The Big TEGO

The ultimate reference for the paint and coatings industry

4th revised edition 2014
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TEGO®, ADDID®, SILIKOFTEL®, SILIKOPHEN®, SILIKOPON®, SILIKOPUR®, NANOCRYL®, NANOPOL®, NANOPOX®, ALBIDUR®, ALBIFLEX®, SIPERNAT®, AEROSIL®, VESTANAT®, DYNASYLAN® are registered trade marks of Evonik Industries AG or one of its subsidiary companies and they are written in capital letters.
Dear Reader,

The old adage goes: “Great oaks from little acorns grow” – and you’ve surely experienced the truth of this and can recall plenty of examples. It is often the small things, the things you barely notice or perceive, that make the difference.

For example, spices improve the flavor of our food and greatly contribute to our enjoyment of it. Similar remarks apply to many of Evonik’s TEGO products in the coatings and printing ink industries. Added to paints, coatings, and printing inks, often only in small quantities, they substantially improve the quality and performance characteristics of coating films. That’s the meaning of our motto: Adding Advantages, which you’ve been seeing on all our communications since early 2011.

The coatings and printing ink industries are important target markets for Evonik. Always on top of technological advances, Evonik can help customers develop scratch-resistant coatings for cars, wood flooring, and even cell phones or wall paints that do not soil easily or contain self-cleaning mechanisms. There are even products with strong anti-graffiti effects which prevent adhesion of spray paint or help remove it easily.
In the area of coating materials, Evonik is represented in almost all product classes. Our leading market positions are secured through our research and development. We demand and promote a lively exchange of information between specialists of the individual business lines that supply the coatings industry. Time and again, this has allowed joint projects with customers to develop solutions that a unit working in isolation would have struggled to achieve. This is one of Evonik’s great strengths.

As previously mentioned, TEGO products are often used in very small quantities, usually in proportions of less than one percent, as in the case of TEGO additives. Despite their small presence in formulations, their action is usually crucial. Many advanced coating techniques would be inconceivable without the use of these Evonik products. Our additives also help protect the environment by effectively reducing the use of solvents or allowing replacement of solvents with water, as in the case of defoamers and deaerators. Many of today’s waterborne coatings would not exist without the use of our additives.

In the area of specialty binders such as silicone resins, Evonik has once again attracted attention through its innovations. While the focus was initially on heat-resistant coatings for bakeware, today’s applications go far beyond the kitchen. Silicone resins are now also used as waterproofing agents in exterior wall paints and as corrosion protection coatings. The use of specialty silicone hybrid resins allows production of many industrial coatings of particularly low solvent content.

TEGO co-binders are distinguished by a particularly wide property spectrum. In many coatings and printing inks, they improve drying behavior, flexibility, and adhesive strength in addition to increasing film hardness and gloss.

With last year’s introduction of silica-nanocomposites, Evonik brought a new product group to its portfolio. This line is distinguished primarily by improved abrasion resistance combined with high transparency in applications such as wood and plastic coatings.

But it isn’t just our innovative products that you can rely on: our employees in sales and application technology also offer outstanding customer service. Our experts would be happy to help answer your questions about products and formulations. We are prepared to develop or
optimize coating formulations jointly with you – in any of our 11 applied technology service centers around the world. Innovation and service are what Evonik’s been offering under the TEGO brand name for 27 years.

We are convinced that innovative power and creativity will continue to remain the cornerstones of our future partnerships with you, our customers. Our investment in a new laboratory building in Essen and the initiation of R&D activities in Asia underscore this belief. In conjunction with you, we’re always on the search for future-oriented solutions. And in this endeavor, we focus primarily on that which matters the most to people: environmental compatibility and conservation of resources such as energy and raw materials.

Communicating with you in depth is important to us; this correspondence allows us to understand market needs, customer motivations, and innovation projects. It makes us think actively about what markets and consumers expect for the future and how we can support our customers today in developing their technologies of tomorrow.

I would like to thank all those who have given us the opportunity for open dialogue. Their readiness to enter into a trusting working relationship with us has greatly contributed to our mutual growth. We have been happy to take up their suggestions for product development and have implemented these wherever possible.

Please continue to place your trust in us. Give us your feedback on our products and services. In this way we can continue to improve and exceed your expectations.

The 4th edition of the TEGO Journal, with the new title “The Big TEGO”, that you’re now reading collects the most important information on TEGO products. The mechanisms of action of our additives, specialty binders, co-binders, and of the silica-nanocomposites are explained with detailed technical information. Our product highlights showcase the most important products in individual fields of application, while the product recommendation tables simplify your search for the optimal active agent for your systems. In addition, a selection of technical data sheets affords an overview of the technical properties of our products. You’ll also find contributions on the subject of resource efficiency and various articles presenting our spectrum of expertise.

I hope you find The Big TEGO to be a great resource. Ideally, it will make your work easier and provide valuable suggestions to help you meet the challenges you face. And, of course, that TEGO products will continue to be your number one choice in the future.

Yours sincerely

Dr. Dietmar Schaefer
Managing Director
Portrait
The TEGO Brand within Evonik

Evonik Industries, one of the world’s leading specialty chemical companies, is active in more than 100 countries. Creativity, specialization, continuous self renewal and reliability are the hallmarks of the company’s performance.

In the specialty chemicals sector, Evonik concentrates on high-growth megatrends – especially health, nutrition, resource efficiency, and globalization – and on entering attractive future-oriented markets. Chemical products from Evonik are used in the most diverse products and industries.

In 2010, Evonik generated 80% of its sales from leading market positions. The operational activities are divided into three segments: Consumer Health & Nutrition, Specialty Materials and Resource Efficiency. Two business units which act as entrepreneurs in the enterprise are attached to each segment.
The Consumer, Health & Nutrition segment serves customers from the consumer products, animal feed and pharma industries and produces specialty chemicals for selected industrial markets. The segment comprises the Consumer Specialties as well as the Health & Nutrition business unit. Product-based activities relating to polymeric materials and their precursors as well as additives are concentrated in the Specialty Materials segment. The segment contains the Performance Polymers and Advanced Intermediates business units.

The third segment, Resource Efficiency, offers solutions for efficient utilization of natural resources. Both the Inorganic Materials and Coatings & Additives business units are attached to this segment.

With its wide product range, the Coatings & Additives business unit serves companies in the coatings, printing inks, adhesives and sealants industries. Furthermore, the business unit develops customized functional polymers for oil additives and binders. In the Coatings & Additives Business Unit, Evonik is active world-wide in 24 production and technology facilities. The business unit has 4 business lines, each occupying a leading position in global markets: Crosslinkers, Coating Additives, Coating & Adhesive Resins and Oil Additives. With its superior products, innovations, applicational expertise and global distribution network, Coatings & Additives offers its customers all over the world a highly attractive package.

As one of the four business lines within the Coatings & Additives business unit, Coating Additives and its TEGO brand name stand for additives, specialty- and co-binders as well as nanoresins. In the Coating Additives business line, Evonik offers the coatings and printing inks industry a unique range of products – the result of over 27 years of experience during which the unit researched and developed optimum solutions together with and for its customers. With over 200 products, the range now comprises not only deaerators and defoamers but also wetting and dispersing additives, flow additives, radiation-curing additives, substrate wetting additives, rheological additives and hydrophobing agents as well as co-binders, specialty binders and nanoresins for use in waterborne, UV and solventborne coatings.
TEGO and Environment

TEGO Regulatory Product Finder – the search engine for products which conform to guidelines

Consumer and environmental protection are increasingly important. To meet this challenge various governments have issued regulations and guidelines. Many consumer-oriented companies have also formulated their own standards.

As the regulations are not harmonized, manufacturers of coatings and printing inks must take care to conform to the guidelines appropriate to their market.

TEGO helps to get an overview:

You will find the TEGO Regulatory Product Finder at www.tego.de. This search engine offers quick and easy access to the recommendations for additives and products according to the current guidelines.

Of course our experts in product safety will be pleased to help you further with problems concerning "TEGO Additives/Resins and Guidelines".
REACH – on track

For the many problems which can be solved by additives, there are suitable TEGO products. The implementation of REACH regulations, therefore, poses a particular challenge for Evonik.

Considerable staff time and effort has enabled us to introduce the necessary measures early, to our customers’ satisfaction. With the successful conclusion of pre-registration, we have created the conditions for continued marketing of our products. We can now concentrate on registration within the legally defined time limits. As partners with our customers, it is also our aim to ensure reliable delivery of our products.
In recent years, there have been various attempts by the coatings industry to find a response to the general trend towards ecological responsibility. There has been a general consensus with regards to the aim: environmentally responsible use of raw materials, production processes, and applications right through to disposal without compromising technological advancements or product quality.

Resource Efficiency

Various paths have been explored by the coatings industry to achieve ecological responsibility. For example, using renewable raw materials and testing product biodegradability has proven useful. Evonik’s strategy of Resource Efficiency is an additional way of dealing with this issue in the coatings field.

The comprehensive term Resource Efficiency covers many aspects, and the theme is of major importance at Evonik. So much so that it is reflected in the title of one of the three reporting units of the Evonik Group. The Evonik business lines in the coatings field are part of this reporting unit. A further description of how we contribute to Resource Efficiency is discussed in the following section.
Coatings have two important functions: to produce a visual impression and to protect substrates. In both cases, the more efficiently these functions can be achieved the less paint is necessary, thus lowering the consumption of resources. The term Resource Efficiency comprises more than that. For instance, the better the coating, the more efficiently the object will be protected which prolongs its life. In this case, the complete view encompasses more than the raw materials used in the manufacture and application of the paint.

The resources used in manufacturing the coated object must also be considered. For example, a few hundred micrometers thicker corrosion protection significantly extends the life of an extremely heavy steel bridge. Therefore, the raw materials and energy expended in manufacturing the bridge are more efficiently used.

The aim of Evonik products in the TEGO brand is to enable our customers to formulate outstanding paints and coatings. Thus our additives, specialty- and co-binders help modern coating systems to protect natural resources. The following examples illustrate this.

TEGO® Airex – fewer pinholes, less corrosion

Microfoam and pinholes are not just blemishes on a coat of paint. The thinner film at these weak points also drastically reduces the protection. Often, on coated metal showing no sign of obvious damage, the first rust originates from these deaerating defects which are only a few tenths of a millimeter in size.

The field of corrosion protection shows more clearly than any other the effect of perfectly matched additives on the function of the entire coating and therefore on the protection and life of valuable objects.

TEGO® Airex products extend the choice of usable substrates. Together with very effective and quick substrate wetting additives from the TEGO® Wet range, they enable species of wood to be coated which would otherwise not be viable industrially. Many slow-maturing hardwoods naturally have a fine grain with few pores.

