3-ethyl-2-methyl-2-(3-methylbutyl)-1,3-oxazolidine
CAS Reg. No. 143860-04-2

ZOLDINE MS-PLUS Moisture Scavenger is a fast-reacting, low viscosity oxazolidine-based moisture scavenger for use in polyurethane and polyurea coatings, sealants and elastomers. ZOLDINE MS-PLUS Moisture Scavenger will safely and effectively eliminate moisture from the raw materials used in most polyurethane and polyurea systems. ZOLDINE MS-PLUS also eliminates problems caused by humidity during the cast or spray application of two-component polyurethane and polyurea systems.

The following benefits are obtained when using ZOLDINE MS-PLUS Moisture Scavenger:

- Minimizes downglossing and hazing under high humidity application conditions.
- Eliminates CO_2 bubbles and pinholes in two-component systems.
- Improves film integrity and substrate adhesion.
- Improves gloss, abrasion resistance and chemical resistance.
- Prevents gassing and gelling in IPDI-based one-component (1K) moisture-cure systems.
- Forms no insoluble precipitates upon reaction with moisture or isocyanates.
- Fully reacts into polyurethane and polyurea polymer matrix.
- Excellent handling properties.

Typical Properties

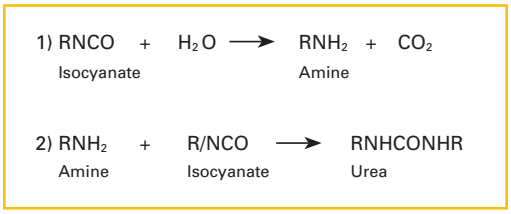
The following are typical properties of ZOLDINE MS-PLUS Moisture Scavenger. They are not to be considered product specifications.

Freezing Point	<-35°C/-31°F
Equivalent Weight	93
Molecular Weight	185
Density @ 24°C	0.872 g/mL
Weight/Gallon	7.27 lb.
Boiling Point	209°C/408°F
Flash Point (Pensky-Martens Closed Cup)	79°C/174°F
Viscosity (Brookfield)	<100 cps
Vapor Pressure @ 25°C	2.4 mm Hg
Solubility	Soluble in polyols and most organic solvents (e.g., toluene, MIBK, butyl acetate)
Activity	100%
Functionality	2

Effect of Moisture

Reaction
Reduction of moisture is an essential step in the production of high performance polyurethane and polyurea systems. The inherent reactivity of moisture with isocyanates and isocyanate prepolymers significantly degrades the performance of polyurethane and polyurea coatings, sealants and elastomers.

Moisture is introduced into polyurethane and polyurea systems in the form of atmospheric humidity, dissolved water in solvents and polyols, and adsorbed water in fillers and pigments. If not removed, moisture will react with the isocyanate constituent to form gaseous carbon dioxide and an amine. The amine continues to react with additional isocyanate to form higher molecular weight ureas. These reactions are summarized below:



Excessive humidity in the application environment is probably the most widely recognized source of moisture problems in two-component polyurethane and polyurea systems. Moisture in the air or on the substrate can create serious appearance and performance problems as bubbles or pinholes form in the curing film.

Downglossing
In addition, when polyurethane and polyureaurethane coatings are applied under conditions of high humidity, a phenomenon called downglossing frequently occurs. Downglossing (or dieback) is caused by the reaction of water (humidity) with isocyanate, resulting in microbubbles on the surface which reduce gloss. Often this problem becomes so severe that a haze actually forms in the coating. Additionally, reaction with moisture leads to by-products which can increase system viscosity and reduce flow during application. This also can result in surface imperfections and reduced gloss.

Pinholing
Another source of moisture contamination can exist within the formulation itself. Most raw materials used in polyurethane and polyurea formulations are specified to be very low in moisture content (e.g. polyols, isocyanate prepolymers). However, pigments, fillers and flatting agents are not generally available in low moisture urethane grades. In lower solids two-component systems, these raw materials may pose only minor moisture-related problems.

In higher solids or faster curing polyurethane and polyurea systems, however, the carbon dioxide gas formed when moisture reacts with the isocyanate component cannot readily escape from the curing product. Because higher solids systems (i.e. 3.5 lb./gal./420 g/L VOC or lower) contain higher concentrations of pigments and fillers, the average system moisture content is significantly greater.

As a result, entrapped bubbles or pinholes appear which detract from system performance as well as appearance. This is especially true in higher build films such as those commonly found in sealants, elastomers and industrial maintenance coatings.