To coat these without defects is state of the art nowadays. With demand increasing rapidly all over the world, it has for many years been necessary to resort to faster-growing species of wood which often have large surface pores. Optimally formulated coatings are essential to effectively wet such woods so that windows or doors manufactured from them are of high quality and durability. TEGO additives contribute to formulating these coatings.
**TEGO® Wet – only where a paint wets can it also protect**

When a paint – whether waterborne or solventborne – is applied to a substrate, the interfacial surface tension determines if it contracts or if it forms a continuous film. TEGO® Wet products help to ensure the outcome is to our customers’ advantage. Here too, the effect on the protective action of the coating can be seen. A coating can only effectively protect if it dries without imperfections or wetting defects.

The contribution of TEGO® Wet additives to conserving resources goes much further. Water, the ecologically-friendly solvent, has a much higher surface tension than organic solvents and this means that wetting problems frequently occur when changing from solventborne to waterborne formulations. TEGO® Wet additives lower the surface tension sufficiently to permit the change to waterborne systems without compromising the quality of the coating.

**TEGO® Foamex – combats foam and makes waterborne formulations possible**

In the change to waterborne formulations, a further difficulty must often be overcome – the occurrence of foam. The TEGO® Foamex range assists in preventing foam both during manufacture and application of the paint. The change from solventborne to waterborne formulations was first made possible by the use of these TEGO products. Avoiding foam during paint manufacture makes more efficient use of the dispersion energy and guarantees defect-free paint films on application.

**TEGO® Dispers – high color strength with low energy expenditure**

The TEGO® Dispers range enables color pigments (which are often expensive) to be used as efficiently as possible. Because they can produce rapid pigment wetting, TEGO® Dispers products also save valuable time and energy during the dispersion process. The TEGO® brand offers a particularly broad range of dispersing additives for waterborne coating systems and thereby supports the trend from solvent to waterborne formulations.

**TEGO® Rad – for emission-free, long-lasting UV curing systems**

Radiation-curing systems are a prime example of resource efficiency. TEGO® Rad products are exactly right for formulations without solvents or water. TEGO® Rad products contain only materials which will form the finished coating after application. The improvements they produce include increased surface slip and better substrate wetting. Additionally, as they are chemically incorporated during curing, they remain effective long-term.
**TEGO® Phobe – reliable protection of valuable buildings**

Coatings incorporating TEGO® Phobe products protect buildings from attack by moisture in the form of rain and dew. The combination of permeability to water vapor and impermeability to water droplets protects the building from damage. TEGO® Phobe products also reduce the tendency of architectural coatings to pick up dirt. Façades therefore remain visually attractive for longer and do not need to be re-painted as often. This also saves resources.

**Co-Binders – ensuring adhesion of the protective coating**

Excellent adhesion to the substrate is essential if a coating is to effectively fulfill its protective function. Co-binders of the TEGO® AddBond and TEGO® VariPlus ranges improve adhesion on numerous surfaces and thereby anchor the protective coating to the substrate.

**Specialty Binders – Silicone resins for high solids systems exposed to severe conditions**

Coatings based on silicone resins protect objects under conditions where other formulations fail. They combine low-solvent formulation with great resistance to high temperatures, chemicals and weathering. Evonik silicone resins are a reliable, low-solvent base for modern high solids formulations whether for corrosion protection in a maritime environment or coating automobile parts which must withstand temperatures of several hundred degrees Celsius.

**Silica-Nanocomposites – small particles, big effect**

Liquid silica-nanocomposites improve the scratch and abrasion resistance as well as the barrier properties of coatings. At the same time, they reduce the shrinkage of the coating. These characteristics contribute to a markedly longer life for the coating.

In conclusion, it can be said of all resources: the lower the consumption, the better for the environment. With each new generation of products, our development work aims to reduce the amounts required. Highly efficient additives, specialty binders and co-binders even in the smallest amounts contribute in their respective areas of application to the formulation of the best possible coating.

TEGO is contributing in a multitude of ways to resource efficiency in the coatings field.
TEGO Tools

The Big TEGO
The Big TEGO is among the most important TEGO tools available. With more than 300 pages, it provides comprehensive information on the various TEGO products and a detailed insight into their background and function. Now available in eight languages, it also offers selection tables and technical information sheets as well as a number of interesting reports and contributions on various topics.

The Little TEGO
Our small, compact reference work fits comfortably into the pocket of your lab coat and so is always at hand. It offers an extensive collection of information to support you in your daily work. In addition to various formulas, conversions, and standards, you will find information on topics such as paints and color, raw materials, and typical coating defects. The Little TEGO also includes a coatings glossary in five languages.

“The Little TEGO” App
The mobile version of our concise reference work contains amongst others an integrated collection of formulas which enable important parameters and data to be calculated immediately. Detailed photos show common coatings defects. Advice on hazards and safety rounds off this attractive source of information. The App is available free of charge from the iTunes Store and Android Market.

Brochures and other general descriptive material, flyers
The various general brochures and flyers provide an overview of the TEGO product range. They present the highlights of TEGO products and offer information on their diverse areas of application.

Product Overview
The TEGO Product Overview offers a detailed survey of the different product groups and individual products. You’ll also find information here on the use of the products in various fields of application.
Brochures for specific application areas
These various brochures give selective information on TEGO additives for the specific application areas of printing inks and coatings as well as building protection coatings.

Internet
On the TEGO internet website, you'll find a wide variety of options for obtaining comprehensive information on all TEGO products. Apart from detailed product overviews and other texts highlighting various aspects, the website offers you the opportunity to order samples and download technical data sheets, safety data sheets and suggested formulations. The product finder quickly directs you to the latest product recommendations. You'll also find useful information on the company and discover the varied application areas of TEGO products. Visit us at www.tego.de. We're looking forward to seeing you there!

Further information on Evonik products specifically for the paints and coatings market is available at www.smartformulating.com.

TEGO Talk and TEGO Mail
The TEGO Talk and TEGO Mail newsletters bring you regular information on new products and technical developments, summarizing for you the latest news of the TEGO product range. These newsletters also inform you about our trade show exhibits. In this way, you're always kept right up to date on the various TEGO products.

Not yet subscribed to TEGO Talk or TEGO Mail? You can order the newsletters via the Products menu item in the download area at www.tego.de. And of course you're always welcome to contact TEGO Sales Support.

TEGO Tip
With every sample dispatch we include a TEGO Tip. Every month, this flyer features a different product and gives you useful information on its properties and uses.

Smart Formulating Journal
The Smart Formulating Journal gives you an excellent overview of all Evonik’s activities in the paints and coatings market. The content is not restricted to the TEGO product range, but extends also to all other Evonik Group products in the area of paints and coatings. Twice a year, for example, the Journal reports on current developments in Evonik’s Coatings unit, covering all coating components. The Smart Formulating Journal is also available on the internet at www.smartformulating.com.

TEGO Sample Rack
The TEGO Sample Rack displays TEGO sample bottles to best effect. Every sample bottle has its own place on this practical rack and is readily located. The custom designed rack is easily installed and an attractive eye-catcher in every workplace. Lists of the most important samples for every application area are available for the rack.
Global networking – a foundation for success

Successful people usually have a large, intensive network of social relationships. Networking is a methodical, systematic procedure for forming contacts, cultivating relationships and maintaining them long-term. The aim includes the interchange and mutual promotion of interests.

People with an effective network achieve their goals more quickly in both their professional and private life. This is also true for us.

A comprehensive, focused worldwide network of contacts is the foundation for the long-term success of TEGO. The interface with our customers plays a crucial role. Thus in the "Contacts" section of this "Big TEGO" alone there are some 80 contacts – that is 80 opportunities to discuss your concerns with experts.

Networking also plays a remarkable role in innovation. We are always fine-tuning our internal networks to encourage creative innovation. Instilling a corporate culture which encourages a willingness to learn and the shortening of paths by which information is circulated are important factors.

Of the most importance to us are the networks with our customers and raw-material suppliers which allow us to collect and understand information about customer requirements and changes in the market. Partnerships are important particularly in the innovation process so that new, open and creative solutions can be found.

Here, networking of TEGO with Evonik’s research resources plays a decisive role. Access to the Evonik Chemicals Business Area’s key technologies and know-how provides an ideal basis for a quick response to market demands for innovative products and concepts.

Effective networks are not measured by size alone but also by their structure. The network of relationships should not be too complex at the crucial points. Alongside tailor-made courses for customers, our philosophy includes close cooperation with agents, distributors and the end-users. Of course, this involves joint customer visits and a mutual exchange of information and knowledge.
Our Sales Support Department rounds out customer and partner relations management. A team of international, multilingual colleagues guarantees effective communication with our customers.

Just as three-dimensional networks of binder molecules are often the basis for the unique properties of coatings and printing inks, our communication network is also multidimensional. Involvement of customers so that they feel an integral part of the partnership is key to us.