In solvents, moisture contamination leads to the precipitation of urea crystals when wet solvents are used to dilute isocyanates and prepolymers. The insoluble particles can clog filters in production and/or detract from gloss and clarity in two-component clearcoats.

One-Component Systems
In one-component moisture-cure polyurethanes, the carbon dioxide gas formed from the reaction of moisture with isocyanate manifests itself as vapor pressure in the headspace of the product container. As this problem becomes more acute, containers may bulge and their lids may be blown off. Even if this does not occur, dissolved CO_2 in the product can cause it to foam excessively once it is opened.

Moisture contamination in one-component moisture-cure polyurethanes is the single greatest cause for failures in the manufacturing environment. As moisture reacts with isocyanate prepolymers in one-component systems, higher molecular weight ureas are formed. This results in a dramatic increase in system viscosity, often gelling the product and rendering it unusable.

ZOLDINE MS-PLUS Technology
ZOLDINE MS-PLUS Moisture Scavenger will effectively control the effects of humidity in the application of two-component polyurethane and polyurea systems. ZOLDINE MS-PLUS Moisture Scavenger can also be used to dehydrate a variety of components commonly found in urethane systems. ZOLDINE MS-PLUS Moisture Scavenger will react rapidly with water and safely eliminate it from the formulation without generating volatile carbon dioxide gas.

ZOLDINE MS-PLUS Moisture Scavenger reacts with water to form a secondary amino alcohol (N-ethylethanolamine) and a ketone (methyl isoamyl ketone, MIAK)–see reaction on the next page. The amino alcohol has a molecular weight of 89 and a functionality of two. MIAK serves as an excellent urethane solvent which eventually volatilizes along with the other solvents from the composition.

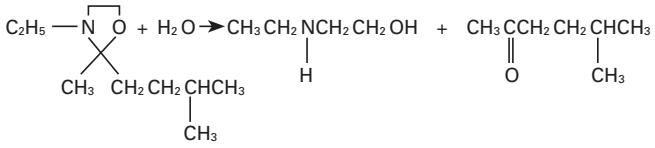
Thus, ZOLDINE MS-PLUS Moisture Scavenger and its reaction products either become a part of the polyurethane or polyurea matrix or leave the film completely. There is no unreacted material left behind to detract from the appearance or structural integrity of the film. The photographs below (2.2 times actual size) illustrate how ZOLDINE MS-PLUS Moisture Scavenger eliminates moisture and hence the development of CO_2 bubbles in a high solids, two-component industrial maintenance coating.

With ZOLDINE MS-PLUS

No bubbles or pinholes. Light reflection is distinct (upper left corner).

Without ZOLDINE MS-PLUS

Bubbles and pinholes throughout. Light reflection is uneven.



ZOLDINE MS-PLUS | N-ethylethanolamine | Methyl Isoamyl Ketone (MIAK)

Downglossing

In order to demonstrate this phenomenon, a 3.5 lb./gal. (420 g/L) VOC, two-component, medium gloss general industrial coating based upon HDI with a polyester polyol was formulated with and without ZOLDINE MS-PLUS Moisture Scavenger.

Panels were sprayed at various temperatures and relative humidity to 1.7-2.3 mils dry. The panels were allowed to cure for four to five hours at these conditions and then dried overnight at 70°F and 60% relative humidity. The following graph shows the results of adding ZOLDINE MS-PLUS Moisture Scavenger to the system with the subsequent minimization of downglossing.

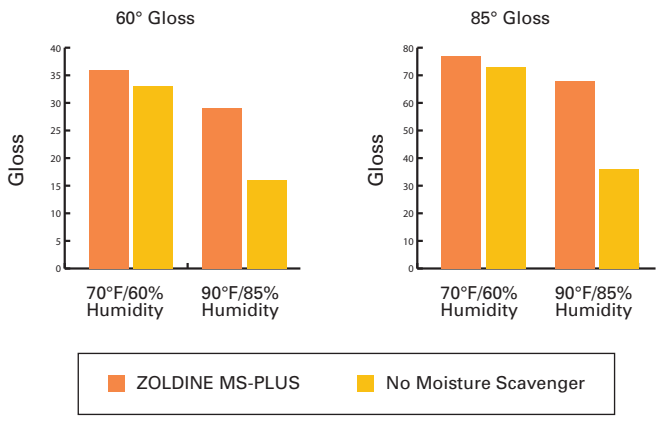
Two-Component, Medium Gloss Polyurthane Coating	
COMPONENT 1	**Wt.%**
Polyester Polyol	17.0
n-ButylAcetate/MEK/Toluene	11.9
Antisettling/Dispersant/Flow-control Agent	<0.9
Titanium Dioxide	8.5
Color Pigments	1.3
Fillers/Flatting Agents	6.4
Anti-mar Agent	<0.4
Catalysts	<2.0
UV Absorbers	<0.4
Zoldine MS-PLUS Moisture Scavenger	2.5
COMPONENT 2	
n-Butyl Acetate/MEK/Toluene	5-15
HDI Polyisocyanate	35-45
	Total: 100.0
Typical Properties	
VOC:	3.5 lb./gal. (420 g/L)
Pigment/Binder Ratio:	0.34
Density:	10.3 lb./gal. (1234 g/L)
Solids (by Weight):	66.0%