Become part of our network – it is worth it!
Europe
Austria
Eric Godden
PHONE +32 3 2857344
FAX +32 3 8289164
eric.godden@evonik.com
Belarus
COOC Tecom-Chemie
PHONE +375 172 984-214
FAX +375 172 984-215
e.petrashko@hsh-chemie.com
Belgium
Eric Godden
PHONE +32 38257344
FAX +32 38283944
Dirk Werckx
PHONE +32 11277144
FAX +32 11891744
dirk.werckx@evonik.com
Bosnia and Herzegovina
Parka distribucija d.o.o.
PHONE +38 3 16612-095
FAX +38 3 16612-098
info.hr@parkagroup.com
Bulgaria
HSH Chemie EOOD
PHONE +359 2808-8285
FAX +359 2808-8260
m.shivarova@hsh-chemie.com
Croatia
Parka distribucija d.o.o.
PHONE +386 45022-810
FAX +386 45022-819
djuro.nenadovic@parkagroup.com
Czech Republic
HSK Chemie s.r.o.
PHONE +420 2 612-23555
FAX +420 2 612-25971
k.kukastikova@hsh-chemie.com
Denmark
Martin Spahn
PHONE +45 6051 977947
FAX +45 6051 977947
martin.spahn@evonik.com
Finland
Neil Cordwell
PHONE +358 161 7629773
FAX +358 161 7629773
neil.cordwell@evonik.com
Andrew Gent
PHONE +44 7980172415
FAX +44 1642279503
andrew.gent@evonik.com
Netherlands
Eric Godden
PHONE +32 3 8253744
FAX +32 3 8283944
eric.godden@evonik.com
Dirk Werckx
PHONE +32 3 2177744
FAX +32 3 8578164
dirk.werckx@evonik.com
France
Sylvie Baert
PHONE +33 160823779
sylvie.baert@evonik.com
Christian Cète
PHONE +33 474575052
christian.cote@evonik.com
Germany
Evonik Industries AG
PHONE +49 201 173-2222
FAX +49 201 173-1939
info-tego@evonik.com
Liane Lauer
PHONE +49 511 2135396
FAX +49 511 2138382
liane.lauer@evonik.com
Martin Spahn
PHONE +49 6051 977947
FAX +49 6051 977947
martin.spahn@evonik.com
Burghard Wunderlich
PHONE +49 2151 5604084
FAX +49 2151 5604085
burghard.wunderlich@evonik.com
Great Britain
Neil Cordwell
PHONE +44 161 7629773
FAX +44 161 7629773
neil.cordwell@evonik.com
Andrew Gent
PHONE +44 7980172415
FAX +44 1642279503
andrew.gent@evonik.com
Dr. Benjamin Stiefvater-Thomas
PHONE +47 1772 432 395
TELEFAX +47 9217 868 005
benjamin.thomas@evonik.com
Hungary
HSH Chemie Kft.,
PHONE +36 1 450-3229
FAX +36 1 450-3229
m.nemeth@hsh-chemie.com
Italy
Gianmarco Brugnoli
PHONE +39 3483643775
FAX +39 3483643775
gianmarco.brugnoli@evonik.com
Massimo Cova
PHONE +39 3483643775
massimo.cova@evonik.com
Valerio Restelli
PHONE +39 3483643774
valerio.restelli@evonik.com
Montenegro
Parka d.o.o.
PHONE +381 112287560
FAX +381 112272970
nenad.stojmenovic@parkagroup.com
FYR Macedonia
Parka d.o.o.
PHONE +385 112287560
FAX +385 112272970
nenad.stojmenovic@parkagroup.com
Sweden
Neil Cordwell
PHONE +46 161 7629773
FAX +46 161 7629773
neil.cordwell@evonik.com
Andrew Gent
PHONE +44 7980172415
FAX +44 1642279503
andrew.gent@evonik.com
Poland
Robert Styzynski
PHONE +48 22 7536-10
FAX +48 22 7536-05
robert.styzynski@evonik.com
Remigiusz Debczak
PHONE +48 22 751168
remigiusz.debczak@evonik.com
Portugal
Horquim-Representaçoes, Lda.
PHONE +351 22 967-0496
FAX +351 22 967-3187
horquim@horquim.pt
Romania
HSH Chemie SRL
PHONE +40 21 313-7778
FAX +40 21 315-7864
v.zamfir@hsh-chemie.com
Russia
Evgeny Averin
PHONE +7 495 72128-62
FAX +7 495 72128-52
evgeny.averin@evonik.com
Republic of Serbia
Parka d.o.o.
PHONE +381 1122 85760
FAX +381 1122 7290
nenad.stojmenovic@parkagroup.com
Slovakia
HSH Chemie s.r.o.
PHONE +420 261 233555-9
FAX +420 261 225977
k.lukastikova@hsh-chemie.com
Slovenia
Parka d.o.o.
PHONE +386 4 502-2810
FAX +386 4 502-2819
irena.oman@parkagroup.com
Spain
Ramon Garriga
PHONE +34 93 362 621 591
FAX +34 93 362 621 592
ramon.garriga@evonik.com
Ukraine
Tecom Ltd.
PHONE +380 44 248-1225
FAX +380 44 248-1226
s.kostrov@hsh-chemie.com

NAFTA
Canada
Evonik Goldschmidt Corporation
PHONE +1 905 319-4186
FAX +1 905 633-7553
asktego@evonik.com
Mexico
Evonik Degussa México, S.A. de C.V.
PHONE +52 555 483-1004
FAX +52 555 673-8649
asktego@evonik.com
USA
Evonik Corporation
PHONE +1 800 446-1809
FAX +1 804 567-6290
asktego@evonik.com

Asia
Australia (Sydney)
Brenntag Australia Pty. Ltd.
PHONE +61 2 9506-2400
FAX +61 2 9580-8045
snair@brenntag-asia.com
Hong Kong
Evonik Hong Kong Ltd.
PHONE +852 2225-6100
FAX +852 2225-6179
sharon.ma@evonik.com
Indonesia
PT. DKS Indonesia
PHONE +62 21 2597-1570
FAX +62 21 2597-1571
setya.herdiyani@dksh.com
Japan (Osaka)
Evonik Japan Co., Ltd.
PHONE +81 6 6644-1575
FAX +81 6 6644-1578
katsuhiko.ishi@evonik.com

Your Contact Partners Worldwide
Competences
Adding Advantages

Additional benefits and special effects with TEGO products

For over 27 years, TEGO has been a reliable partner with innovative solutions. We aim to develop with our customers eco-friendly products for new areas of application. The TEGO portfolio comprises various product groups which generate different effects to improve the properties of coatings for widely differing uses in the coatings industry.

Our additives, such as hydrophobing agents, specialty binders and co-binders can provide our customers with additional benefits which are not always immediately obvious. Since these effects are as different as they are diverse, we will limit ourselves at this point to describing the characteristics generated by our TEGO® Glide additives.

It is generally accepted that the use of surface-active additives in coatings is necessary to smooth out all the irregularities caused by the topography of the substrate or by the application process.
Surface active additives include modified siloxanes derived from low molecular weight polydimethyl siloxanes in which individual methyl groups are replaced by a variety of organic side chains such as polyethers. Usually they are products with a molecular weight range between 1,000 and 15,000 g/mol. In principle, the property profile of modified siloxanes is dependent on their silicone content, the structure of the siloxane backbone and the side chains.

Polyethers are generally made up of ethylene oxide units (EO) and propylene oxide units (PO). Polyethylene oxide is very hydrophilic (polar), polypropylene oxide, in contrast, is hydrophobic (nonpolar). The polarity can thus be adjusted via the EO/PO ratio. Besides the EO/PO ratio of the polyether and the number of polyether chains, properties essentially depend on whether the side chains are statistically distributed along the polysiloxane chain (comb-like structure), whether a block structure is present or the polysiloxane chain is only terminally modified. The way the polyether side chain is attached to the basic polysiloxane framework is also important.

Silicone additives are often mentioned in the paint industry and many formulators associate these with cratering which can be caused by silicone oils. Although polyether siloxanes differ considerably from silicone oils, the use of this product group is frequently avoided. Modification by our polyether chemistry is, however, the key factor to rule out such cratering.

Insufficient flow in the applied paint film, particularly in the interval between application and curing is thought to be caused by the formation of surface tension gradients which frequently hinder the generation of a “smooth” surface. One cause is evaporation of the solvent used in paints.

The term “smooth” can be used in two ways when referring to paint surfaces. On the one hand, it can describe a surface which is texture (pitting) free. “Smooth” can also describe the slip characteristics and is then a measure of the frictional resistance or sliding resistance of the surface.

To obtain a “smooth” surface, free of texture which also exhibits a low frictional resistance, surface flow control additives are used in both waterborne and solventborne paints.
These surface-active additives can improve more properties than is initially apparent, including:
- inadequate substrate wetting
- cratering caused by spray mist or dust inclusion
- air-draught sensitivity
- ghosting
- Bénard cells

These additional benefits are achieved by modifying the silicone skeleton to suit the application and also varying the chain length.

Thus products which improve substrate wetting have an amphiphilic structure, i.e. the molecule contains hydrophilic and hydrophobic parts, giving them the ability to orient themselves to the interface.

These surface-active additives have up to seven siloxane units; the higher the proportion of Si in the molecule, the greater is its interfacial activity.

Prevention of cratering stems from the capacity of this class of products to reduce static surface tension which permits wetting and coating of impurities. Spray mist absorption is also improved.

Air-draught sensitivity, which occurs frequently especially when applying wood coatings using curtain coating equipment, can be avoided by using alkyl-modified siloxanes. Such products are also helpful with regard to a more uniform orientation of the matting agent used.

The phenomenon of “ghosting” cannot always be totally eliminated but polyethersiloxanes with a high PO content can reduce this effect drastically.
An important relevant effect is the occurrence of Bénard cells. During evaporation of the solvent, relatively solvent-rich (low viscosity) paint with a lower density flows from deeper paint layers to the surface where it spreads and the solvent evaporates. As a result, the paint in the uppermost layer of the coating has a greater density than underlying layers and subsequently sinks.

During these flows, vortices occur which may entrain pigments of differing density. Since the viscosity of the paint increases as the solvent evaporates, these flows come to a halt as the paint dries. In the ideal case, a more or less regular hexagonal honeycomb structure forms on horizontal surfaces, the so-called Bénard cells. On vertical surfaces these cells merge into stripes (silking).

In matted clear coats, the matting agent can play the role of the less mobile pigment. This also leads to a honeycomb structure or to silking in the case of vertical surfaces. With unpigmented systems, irregular finishes result. Besides these differences in surface tension occurring in the paint itself, defects can also be caused by differences in surface tension between substrate and coating.

All these phenomena can be counteracted with surface-active additives (TEGO® Glide) since they maintain the surface tension at a uniformly low level during the entire film-forming and curing process.
Shaping Technological Change with TEGO

As leading manufacturers of eco-friendly coatings and printing inks, we are actively shaping technological change to meet the demand for eco-friendly technologies which combine maximum performance, highest quality and cost-effectiveness.

Our own commitment, as well as environmental requirements, has resulted in many traditional solventborne formulations being modified to incorporate modern technologies.

However, not only waterborne and radiation-curing formulations are experiencing high growth rates. At present, the highest relative growth rates are found with solventborne, high solids coatings.
Global figures give only a limited picture as trends differ significantly from region to region and which "new technology" ultimately prevails depends strongly on the end use. Thus, in architectural coatings, waterborne paints and coatings continue to be the norm with increasingly less dependence on organic co-solvents. Up to now, radiation-curing formulations have been mainly used in wood finishes and printing inks.

Alongside this, growth in pigmented formulations has been disproportionately high. In corrosion protection and with many industrial coatings, formulators are frequently reducing VOC emissions by increasing the solids content in high solids and ultra high solids formulations.

Even though ecological aspects are often the main concern, technological change is also being driven by other demands.

Heightened user awareness of product performance, quality and customization is affecting the choice of high performance products. Many innovations in coatings development show that such demands need not be inconsistent with cost effectiveness.

For example, traditional batch processes are being increasingly replaced by semi-finished product manufacture. In coatings, pigment concentrates allow rapid production of color tints. However, pigment concentrates are also being used in decorative coatings so that end-users can individually set "their" color tint.

The raw materials industry has been closely involved in implementing and even initiating these changes. No matter whether developing solventborne high solids, waterborne or radiation-curing formulations, TEGO is the right partner to have at your side.

With our know-how and broad portfolio of innovative functional additives, co-binders and specialty binders for solventborne high solids, waterborne or radiation-curing formulations we provide you with support in the development of modern coatings and printing inks. We contribute the critical difference which makes your formulations even more successful.
Flow and deaerating problems are increasingly important when formulating high solids coating systems. At the same time high pigment and filler loads pose a challenge to maintaining application characteristics. The lower the solvent content of the formulation, the more important are powerful additives to ensure problem-free application and optimum properties of the coating. Evonik is at the forefront in this respect with its tailor-made deaerators, anti-crater-, flow-, wetting- and dispersing additives and its continually expanding product range.

TEGO co-binders improve adhesion to many metal and plastic substrates and the mechanical properties of the coating. Many of these products are themselves "high solids" and thus solvent-free or low in solvent thereby contributing to reduction in VOC. Evonik even has a sole binder, Silikopon® EF, for ultra high solids anti-corrosion coatings.

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The trend to completely solvent-free products is also apparent with radiation-curing coatings and printing inks. The use of solvents has either been eliminated or reduced to a minimum even in areas of application where they have traditionally been used. The challenges associated with this show up in the areas of manufacture and above all application.
Rheological problems increase dramatically and it becomes increasingly difficult to ensure good substrate wetting, defoaming and flow.

For many years, TEGO’s portfolio has included special solvent-free additives for radiation-curing formulations and this range is continuously increasing. We offer a complete range of tailor-made radically crosslinkable surface-active additives for radiation-curing under the TEGO® Rad brand. These ensure highly effective, low-migration wetting and flow and some grades also produce slip and release properties. Please enquire about our powerful, naturally solvent-free, wetting and dispersing additives for radiation-curing formulations. Finally, a broad portfolio of defoamers and deaerators eliminates foam problems in coatings ranging from sprayed UV clear-coats to pigmented screen printing inks.
Competence in Synthesis

We are indebted to our predecessors as their ground-breaking work and innovations in the field of organo-modified silicones laid the foundation for the subsequent success of Evonik Industries in the coatings and printing inks sector.

However, we have continued to move forward and our innovations have set new benchmarks for the development of eco-friendly coatings systems. Here we would like to give you an understanding of the extraordinarily broad range of technologies on which our innovative products are based.

The origins of many of our current products can be traced back to the broad technological foundations of the former Goldschmidt-Chemie. Today, as part of the modern specialty chemicals company Evonik, TEGO can draw on a vastly greater range of chemical knowledge and processes.
We are now experts in new methods of polymerization as in the synthesis and use of ionic liquids in special applications or modern, highly selective enzyme technologies.

As can be seen from the illustration, a key factor is silicone technology which is used in a complex, flexible and powerful silicone-composite structure in manufacturing and various research platforms. This has permitted numerous structure, topology and functionalization possibilities for the ever growing group of organo-modified silicone products.

Expertise in manufacturing, defined branched siloxane structures, and controlling production processes is one of the most important prerequisites for being able to manufacture high performance coatings additives. For example, new, innovative silicone multi-functional surfactants with very compact structures result in properties for substrate wetting additives unobtainable with conventional structures. Furthermore, radiation-curing, which allows chemical incorporation of multi-functional, organo-modified silicone additives, offers numerous possible solutions particularly for satisfying the requirements of low-migration coatings systems.

Another key resource in the field of organo-modified silicones is polyether technology. This enables customized polyethers to be manufactured from a wide range of monomers using various production processes depending on the subsequent application. Special allyl polyethers, for example, are used as important building blocks in the manufacture of silicone polyethers. Besides the choice of suitable alkylene oxides, the ability to build up the monomers block by block is a decisive criterion for application properties.

However, tailor-made polyethers are also used in various areas of modern additives. Certain special polyethers with longer, non-polar head groups have proved excellent organic surfactants, even under dynamic conditions. Ionic and non-ionic styrene oxide polyethers, on the other hand, can be processed into high-performance dispersing additives for use in universal pigment pastes. Finally, new polyether catalysis technologies are expected to lead to numerous innovative products which have been inaccessible via conventional technologies up to now.

Another mainstay in our technology portfolio are functional, organic polymers used in high quality dispersing additives, deaerators and flow and leveling agents. The intelligent linking of pigment-affinic groups (the functional groups) with a suitable polymer architecture and the widest possible range of polarity characterizes modern high-performance dispersing additives.

Besides the traditional chemical technologies for dispersing additives, which are all used at Evonik, we also use modern, controlled polymerization technologies. An understanding of interfacial interactions, such as the molecular adsorption processes on pigment surfaces, is crucial for synthesis design, a task implemented efficiently at Evonik using statistical test plans.
Our innovative silicone resin hybrid binders can play an important role in the search for new, modern, low-VOC, high solids coatings systems. Water-based primary or secondary silicone-resin emulsions are also important for our customers’ eco-friendly coatings.

Since it is often advantageous to use additives as formulated products or multi-substance mixtures, specialist formulation know-how is a core competence of our research and development chemists. Thanks to our knowledge of physical, chemical and interfacial interactions, we can increase the effect of defoamer concentrates using hydrophobic, micro-scale solids or stabilized emulsions. Besides commercially-available emulsifiers, we also have our own emulsifier portfolio.

We hope that this short overview of our technology portfolio will show you that we are one of the most versatile manufacturers of coatings additives. New technologies and resulting innovations will continue to be an important factor.
Webinars on TEGO Products

For many years now, we’ve been training customers in the use of our TEGO products, mainly through personal contact. However, your daily routine doesn’t always leave time for seminars at which you can be physically present.

Therefore, we will be offering web-based seminars, or webinars, enabling our customers to participate in online training for newly introduced products. On our Internet website www.tego.de, you will find a webinars area, where you can get an initial overview of our online training offers and register for our web-based training. Following successful registration and login, further information on individual training modules will be provided.

Webinars will allow our customers located anywhere in the world to participate in our training modules for newly launched products.
Analytics at Evonik

The international success of a company in the chemical industry is reliant on the quality of its products. The high demands made by customers on chemical products and product mixtures relate mainly to purity and reproducibility in the production process. The synthesis of a new product right through to its final stage requires reliable, modern instrumental methods of analysis which can continuously monitor purity both qualitatively and quantitatively.

Evonik uses the following modern instrumental analytical methods

1. **NMR: Nuclear Magnetic Resonance Spectroscopy**
This method is used to carry out structural characterization of soluble organic compounds for the following: product monitoring, batch analysis, purity (qualitative and quantitative), determination of end-groups, determination of chain length or degree of polymerization, determination of polymer identities and quantities in co-polymers, detection of silicone oil in coatings, characterization and differentiation of a silicone oil or a polyethersiloxane to trace levels, reaction optimization by kinetic NMR measurements, investigation of products down to a detection limit of approx. 1 ppm.

2. **IR: Infrared Spectroscopy**
This method allows several specific investigations of structure: soluble and insoluble organic compounds, special investigations of fillers, qualitative and quantitative investigations of products with a detection limit of approx. 0.1%, surface investigations of a coating, investigation of cratering on a coating, and determination of inhomogeneity of a polymer compound.

3. **HPLC-NMR: High Performance Liquid Chromatography and NMR Spectroscopy**
The combination of HPLC with NMR Spectroscopy allows mixtures to be separated into pure fractions followed by exact structural investigations using NMR.

4. **GC-MS: Gas Chromatography and Mass Spectroscopy**
All volatile components of a mixture can be characterized using this combined method. Evaluation involves the use of extensive software.
5. LC-MS: Liquid Chromatography and Mass Spectroscopy
This method is a combination of liquid chromatography with mass spectrometry. The chromatography separates components and mass spectrometry is used to identify and/or quantify the individual components.

6. GPC: Gel Permeation Chromatography
GPC characterization of polymer samples encompasses determination of the molecular mass distribution and average molecular mass with a RI (Refractive Index) detector. Peak position calibration is carried out using commercially available, linear-structure standards.

7. MALDI: Matrix Assisted Desorption Ionization
MALDI is a method for characterization of biomolecules and synthetic polymers. The principle involves ionization produced using a UV laser. The polymer under investigation is incorporated in a UV-active matrix. Molecular cations are formed. The matrix prevents molecular fragmentation.

8. Organic wet chemistry
Effective methods for rapid determination of characteristic values are important. Parameters such as hydroxyl value, acid value, iodine value, amine value, color index, betaine concentration, and anionic- and cationic-surfactant concentrations can be rapidly determined by wet chemical methods.

The combination of all the analytical methods which are available to us at Evonik enables investigation of all relevant chemical materials and product mixtures and thus allows us to satisfy the demands of our customers.
**Product Group Co-Binders**

**TEGO® VariPlus – for a brilliant appearance**

With TEGO® VariPlus, Evonik offers a comprehensive range of special purpose resins for customizing the properties of coatings and printing inks.

TEGO® VariPlus are film-forming co-binders based on modified ketone-aldehyde resins. These are widely compatible with the most diverse binder systems and solvents.

With the help of TEGO® VariPlus, the solids content in paints can be increased. The hyper-branched polymer structures result in low solution viscosities which can lead to significantly lower solvent content in paints formulated with them. Furthermore, film hardness, adhesion to various substrates, gloss and film build can be modified.

Since TEGO® VariPlus products are unsaponifiable, corrosion protection is also improved. Some of the products are very resistant to, for example, heat, acids and alkali solutions and can thus improve resistance to yellowing and chemicals. The customized incorporation of functional groups makes TEGO® VariPlus well suited for high color intensity pigment pastes.

Consequently, they are used as resins for pigment pastes in coatings formulations which cure at moderate baking temperatures. Pigment loading can be increased and even at high pigment content, excellent gloss can be obtained.

TEGO® VariPlus products can be used in solventborne formulations with low VOC content, waterborne or radiation-curing systems.
**TEGO® AddBond – for maximum adhesion**

Under the TEGO® AddBond brand name, Evonik markets high performance products for use as adhesion promoters in coatings and printing inks. TEGO® AddBond products are based on special purpose polyesters which, because of their polymer structure and functional groups, are effective on different substrates.

Improved adhesion is achieved on numerous substrates (metals, minerals and plastics) and TEGO® AddBond products are thus frequently used in primers. Furthermore, they improve intercoat adhesion so that they are also highly recommended for use in multi-coat systems. In special effect coatings, they improve cohesion within the film. The adhesion properties and excellent resistance to hydrolysis of TEGO® AddBond products lead to significantly improved corrosion protection by the coating. The flexibility and hardness of the coating can also be adjusted by the various products to meet individual requirements.