Application Humidity Control

ZOLDINE MS-PLUS Moisture Scavenger can be used to prevent downglossing, bubbles, pinholes or hazing caused by excessive humidity during the application of two-component polyurethane and polyurea systems. It reacts with moisture more rapidly than does isocyanate, thus preventing the formation of CO_2 in the cast or sprayed film.

For control of humidity during the spray application of two-component polyurethane and polyurea systems, ZOLDINE MS-PLUS Moisture Scavenger can be added at virtually any time to the polyol or amine side of the formulation. Usually about three to five percent by weight is enough to totally eliminate these problems.

Downglossing/Air Dry Two-Component, Medium Gloss General Industrial Coating

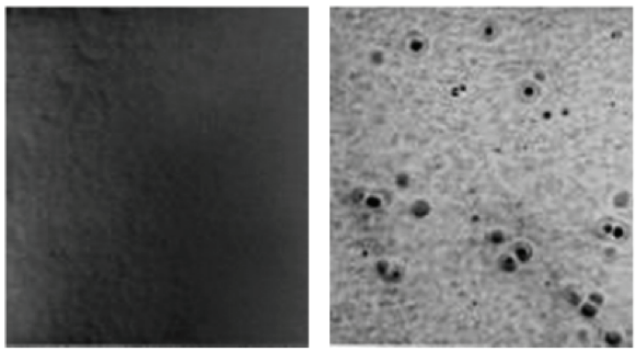


Bubbles and Pinholes

In order to demonstrate this phenomenon, a 2.8 lb./gal. (340 g/L) VOC, two-component, high gloss general industrial coating based on HDI with a polyester polyol was formulated with and without ZOLDINE MS-PLUS Moisture Scavenger. Panels were sprayed and cured under procedures similar to the previous downglossing test.

Two-Component High Gloss Polyurethane Coating	
COMPONENT 1	**Wt.%**
Polyester Polyol	25.37
Ketone/Ester Solvent Blend	26.87
Titanium Dioxide	20.74
Additives	0.49
Dibutyl Tin Dilaurate	0.01
ZOLDINE MS-PLUS Moisture Scavenger	3.50
COMPONENT 2	
HDI Trimer	23.02
	Total: 100.0
Typical Properties	
VOC:	2.8 lb./gal. (340 g/L)
Density:	10.01 lb./gal. (1199 g/L)
Solids (by Weight):	72.04%

As the photomicrographs below illustrate, ZOLDINE MS-PLUS Moisture Scavenger eliminated bubbles and pinholes in this high solids two-component polyurethane coating.



With ZOLDINE MS-PLUS

Without ZOLDINE MS-PLUS

ZOLDINE MS-PLUS Moisture Scavenger has produced very similar results in two-component urethane adhesives. The addition of ZOLDINE MS-PLUS Moisture Scavenger eliminates bubbles and pinholes in these compositions, thus greatly improving substrate wetting and the integrity of the bond.

Moisture Removal from System Components

ZOLDINE MS-PLUS Moisture Scavenger can be used to remove water from the components of a polyurethane or polyurea coating system. It is recommended that the solvent, polyol and/oramine and pigments be combined prior to the addition of the moisture scavenger. Effective drying can then be accomplished as the pigment grinding is done. Generally, sufficient heat (110-140°F/43-60°C) is generated during the pigment grinding operation to assist the moisture scavenger in effecting a complete drying of the system. Once the components of the pigment grind are combined, the total moisture content of the mixture can be measured. A level of 20 parts of ZOLDINE MS-PLUS Moisture Scavenger should then be added for each part of water to the mixture.

Several pigment grinds were prepared to demonstrate the efficiency of ZOLDINE MS-PLUS Moisture Scavenger in removing moisture. The following table presents the pigment grind system used to develop drying data.