The TEGO® AddBond range comprises polyester resins for use in solventborne, waterborne and radiation-curing coatings and printing inks. These systems can be physically or oxidatively drying, radiation-curing or heat-curing. Broad compatibility is guaranteed in various binder systems and solvents. The product portfolio also includes high solids binders enabling VOC content to be lowered in paint formulations.
\[ \theta = \cos^{-1} \left( \frac{\theta_1 - \theta_2}{\theta_1} \right) \]

- \( \theta \) = Contact angle
- \( \theta_1 \) = Surface tension of the liquid
- \( \theta_2 \) = Free surface energy of the solid
- \( \theta_s \) = Solid/liquid contact angle
Technical Background
## Comparison of viscosity measurements

### Dynamic viscosity

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Kinematic viscosities are only valid for liquids with Newtonian flow and the above information must therefore be regarded only as approximate.
## Units

### Units of length

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### Units of volume

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<tr>
<th>Units</th>
<th>in^3</th>
<th>ft^3</th>
<th>yd^3</th>
<th>cm^3</th>
<th>dm^3</th>
<th>m^3</th>
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### Units of area

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<th>dm^2</th>
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### Other units

- 1 mil = 10^-3 in = 0.0254 mm
- 1 sq mil = 10^-6 sq in = 645.16 µm^2
- 1 English mile = 1,609 m
- 1 Imp. gallon (Imperial gallon) = 4.546 l
- 1 US gallon (United States gallon) = 3.785 l
- 1 stone (GB) = 14 lb = 6.35 kg
- 1 short quarter (US) = 11.34 kg
- 1 long quarter (GB, US) = 12.70 kg
- 1 short ton (US) = 0.90718 t

### Units of weight

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### Dispersion and grinding fineness

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## Formulary

Important formulas for the coatings formulator

### PVC (Pigment volume concentration)

\[
PVC = \frac{\Sigma V_{\text{Pigments}} + \Sigma V_{\text{Fillers}}}{\Sigma V_{\text{Pigments}} + \Sigma V_{\text{Fillers}} + \Sigma V_{\text{Binders}}} \cdot 100\% 
\]

### Epoxide amine curing

EP value x (NH) equivalent mass = g hardener per 100 g EP resin

### Mix ratio isocyanates

\[
\frac{\text{NCO components}}{\text{OH components}} = \frac{\text{proportional weight NCO components} \times 17 \times \% \text{NCO}}{\text{proportional weight OH components} \times 42 \times \% \text{OH}} 
\]

### Spreading rate

\[
\text{Spreading rate} = \frac{\text{solid body} \times 100}{\text{dry film density} \times \text{film density} \times 100} 
\]

### Conversion of OH-number to OH-% content:

\[
\text{OH-% content} = \text{OH-number (mg/g)} \times 0.0303 
\]

### Isocyanates

\[
\begin{align*}
\text{equivalent weight NCO components (g)} & = \frac{42}{\% \text{NCO}} \times 100 \\
\text{equivalent weight OH components (g)} & = \frac{17}{\% \text{OH}} \times 100
\end{align*} 
\]

### Epoxide isocyanate curing

Hydroxyl value EP x isocyanate-equivalent mass = g isocyanate per 100 g EP resin

### OH-number

OH-number: The weight of KOH in mg, which contains the same amount of hydroxyl groups as 1 g of the substance. Units are [mg/g].
## Temperature

### Temperature Conversion Formulas

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<th>°F</th>
<th>° Réaumur</th>
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## MESH Conversion Table

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TEGO Product Groups

Additives

**Defoamers**
*TEGO® Foamex*
Defoamers prevent formation of foam during manufacture and application of coatings and printing inks. Foam already formed is destroyed and air occlusions prevented.

**Deaerators**
*TEGO® Airex*
Deaerators prevent development of air occlusions and pinholes. This is particularly important in high-viscosity and high solids formulations and indispensable for airless- /airmix applications.

**Slip and flow additives**
*TEGO® Glide & Flow*
Surface additives improve flow, slip and scratch resistance of coatings. They also prevent crater formation and flooding of pigments.

**Substrate wetting additives**
*TEGO® Wet*
Substrate wetting additives make possible uniform wetting by coatings and printing inks even on low-energy surfaces. This prevents defects in the coating such as crater formation, poor leveling or inadequate adhesion of the coating film.

**Wetting and dispersing additives**
*TEGO® Dispers*
Wetting and dispersing additives prevent floating, flooding and sedimentation of pigments in paints, lacquers and pigment concentrates. They improve color strength development, transparency and gloss. All TEGO® Dispers products are free of alkylphenolethoxylates.

**Hydrophobing agents**
*TEGO® Phobe*
Hydrophobing agents reduce the water uptake of mineral substrates, plasters and paints. The ability of the substrate to breathe (water vapor permeability) is minimally affected.

**Rheological additives**
*TEGO® ViscoPlus*
Rheological additives adjust the viscosity of paints and coatings in a targeted manner. The TEGO® ViscoPlus product line consists of associative polyurethane thickeners which satisfy the latest requirements of the industry.

All TEGO® ViscoPlus products are liquid and free of organic solvents and alkylphenolethoxylates. Furthermore, they are manufactured without the addition of organo-tin compounds.

**Radiation-curing additives**
*TEGO® Rad*
These crosslinkable additives for radiation-curing formulations increase slip and scratch resistance, improve flow and additionally prevent formation of foam.

**Multi-functional surfactants**
*TEGO® Twin*
The unique technology of the TEGO® Twin range produces excellent substrate wetting even on critical substrates and simultaneously suppresses foam formation, particularly in waterborne formulations.

**Anti-graffiti additives**
*TEGO® Protect*
TEGO® Protect provides anti-graffiti and easy-to-clean properties in 2-pack polyurethane coatings. The TEGO® Protect range is used as a crosslinkable co-binder in solventborne or waterborne, pigmented or colorless coatings.

**Miscellaneous**

**ADDID®**
This product line includes silane adhesion promoters and polybutadienes. Silane adhesion promoters form a permanent chemical link between the coating and substrate leading to a marked improvement in adhesion. Polybutadienes are used both to reduce viscosity and achieve faster drying of offset printing inks.

**Hammer effect additives**
*TEGO® Hammer*
Additive for producing a hammer effect finish. The strength of the hammer effect can be changed by adjusting the amount.
Co-Binders

Synthetic resins
TEGO® VariPlus
TEGO® VariPlus resins are non-film-forming co-binders based on modified ketone-aldehyde resins. These special resins allow targeted adjustment of the properties of paints, coatings, printing inks and other inks. TEGO® VariPlus resins can raise the solids content in paints, the hardness of coatings and the color strength of pigmented systems.

Adhesive resins
TEGO® AddBond
The TEGO® AddBond range consists of powerful adhesion-promoting components for paints and printing inks. Adhesion is promoted on a wide variety of substrates. The TEGO® AddBond range includes polyester resins for use both in solventborne, waterborne or radiation-curing paints and printing inks.

Specialty Binders

Silicone resins
SILIKOPHEN®
The SILIKOPHEN® range is based on methyl-phenyl silicone resins. Depending on the formulation, it offers corrosion protection up to 650°C and is used, for example, in car exhaust systems or combustion chambers. SILIKOPHEN® P resins can be cold mixed with organic binders (alkyd or acrylic) and are suitable for manufacturing coatings with a variety of properties.

Silicone polyester resins
SILIKOFTAL®
SILIKOFTAL® resins are suitable for heat resistant coatings with long-term heat resistance up to 250°C. This product group combines the properties of the silicone resin with those of the polyester and is therefore particularly suitable for decorative coatings such as cookware, bakeware, electrical household appliances and industrial equipment.

Silicone epoxy resins
SILIKOPON®
SILIKOPON® resins are the basis for isocyanate-free, air drying, 2-pack, anti-corrosion coatings. Coatings made from SILIKOPON® are strongly resistant to chemicals and have a high color stability while retaining excellent gloss.

Nanoresins

Silica-nanocomposites
NANOCRYL®, NANOPOX® and NANOPOL®
Silica-nanocomposites are preferred where high scratch and abrasion resistance is needed at the same time as transparency. The NANOCRYL® range consists of silica-nanocomposites in different common UV-curable acrylate monomers. They are intended for use in radically cured UV paints. NANOPOX® materials are based on epoxide resins and corresponding reactive thinners. The NANOPOL® range can be used in solventborne products and is almost universally applicable. In spite of the high degree of filling (50% silica nanoparticles), they remain crystal clear.
Defoamers
TEGO® Foamex
Foam is a phenomenon which frequently occurs during the manufacture and application of coatings and printing inks. The formation of foam interrupts, for example, production processes, reduces the effective volumes in the production plant and leads to unnecessary downtimes. Foam also interferes with the application process. In printing, foam can cause the ink reservoirs to overflow and impairs ink transfer from the printing cylinder to the substrate. Dried foam leaves surface defects in the paint film.

The cause of foam is the introduction of gas into the liquid material. This can occur by:
- mechanical introduction of air during manufacture by stirring and mixing
- displacement of air during wetting of pigments and fillers
- mechanical introduction of air during applications such as rolling, spraying, printing
- displacement of air when coating porous substrates
- chemical reaction such as the secondary reaction of isocyanates with water

Stabilization of the liberated air to form foam occurs as a result of surface-active substances (surfactants) present in coatings and printing ink formulations where they are essential for stabilizing, dispersing and wetting the formulation.

The occurrence of foam must therefore be considered as an undesirable but unavoidable phenomenon in coatings and printing inks. To prevent foam and destroy any foam present, defoamers have to be added to the formulation.

What is foam?

A stable dispersion of gas in a liquid is called foam. If a stream of air is introduced into a liquid, the bubbles produced assume a spherical shape. Since they are lighter than the liquid, the bubbles rise. A gas bubble, which has penetrated a surfactant-free liquid, has only limited stability and bursts spontaneously. Air from the bubbles escapes and the liquid previously surrounding the air flows back. Therefore, stable foam does not form in pure, surfactant-free liquids (fig. 1).

In liquids such as paints containing surfactants, the gas bubbles are stabilized by the surfactants. A surfactant film forms around the gas bubble. If these bubbles reach the surface, which is also coated with surfactants, a surfactant-stabilized double layer or duplex film is formed (fig. 2).
Duplex films can occasionally be fractions of a millimeter thick. Despite their very small film thickness, they can form very stable foams which are extremely difficult to destroy.

One can distinguish between two types of foam: macro- and micro-foam. Macro-foam is the foam visible on the surface. Foam bubbles generally have a diameter of more than 50 μm and are stabilized by a duplex film. Very fine foam bubbles, which are entrapped in the matrix of the coating film, are called micro-foam. To eliminate macro-foam, defoamers are used; to eliminate micro-foam, deaerators are used. (see “Technical Background Deaerators”).

Once the macro-foam bubbles have penetrated the surface, they initially become spherical. In this phase, the volume of the liquid in the foam is greater than the volume of the air in the foam bubbles. Therefore, this foam is termed wet foam. The foam bubbles are still spherical and are stabilized by thick foam lamellas. The bubbles from the liquid cause a continuous rise in the foam head.

The liquid flows out of the foam lamella under gravity. During this so-called drainage process, the proportion of air in the foam increases. The spherical foam is now forced to take on a more stable polyhedral shape. The polyhedral foam is termed dry foam because the volume content of liquid is small. Polyhedral foam consists of very thin (approx. 100 nm) but very elastic foam lamellas, which are stabilized by the surfactant molecules coating the surface. The varying structure of foam is summarized in fig. 3.

**Foam stabilization**

Drainage would be expected to completely remove the water from foam lamellas which would then collapse on their own accord. In practice, drainage comes to a halt when loss of liquid in the lamellas causes the surfactant concentration to be so high that steric or electro-static repulsion forces between the surfactant molecules prevent further retraction of the lamella walls. The foam lamella attains a thermodynamically stable state of equilibrium between drainage and

---

**Figure 3: Structure of foam and stabilization of the lamella by surfactants**
surfactant repulsion. Highly thinned foam lamellas are therefore very stable and very elastic. The elasticity of the lamellas can be explained in terms of the Gibbs-Marangoni elasticity. An increase in the lamella surface caused by deformation of the foam lamella leads to a locally reduced concentration of surfactant and, with it, an increase in the surface tension of the lamella. The resultant imbalance results in strong restoring forces towards the energetically more favorable unstretched state of the foam lamella (fig. 4).

**How do defoamers work?**

Whether defoamers or deaerators are used depends on the type of foam, i.e. macro- or micro-foam. To eliminate macro-foam on the surface, prevent large air occlusions and for rapid foam collapse in waterborne formulations, defoamers are preferred. If finely dispersed air needs to be removed from the system, deaerators are preferred. In practice, it is usually not possible to differentiate clearly between defoamers and deaerators. Most defoamers are also effective to some degree as deaerators and the reverse is true. The mechanisms of deaeration are described in the section on deaerators.

Defoamers work by penetrating the foam lamella, destabilizing it and making it burst. Investigations using model systems have resulted in various mechanisms of defoaming being discussed in the literature. From the models, it is possible to deduce the requirements a compound or formulation must meet to be effective as a defoamer.

**Requirements for defoamers:**
- insoluble in the formulation to be defoamed
- low surface tension
- positive penetration coefficient (E)
- positive spreading coefficient (S) or positive bridging coefficient and dewetting characteristics

Fundamentally, a defoamer must be insoluble in the formulation to be defoamed where it should be present in the form of finely divided droplets. Furthermore, it is necessary for it to be sufficiently compatible with the medium to be defoamed not to cause surface defects such as craters. The choice of defoamer is therefore always a compromise between defoaming performance and compatibility/insolubility.

As already described, defoamers work by penetrating and destroying the foam lamellas. It is a prerequisite that the defoamer is in a position to penetrate the surface of the foam lamella. The first barrier to be overcome when penetrating is the pseudoemulsion film. This is a thin liquid lamella between the rising defoamer droplet and the liquid surface. If the pseudoemulsion film is too stable, a defoamer droplet cannot penetrate the surface and defoaming is not possible.

Once the defoamer droplet has overcome the pseudoemulsion film and penetrated the lamella, its further behavior can be described using the penetration coefficient which can be calculated from the interfacial tensions between the three phases: the liquid to be defoamed, defoamer and air. It describes the force equilibrium between the three phases.

![Figure 4: Gibbs-Marangoni elasticity](image-url)
Only if the penetration coefficient remains positive, does the defoamer remain permanently on the lamella surface. If the penetration coefficient is negative, the defoamer drop can migrate back to the liquid phase.

\[ S = \gamma_{wa} - \gamma_{wo} - \gamma_{oa} = \gamma_{wa} - (\gamma_{wo} + \gamma_{oa}) \]

spread coefficients formula

\[ E = \gamma_{wa} + \gamma_{wo} - \gamma_{oa} \]

\( \gamma_{wa} \) = surface tension of the foaming liquid
\( \gamma_{wo} \) = interfacial tension between the defoamer and the foaming liquid
\( \gamma_{oa} \) = surface tension of the defoamer

If one assumes the interfacial tension of the foaming medium \( \gamma_{wo} \) is constant, the equation shows that a positive spreading coefficient can only be achieved if the surface tension of the defoamer \( \gamma_{oa} \) is sufficiently small.

The defoamer droplet may spread after penetrating the lamella. If a defoamer can spread on the surface, it forms a defoamer lens at the lamella surface and displaces the surfactants at this location. As a result, the stability and flexibility of the lamella are impaired and it may collapse. The spreading process leads to flow of the lamella liquid along the direction of spreading. This phenomenon, also known as Marangoni flow, causes a local thinning of the lamella at the location of the spreading defoamer droplet and leads to further destabilization of the lamella. The penetration and spreading of a defoamer droplet is illustrated in fig. 5.

Defoamers with insufficient spreading power may defoam through another mechanism called bridging. The basic prerequisite is that the defoamer is capable of penetrating the foam lamella and has a positive penetration coefficient. Defoaming by bridging requires that a defoamer droplet which has penetrated the lamella surface must also be capable of penetrating the opposite lamella side. Frequently, this is only possible once the lamella has been sufficiently thinned by continued drainage. In some cases, defoamer droplets become sufficiently large by coalescing with other defoamer droplets for the bridging mechanism to occur. If the defoamer droplet has penetrated both sides of the lamella, a subsequent dewetting or stretching mechanism can lead to rupture of the lamella.

The spreading behavior can be described via the spreading coefficients as the equilibrium of the surface tensions of the three phases with each other. Only defoamer droplets with positive spreading coefficients can spread on the surface of the medium to be defoamed.

The equation for spreading coefficients shows that defoamers can only spread if the sum of their interfacial tensions to air and to the medium to be defoamed is smaller than the surface tension of the foaming liquid.

Figure 5: Penetration and spreading of the active ingredient of the defoamer
Technical Background_Defoamers

A basic condition for both mechanisms is for the bridging coefficient of the defoamer to be positive.

Calculation of the bridging coefficients involves the square of the interfacial tensions. The bridging coefficient can only be positive if the interfacial tension between the defoamer and air is sufficiently small.

In the case of the dewetting mechanism, the foaming liquid is not capable of wetting the surface of the defoamer droplet. Consequently, dewetting of the defoamer droplet occurs and the foam bubble collapses. Solid defoaming agents can also act via a dewetting mechanism (fig. 6).

If defoaming takes place via a stretching mechanism, the bridging defoamer droplet marks the weakest point in the lamella. If the lamella stretches, it ruptures at even very low stretching forces on the defoamer droplet (fig. 7).

**Figure 6: Film bridging during defoaming**

**Figure 7: Dewetting during defoaming**
Typical active substances for formulating defoamers for waterborne coatings are: polysiloxanes (silicones), mineral-, vegetable-oils and/or polymers. Particularly effective defoamers tailored to specific applications can be formulated by combining the substances with each other and also by adding fine-particle hydrophobic solids such as silicas.

**Silicone defoamers (polysiloxanes)**

Polysiloxanes and modified polysiloxanes belong to the most widely used group of defoaming substances. An enormous range of defoaming agents is accessible via modification with polyethers or other polymers. The compatibility and effectiveness of these can be adjusted to suit individual coatings formulations. Polysiloxane defoamers have very high spreading characteristics and are highly effective. They are used particularly frequently in modern waterborne coatings and printing inks where high demands are made on defoaming characteristics and surface finish. Applications include pigmented and unpigmented wood, architectural and industrial coatings and printing inks. They do not impair gloss and are distinguished by good compatibility. Modified polysiloxanes are synthesized by forming a Si-O-C or a Si-C link between the siloxane block and the organic modification (fig. 8).

**Mineral oil defoamers**

Mineral oils, with their high spreading power and high incompatibility, have long been used as defoaming agents. Nowadays, aliphatic mineral oils are used in defoamer formulations. Aromatic oils are increasingly rare because of environmental and physiological considerations. Mineral oils are frequently used in the architectural paints and printing inks sectors. When used in waterborne formulations, where high demands are made on the gloss of the finish, mineral oils frequently reach their limits since they tend to impair gloss or cause other surface defects.

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**Figure 8: Typical polyether siloxane structures**

- ABA block copolymer
- Branched copolymer
- Comb-shaped copolymer
- $A(BA)_n$ block copolymer

- $Me - Si - O -$ and similar
- Hydrophobic polyether

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Vegetable oil-based defoamers

As renewable raw materials, vegetable oils are increasingly important in the formulation of defoamers. They exhibit high incompatibility and have very similar properties to those of mineral oils. They are used mainly in architectural paints but are increasingly important in other sectors.

Polymer-based defoamers

Examples of polymer-based defoamers include modified fatty acids, polyethers or modified amides. The polarity of the defoamers can be adjusted via the composition of the polymers. The effectiveness of polymeric defoamers is frequently inferior to that of other substances. However, the wide choice of polymeric defoamers enables the effectiveness and compatibility of the defoamer to be precisely adjusted for very critical coatings systems. Therefore, polymeric defoamers are frequently used in formulations where other defoamer technologies are too incompatible.

How are defoamers incorporated?

Choosing the method of incorporating a defoamer is largely dependent on the form in which it is supplied. Common forms are defoamer emulsions or concentrates.

In defoamer emulsions, the active substance is already finely distributed in an emulsified form. Defoamer emulsions can therefore be incorporated in the formulation using low stirring intensity. They are also suitable for subsequent addition in the ready-to-use formulation. Typical examples of Evonik’s defoamer emulsions for waterborne coatings and printing inks are TEGO® Foamex 805 N, 815 N, 822, 825 or 1488.

Defoamer concentrates consist mainly of the active defoamer substance. They are water- and solvent-free. In contrast to defoamer emulsions, the defoamer droplets which provide the defoaming effect in the finished coatings formulation must first be generated. This is typically done during incorporation of the concentrate by finely dispersing the defoamer in the coating using sufficiently high shear forces. It is therefore recommended that the defoamer concentrate be added to the millbase. The incorporation conditions can directly influence the effectiveness of the defoamer. Dispersing which is too weak results in defoamer droplets which are too large and causes surface defects. If the defoamer is too strongly dispersed, the defoamer droplets are too small and cannot develop their full effectiveness (fig. 9). Defoamer concentrates from the TEGO product range are TEGO® Foamex 3062, 810, 883 and 8050.

![Figure 9: Effectiveness as a function of droplet size](image)
Which tests are recommended for evaluating defoamers?

Decisive criteria for choosing a defoamer are the formulation and application method. Different formulations require different defoamers. Important parameters affecting the formulation include pigment loading or the chemical nature of the binder. The type of application method also affects the incorporation of foam in the coating material and thus the choice of defoamer. Defoamer recommendations from Evonik take into account suitability for particular formulations and application methods. Nevertheless, it is recommended that defoamers are tested in the laboratory before using them in production.

When choosing a defoamer for a formulation, its effectiveness should first be checked in the laboratory. Since defoaming characteristics are strongly influenced by the conditions during manufacturing and application of the paint, it is recommended that the test method permits evaluation under conditions close to those in practice. The method should also include an assessment of possible surface defects that could be caused by the defoamer.

**Stir tests**

A frequently used method for low to medium viscosity formulations is the stir test in which air is stirred into the formulation with a fast running stirrer. The effectiveness of different defoamers can be compared via the volume of foamed material. It is recommended that the volume of a control sample without defoamer is checked before and after the stir test.

**Flow test**

In this test, air is stirred into the formulation with a fast running stirrer. The freshly foamed sample is poured onto a surface. The activity of the defoamer can be assessed from the fresh pour-down. After the pour-down dries, the film can be visually assessed for foam and surface defects. The flow test frequently complements the stir test and is similarly suitable for low to medium viscosity paints.
Roller test

The roller test is used for testing paints which are applied with rollers and simulates real application conditions. The paint is applied with a roller to a substrate and foaming during application is assessed. Surface defects caused by foam, incompatibilities or air occlusions in the coating can be assessed on the dried paint film.

All procedures are shown in videos on our homepage.

FAQs:

We use TEGO® Foamex 810 in a pigmented UV wood finish and sometimes have isolated craters on the application unit. Unfortunately, we cannot reproduce this defect in the laboratory. What can we do?
One way of eliminating craters is by adding a wetting agent such as TEGO® Wet 270 or TEGO® Twin 4100 in amounts of 0.1% to 0.4%.