Typical Pigment Grind	
	Wt.%
MEK, n-Butyl Acetate, Xylene	9.3
Polyester Polyol	37.3
Wetting/Dispersing Agent	1.9
Titanium Dioxide	28.0
Extender Pigment	18.7
ZOLDINE MS-PLUS Moisture Scavenger	4.8
	100.0

As evidenced by the data in the following table, ZOLDINE MS-PLUS Moisture Scavenger efficiently and effectively removes moisture from all of the more common pigment/filler combinations found in urethane coatings, sealants and elastomers. In most cases, the grind viscosity will also be significantly reduced upon incorporation of ZOLDINE MS-PLUS Moisture Scavenger. However, individual results may vary depending upon the amount of shear (e.g., high speed dispersator versus sand mill) and temperature developed in a given mill base.

Pigment Grind Drying		
	Wt.%	
Pigments	**Initial**	**After One-Hour**
TiO_2 /Clay	0.30	0.03
TiO_2 /$CaCO_3$	0.20	0.04
TiO_2 /Al_2O_3	0.18	0.05
TiO_2 /Talc	0.24	0.05
TiO_2 /$SrCr_2O_3$	0.22	0.02
TiO_2 /Barytes	0.22	0.05

Note: 18:1 Treatment ratio ZOLDINE MS-PLUS Moisture Scavenger to water in pigment grind at 140°F/ 60°C.

Film Performance Properties

Significant improvements in abrasion resistance, gloss development, gloss retention and accelerated weathering performance are also realized when using ZOLDINE MS-PLUS Moisture Scavenger.

The following high solids two-component formulation was utilized to demonstrate the superior performance attained when ZOLDINE MS-PLUS Moisture Scavenger is incorporated in the coating.

Two-Component Polyurethane Coating Formulation	
COMPONENT 1	**Wt. %**
Xylene/n-Butyl Acetate/MEK	7.44
Polyester Polyol	24.45
Wetting/Dispersing Agent	1.23
Titanium Dioxide	18.34
Clay	12.21
Dibutyltin Dilaurate	0.01
ZOLDINE MS-PLUS Moisture Scavenger	3.13
COMPONENT 2	
Xylene/n-Butyl Acetate/MEK	16.82
HDI Polyisocyanate	16.37
	Total 100.00
Typical Properties	
VOC:	3.5 lb./gal. (420 g/L)
Pigment/Binder Ratio:	0.75/1.0
Density:	10.43 lb./gal. (1250 g/L)
Solids (by Weight):	66.49%
NCO:OH Ratio	1.05

Polyurethane Coating Performance Properties Two-Component Polyester Formulation		
(Substrate was Bonderite 1000 unless otherwise indicated)		
	Control Coating (No Moisture Scavenger)	**ZOLDINE MS-PLUS Coating**
Chemical Resistance:*		
MEK (100 double rubs)	4	5
Toluene (100 double rubs)	3	4
IPA (100 double rubs)	2	3
Mechanical Properties:		
Pencil Hardness	HB	F
Sward Hardness (glass)	24%	16%
Direct Impact (lb)	160 pass	160 pass
Reverse Impact (lb)	160 pass	160 pass
Chip Resistance	4A	4A
Flexibility (conical)	>32°	>32°
Adhesion (cross hatch)		
Initial	5	5
24 hr H2O Immersion	5	5
Taber Abrasion (mg removal/1000 cycles)	105	70
Accelerated Weathering: (QUV 1000 hrs)		
Initial Gloss (60°)	17.1	39.6
% Gloss Retention	59.8	64.5
Color Change Delta E (FMC II)	0.58	0.82
Potlife Zahn #3 (hrs)	2	2
Speed of Dry (minutes)		
Set to touch	19	25
Tack free	93	127
Dry hard	83	127
Dry through	83	137
***A score of 5 represents total chemical resistance; a score of 0 represents no chemical resistance.**		

One-Component Moisture-Cure Polyurethanes

In one-component moisture-cure polyurethanes, ZOLDINE MS-PLUS Moisture Scavenger eliminates moisture without the evolution of gaseous carbon dioxide. Gassing in the container is thus eliminated.