We manufacture various interior paints. The PVC ranges from 50% to 80%. We also use various binders in these paints. At the moment, we are also using a variety of defoamers. Is there a defoamer which is effective in all paints?
Foam formation and stabilization are usually caused by a mix of emulsifiers and stabilizers from the binder and other surface active substances added directly or indirectly via other raw materials for which the defoamer is suited. Therefore, there cannot be a universal defoamer which always functions in all formulations. However, empirical experience has shown that certain defoamers are well suited for individual areas of application. TEGO® Foamex 1488 or TEGO® Foamex 855 or TEGO® Foamex K 8, for example, perform well over a wide spectrum in the PVC range between 50 to 80% and in typical binders for this range of PVC such as styrene acrylic or vinyl acetate copolymers.

Can defoamer emulsions be diluted with glycols to mix the defoamer into coatings without compatibility problems?
We basically recommend adding defoamer emulsions in the form supplied. Diluting with solvents can destabilize the emulsion and cause it to break.

What types of pumps are suitable for conveying defoamer emulsions?
Defoamer emulsions should, in principle, be conveyed with low-shear pumps. Continuous stirring or pumping should be avoided as this can cause changes in or destabilization of the defoamer emulsion.
Deaerators
TEGO® Airex
Foam – a well-known problem

Foam is one of the most common problems which a formulator must consider when developing coatings and printing inks. It is particularly important in waterborne, radiation-curing, solvent-free and high solids formulations.

Foam is a stable distribution of small gas (usually air) bubbles in a liquid. Pure liquids, however, do not foam. A stable foam can only occur when substances with a surfactant structure are present in the liquid.

Surfactants, with their hydrophilic and hydrophobic regions, orient themselves preferentially at the liquid/air interfaces. A liquid with included or incorporated air has such interfaces. Surfactants orient themselves at this interface and thus stabilize the air bubbles producing stable foam.

Not all foams are the same

There are two types of foam: micro-foam and macro-foam. However, it is frequently difficult to distinguish easily between these foam types as they often occur together as a "foam problem."

In principle, it is possible to classify macro- and micro-foam. The former is found in, for example, the coating film surface, the latter is found within the coating film. Both types of foam can be distinguished in the liquid coatings material and in the dried/cured coating film.

Macro-foam bubbles in liquid paint are generally air bubbles surrounded by a duplex film of a surfactant double layer. Two liquid/air interfaces exist here. Micro-foam bubbles can be described as air inclusions which only exhibit one liquid/air interface. The surfactants also orient themselves in this interface and "encapsulate" the micro-foam bubble (fig. 1).

The TEGO® Foamex range of coatings additives from Evonik eliminates primarily macro-foam particularly in waterborne formulations. However, depending on the structure of the additive, they are also effective against micro-foam. These products are fully described in the “Technical Background Defoamers”.

TEGO® Airex additives are predominantly effective against micro-foam although they show positive effects when tackling macro-foam. The mode of operation of the TEGO® Airex family is described below.
Micro-foam is usually only recognized at second glance

Many coating problems are not thought of as being associated directly with micro-foam. Furthermore, entrapped air is often only recognized with the help of visual aids such as a magnifying glass or microscope.

Turbidity effects or a reduction in gloss in a coating can be caused by micro-foam bubbles, an undesirable effect in, for example, high gloss finishes (fig. 2).

Premature corrosion can be caused by micro-foam bubbles since they reduce the effective film thickness of the coating. Micro-foam bubbles can also cause small pinholes as the coating dries. These are small channels which can reach right down to the metallic substrate. The protective function of the coating is compromised and corrosion can progress more rapidly.

How is micro-foam formed?

Micro-foam consists of small air or gas bubbles in the coating. When present, surfactants orient themselves at the air/liquid interface, i.e. the air or gas bubble, and stabilize it (fig. 1).

Air or gas can be incorporated in the coating film by:
- stirring/mixing/dispersing during manufacture of the coating
- mixing when adding curing agents in 2-pack systems
- application processes such as rolling, dipping, spraying and, most importantly, airless-/airmix-spraying
- release of gas by chemical processes during curing of the coating (e.g. release of CO₂ through reaction of isocyanate with moisture)
- application on porous substrates such as wood or stone (air entrapped in pores rises in the coating)
Besides the surfactants, two further factors play a key role in the formation of micro-foam:
- the viscosity of the coating
- the size of the air or gas bubbles

**Micro-foam – relationship between viscosity of the coating and the bubble size**

The factors mentioned are closely related by Stokes’ Law which, in simplified form, is:

\[ v \sim \frac{r^2}{\eta} \]

where
- \( v \) = velocity of rise of the foam bubble
- \( r \) = radius of the foam bubble
- \( \eta \) = viscosity of the coating (fig. 3).

This means that if the coating viscosity \( \eta \) is relatively high, the rate of rise of the air/gas bubble is relatively small. Air/gas bubbles, particularly in formulations with a relatively high viscosity (e.g. high solids or UV formulations, floor coatings, high build glazes, anti-corrosion coatings), rise slowly to the coating surface. The viscosity of the coating increases as drying/curing progresses. As a consequence, the bubbles remain in the coating film and result in the well-known problem of micro-foam.

However another important relationship is indicated by Stokes’ Law: the size of the air bubble has a far more marked effect on the rising velocity than the viscosity of the coating because the radius of the bubble appears to the power of 2 in the equation.

Fig. 4 shows the rising velocity of an air/gas bubble at constant velocity as a function of its radius, i.e. its size based on Stokes’ Law.

The rising velocity of very large air/gas bubbles increases exponentially. These reach the surface during curing or drying of the coating where they form macro-foam and can be eliminated with the aid of defoamers (see “Technical Background Defoamers”).

This raises the question: What happens with small air/gas bubbles, known as the micro-foam? An answer is given in the next section.
Can micro-foam bubbles dissolve of their own accord?

Micro-foam bubbles can disappear of their own accord. They continuously shrink until they disappear. This phenomenon can be easily observed using a microscope during, for example, the drying phase of an airless-applied coating. One can easily track how the micro-foam bubbles change during this time (fig. 5).

At first, there is a mixture of micro-bubbles of different sizes. As drying proceeds, the picture alters. Relatively large micro-bubbles slowly become larger while small micro-bubbles rapidly become even smaller. They literally shrink until they disappear.

The driving force for the shrinkage of the small micro-bubbles is the Laplace pressure of the foam bubble. The Laplace pressure is given by the Young-Laplace equation, which relates the internal pressure of a micro-foam bubble to the external pressure of the surrounding medium. The smaller the micro-foam bubble, the greater the rise in the internal pressure compared to the external pressure. This pressure difference causes air from the micro-bubble to diffuse into the surrounding medium. Diffusion, and with it, shrinking of the micro-foam bubble continues faster and faster as the bubble becomes smaller.

How do deaerators work?

Effective deaerators exhibit a partial or targeted insolubility in the medium to be treated and, ideally, a certain surface activity. The deaerators concentrate preferentially at the liquid/air interface and form, in the ideal case, an additive film around the micro-foam bubble. They thus prevent stabilization of the bubble by surfactants. In addition, the partially insoluble active deaerating substances promote diffusion of air from the micro-foam bubble into the surrounding medium.

Young-Laplace equation

The internal pressure of an air bubble is greater than the external pressure as the effect of interfacial tension must be overcome. The ratio of the interfacial tension to the radius of the bubble $2\sigma/r$ is greater the smaller the air bubble. This leads to an increase in the internal pressure $P_i$. For small air bubbles between 10 and 20 μm diameter, the internal pressure can be 10 to 15% higher than the external pressure.

Laplace Pressure

Derived from the Young-Laplace equation with $P_i = P_a + 2\sigma/r$.

- $P_i$ = internal pressure of air bubble
- $P_a$ = external pressure of air bubble
- $\sigma$ = interfacial tension
- $r$ = radius of the air bubble
Partial or targeted incompatibility of the deaerator means that there is an optimum balance between the effectiveness of the deaerator and the coatings formulation. On the one hand, if the deaerator is too compatible it would not be effective. On the other hand, if it is too incompatible, defects such as craters, fish-eyes or turbidity would occur (fig 6).

What substances are effective deaerators?

There is a wide range of chemical compounds which are potentially suitable for use as deaerators in coatings including:
- organic polymers such as polyethers or polyacrylates
- dimethylpolysiloxanes (silicone oils)
- organically modified polysiloxanes, such as aryl-alkyl modified polysiloxanes
- fluorosilicones

These are frequently used for formulating deaerators. Such deaerators are supplied in the following variants:
- as concentrates with 100% active ingredient content
- as solutions in organic solvents
- as aqueous emulsions, specially for use in waterborne formulations

The effect of deaerator formulations is further enhanced by the addition of hydrophobic solids to the above mentioned active substances. Hydrophobic solids used include silicones, ureas or metallic soaps.

Is there a universal deaerator?

A deaerator is effective against microfoam and, at the same time, sufficiently compatible with the paint, lacquer or printing ink formulation. This means that the deaerator prevents/eliminates microfoam but does not give rise to, for example, flow problems, fisheyes, craters or turbidity.

This balance is dependent on the coating formulation. Changes, particularly in binder or solvent, strongly influence the effectiveness and compatibility of a deaerator. Therefore, there is no universal deaerator for all coatings systems. Rather, not only the effectiveness but also the compatibility of the deaerator with the coatings system must be checked. The choice and amount of deaerator used in the formulation as well as the method of application play important roles. Preliminary tests are certainly helpful in choosing possible deaerators.

It is essential to confirm the choice of deaerators by evaluation under end-application conditions.

Combinations of additives are helpful

In cases where deaerators are highly effective but cause surface defects such as craters, a combination with substrate wetting agents or surface active additives is recommended (see “Technical Background Slip, Flow and Radiation-curing Additives”, and “Substrate Wetting Additives”).

Storage stability tests are necessary

High storage stability is expected from many coatings systems. The ideal deaerator should therefore be effective and compatible even after extended storage. Tests under specified conditions are essential (e.g. four weeks at room temperature, 40 °C and 4 °C). In many cases a combination of several deaerators or a deaerator and defoamer is the best choice.
Which test methods for preliminary selection of deaerators have proven themselves?

Test method for low to medium viscosity coatings formulations

50 g of the coating is stirred for 1 minute at a high speed (3,000 rpm) on a dis-solver with a disc. This causes air to be incorporated and finely distributed in the coating. Immediately after stirring, the coating is poured down on a transparent polyester film fixed on a glass panel inclined at 25° to the perpendicular. During drying, the coating can deaerate. After drying, the film is assessed visually for bubbles, pinholes (effectiveness) and for possible defects such as craters, fish-eyes, turbidity or flow problems (compatibility) (fig. 7).

Evaluation of pigmented coatings can often be difficult because of their poor transparency. In this case, differences in gloss can be used as a criteria: the more micro bubbles, the lower the gloss.

Test method for medium to high viscosity coatings formulations

It is difficult to find the ideal deaerator by means of simple preliminary tests, particularly for formulations applied in thick layers by airless/airmix methods. It is more meaningful to carry out a spray application. After drying/curing, the micro bubble is examined using a magnifying glass or microscope. It can be helpful to document the results using photos.