ZOLDINE MS-PLUS Moisture Scavenger can be formulated into a one-component moisture-cure system using an IPDI-based polyisocyanate as illustrated by the following system:

One-Component Moisture-Cure Polyurethane	
	Wt. %
Xylene	13.0
Antisettling/Wetting Agents	0.9
Titanium Dioxide	20.3
Clay	13.7
ZOLDINE MS-PLUS Moisture Scavenger	2.1
IPDI-based Polyisocyanate	50.0
	Total 100.0
Typical Properties	
VOC:	3.0 lb./gal. (340 g/L)
Pigment/Binder Ratio:	0.97
Density:	9.99 lb./gal. (1197 g/L)
Solids (by Weight):	69.8%

The results below indicate the complete stability of this one-component moisture-cure polyurethane system at both ambient temperatures and under accelerating aging (140°F/60°C). No gassing was noted in the product containers and no foaming was seen in the product itself.

Viscosity Stability (Krebs Units)		
	Ambient Temperature	**140°F/60°C**
Initial Viscosity	59	-
24 Hour Viscosity	59	59
1 Week Viscosity	59	61
2 Week Viscosity	61	65

Formulation Guidelines/Considerations

ZOLDINE MS-PLUS Moisture Scavenger is highly efficient in removing water from two-component polyurethane and polyurea systems. Best results are obtained when:

- ZOLDINE MS-PLUS Moisture Scavenger is added early in the manufacturing process.
- Increased shear and heat improve the performance of ZOLDINE MS-PLUS Moisture Scavenger.
- Inert gas blanketing during manufacture is also recommended to eliminate atmospheric moisture.

A treatment level of 20 parts of ZOLDINE MS-PLUS Moisture Scavenger per part of water is recommended for optimum performance. It is very important that the level of moisture be measured for best results and cost. Moisture can be measured using Karl Fischer or a gas chromatographic method. If ZOLDINE MS-PLUS Moisture Scavenger is utilized in this way early in the manufacturing process (e.g. in a pigment grind or mill base), it will continue to protect two-component polyurethane and polyurea systems from humidity (downglossing) during cast or spray application.

ZOLDINE MS-PLUS Moisture Scavenger eliminates the detrimental effects of excessive humidity during the application of two-component polyurethane and polyurea compositions. If it has not already been incorporated into the product during manufacturing, the addition of three to five weight percent of ZOLDINE MS-PLUS Moisture Scavenger to the polyol and/or amine side of a finished formulation, followed by a minimum of 15 minutes of vigorous mixing, will totally eliminate application humidity problems (e.g. downglossing, haze, bubbles or pinholes).

As ZOLDINE MS-PLUS Moisture Scavenger reacts with water, it hydrolyzes to form a volatile ketone (MIAK) and an amino alcohol (N-ethylethanolamine) with a functionality of two and a molecular weight of 89. Care should be taken not to upset the isocyanate/hydroxyl ratio when incorporating ZOLDINE MS-PLUS Moisture Scavenger into a polyurethane and polyurea composition.

ZOLDINE MS-PLUS Moisture Scavenger is effective in dehydrating the components found in IPDI-based one-component moisture-cure polyurethanes. However, it is not compatible with aromatic isocyanates and is marginally compatible with HDI. Thus, it is only recommended for use in IPDI-based one-component moisture-cure systems.

Handling Guidelines

As with any chemical, proper precautions must be taken to ensure its safe and effective use. Before using this product, refer to the most recent Material Safety Data Sheet from ANGUS Chemical Company, as well as technical data sheets which provides information on toxicology, environmental effects, precautionary labeling, first aid, shipping and packaging, and storage conditions.

Regulatory

The components of ZOLDINE MS-PLUS Moisture Scavenger appear on the U.S. Environmental Protection Agency's TSCA Chemical Substance Inventory.

Product Stewardship

ANGUS encourages its customers to review their applications of ANGUS products from the standpoint of human health and environmental quality. To help ensure that ANGUS products are not used in ways for which they are not intended, ANGUS personnel will assist customers in dealing with environmental and product safety considerations. For assistance, Safety Data Sheets, or other information, please contact your ANGUS representative at the numbers provided in this document. When considering the use of any ANGUS product in a particular application, review the latest Safety Data Sheet to ensure that the intended use is within the scope of approved uses and can be accomplished safely. Before handling any of the products, obtain available product safety information including the Safety Data Sheet(s) and take the necessary steps to ensure safety of use.

Contact Information

angus.com

North America
+1 (847) 808-3887

Latin America
+55 (11) 94245-5307

Western Europe
+33 670654658

Central and Eastern Europe
+33 670654658

Middle East and Africa
+33 670654658

Indian Subcontinent
+33 670654658

Greater China
+65 8686 5712

Japan and Korea
+65 8686 5712

Southeast Asia and New Zealand
+65 8686 5712

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