Testing of high viscosity coatings compounds

For coating compounds (e.g. 2-pack floor coatings) the flow test on inclined surfaces is unsuitable. For such formulations, casting of defined film thicknesses (e.g. 3 mm) has proved satisfactory. In this test, the coating material is sheared for 2 minutes at 2,000 rpm to incorporate air. Directly afterwards, the material is poured onto a PE film. After 10 minutes, one third of the surface is screeded and, after drying/curing, visually assessed for foam bubbles or surface defects. (fig. 8)

In the case of high-build application, the freshly foamed coatings material can simply be filled into a lid (e.g. of a metal paint can or poly beaker) and taken out for assessment after curing (see also video “Deaerating of floor coatings”)

Testing of the finest micro-foam

Micro-foam can occur in such a fine form that it is not visible to the unaided eye and examination through a microscope or magnifying glass, etc., is required. However, there are other methods of rendering visible or measuring the very fine pores which can result from micro-foam bubbles in the coating:

Copper sulphate test

The coating is applied in a realistic thickness to a sand-blasted steel panel. After completely drying or curing, about 4 ml of 10% copper sulphate solution is poured into a small watch glass. The panel is placed coated-surface down on the filled watch glass and the apparatus inverted so that the copper sulphate solution can react. After 24 hours, the coating surface is rinsed with water. If there are fine pores in the coating, they show up as red dots. These red marks are elemental copper deposited from the copper sulphate solution while iron has been dissolved from the panel.
**Pinhole detector**

This method is based on the fact that all electrically insulating coatings materials have a higher dielectric strength than air. Pores are detected by arcing between the test electrode and conductive substrate where there is a defect. The presence of pores is shown optically and acoustically. However, the detector can only be used for coatings on conductive substrates.

**Assessment of entrapped air in coatings for wooden frames or panels**

This method is used to assess entrapped air in coating films (after drying/curing) which are applied to wood substrates. Defined cross-sections of the "coating film/wood substrate" are produced and examined microscopically to assess the number and size of micro-foam bubbles. This method is particularly well suited for pigmented formulations.

**FAQ:**

At what stage in a coatings formulation should the deaerator be added?
Deaerators can be added to the millbase or the let-down. This depends primarily on the incompatibility of the deaerator with the coating system. It is generally true that the greater the incompatibility, the more shear force is required. Some deaerators are excellent as millbase deaerators while others can be used in the let-down or in clear coats. For the ideal point of addition, please see the product data sheets.

How important is the method of application when choosing the deaerator?
The method by which the coating is applied plays a very important role. There are deaerators which, because of their strong incompatibility produce, for example, a break of curtain at the curtain coater machine. In this case, only relatively compatible deaerators should be used.

With airless and airmix application, micro-bubble formation is very strong. This requires especially effective and, therefore, more incompatible deaerators and a good balance between effectiveness and compatibility must be found.

What fundamental ways are there of preventing micro-foam?
There are various possibilities of counter-acting micro-foam in coatings and printing inks. The choice of low-foam raw materials or optimally adjusting the coating viscosity can significantly reduce micro-foam problems in a formulation. Production and application of the coating should be engineered to minimize the entrainment of air in the coatings material. However, parameters such as raw materials, manufacturing regulations and application are usually specified and the room for maneuver is thus significantly restricted. The addition of coatings additives is the simplest way of preventing and eliminating micro-foam.
Slip and Flow Additives
Radiation-Curing Additives
TEGO® Glide – TEGO® Flow – TEGO® Rad
The customer's wish: the perfect finish

Diverse demands are made on paints and varnishes. On the one hand, the requirement is for brilliant, smooth coatings. On the other hand, the desire is for functional, continuous coating films which ensure chemical and mechanical resistance, adequate slip, haptic properties and also a certain antiblocking/release effect.

A coating has a large interfacial area for its volume. There are actually two interfaces, one with the substrate and another with the surrounding air. Slip and flow additives are active at these interfaces where, depending on their structure, they improve substrate wetting, promote flow and impart slip. Thus slip and flow additives significantly reduce the susceptibility to defects, resulting in a high-quality appearance and markedly improved scratch resistance, especially with freshly applied coatings.

Eliminating unevenness: flow or leveling

The term "leveling" indicates the intrinsic property of coatings to even out imperfections which arise from spray mist, brush strokes, etc. (DIN 55945).

The leveling of a coating material is strongly dependent on its flow properties, surface tension, application parameters and drying conditions. If the flow is inadequate, surface defects such as pronounced texture, voids and craters in the coating surface occur. In contrast, coatings with good flow, when applied on a suitable substrate, produce smooth surfaces of exceptional optical brilliance.
Bénard cells: differences in surface tension

To achieve good flow, the surface tension must remain uniform over the complete surface of the coating layer while it is drying. During the drying of a solvent-borne coating film, the solvent on the surface evaporates causing differences in temperature, surface tension, solvent concentration and density within the film. To balance the thermodynamic non-equilibrium, currents occur in the coating film. These currents produce eddies in the drying layer, a phenomenon known as the formation of Bénard cells. The surface tension is higher at the edges of the cells than at their centers and coating material flows from regions of lower surface tension to regions of higher surface tension. The resulting unevenness in the surface dries into the coating film. This produces an irregular surface as the coating shows marked texture (fig. 3).

Producing a uniform surface tension: polyethersiloxanes

Polyethersiloxane-based additives adjust the surface tension of drying coatings to a uniform, low level and thereby even out differences in surface tension. This minimizes flow of material from regions of low surface tension to regions of high surface tension and thus suppresses eddy formation. The solvent evaporates evenly from the whole surface so that the film dries very homogeneously and shows much better leveling.

Orientation of matting agents

Bénard cells are a particular problem in mixed-pigment formulations. The different particle sizes and densities of the various pigments lead to separation of the previously homogeneously distributed pigments. In the resulting eddies, pigments of different densities are dragged along to various extents. Smaller pigment particles are transported further than larger ones and accumulate at the edges of the eddies. The different pigments are partially de-mixed and later a honeycomb structure appears in the drying film (see also "Technical Background Wetting and Dispersing Additives"). In matte clear coats, the large particles mainly remain in the center of the cells. A higher degree of gloss is visible at the edges of the cells than in the centers. When applied to a vertical surface the cells become deformed and streaks become visible (fig. 4).
These effects are also suppressed by additives based on organo-modified siloxanes. Exactly as in the improvement of leveling, the effect is due to an equalization of the surface tension. For this reason some wetting and dispersing additives such as TEGO® Dispers 610 S, contain small amounts of modified siloxanes in addition to their actual active agent.

**Exceptionally good overcoatability: polyacrylates**

Unlike polyethersiloxanes, polyacrylates rarely alter the surface tension. Polyacrylates have limited compatibility in the coating formulation and accumulate at the interfaces during the drying process. The viscous acrylate polymers slow down the process of evaporation. Because of their high molecular weight between 5,000 and 10,000 g/mol, polyacrylates are relatively immobile at the interface. They act as a barrier to the flow of material caused by the difference in surface tension so that texture cannot develop in the surface. The surfaces are already very smooth immediately after the coating is applied and, as the surface energy of the dried coating is not reduced, the wetting properties of a subsequent layer are not critical.

**Matte or slippery?**

Some customers want matte surfaces, for example to lower the danger of slipping when used as floor coatings. Other customers want smooth surfaces to increase the slip of printed items or packaging. High-quality furnishings and cars are also protected against scratching by more slippery surfaces.

Resistance to slip depends on unevenness in the surface of the coating and the body sliding on it as well as the interaction between them. Resistance to slip is particularly low if the interactions within a lubricating film and between the surfaces sliding on each other are small. Slip additives are used to ensure particularly slippery surfaces.

**Smooth surfaces are not susceptible to scratching**

Scratches are visible as linear damage to the surface. They arise when a harder object scrapes over the coating film and irreversibly distorts or even penetrates the surface. Such damage is markedly lowered by increased surface slip which can be achieved by slip additives. The scraping object slips off rather than penetrating into the coating film. Smooth surfaces exhibit markedly reduced scratch susceptibility.

Scratch resistance is improved significantly only if slip additives are formed from segments which interact weakly with each other. Organo-modified siloxanes, with a high proportion of polydimethylsiloxane segments, exhibit particularly weak interactions both with each other and with other materials. This makes them ideal as slip additives. Organo-modified siloxanes minimize unevenness in the surface and help the coating to form particularly smooth surfaces. During the drying process, the organo-modified siloxanes continually...
accumulate at the surface. A film is produced which makes it possible for a solid body to slide. Hydrodynamic lubrication occurs and the slip resistance is significantly reduced.

**Avoiding craters**

Craters are small depressions in coating films, sometimes extending right down to the substrate. Their origin can be traced back to poor wetting by the liquid coating (see also “Technical Background Substrate Wetting Additives”). Craters are either formed on low energy substrates such as plastics or occur due to contamination of the freshly applied coating. The liquid coating does not fully wet the contamination, and this reduces the contact area resulting in a crater. Reduction of the surface tension by polyethersiloxanes facilitates wetting of a contaminated or an inadequately cleaned substrate so that no craters are formed. In extreme cases, substrate wetting additives, such as specially formulated silicone oils like TEGO® Flow ATF 2, are recommended as anti-crater additives.

**Durable release effects**

In contrast to conventional flow and slip additives, TEGO® Rad products can be incorporated into radiation-curing formulations. Here additives should chemically cross-link with the radiation-curing binder matrix. Acrylate groups form a network with the binder on radiation-curing and this minimizes the tendency of the additive to migrate. In this way longer-lasting surface effects and sometimes extreme anti-blocking/release effects can be achieved. Targeted modification allows substrate wetting or deaeration.

TEGO® Rad products offer, depending on the structure, different combinations of effects. TEGO® Rad 2100 combines compatibility with flow promoting properties. TEGO® Rad 2010 combines very good substrate wetting with low surface smoothness. Whereas, TEGO® Rad 2700 exhibits excellent anti-blocking/release and also has a degassing function. Because of the desired incompatibility, products such as TEGO® Rad 2700 have to be incorporated using high shear.

**Formulation counts**

During drying or curing of the paint film, the solubility of the slip additive in the film decreases continuously. Therefore, it accumulates at the surface. In general, the efficacy of the additive is significantly higher in strongly crosslinked formulations than in those which are less cross-linked or dry physically.

Slip additives are particularly effective in solventborne formulations where they are transported with the solvent to the surface during the drying process. After drying, they ensure a low friction interface.

For most physically drying and water-borne coatings, markedly higher additive concentrations are necessary. This is because there are many more interfaces present in emulsions and dispersions to which surface active additives orient than is the case in a homogeneous resin solution. Additionally, the surfactants or emulsifiers interact with the additives. Here again their effectiveness in cross-linking formulations is greater than in those which dry physically.

When the addition is not made in the form of a solution, care must be taken to ensure adequate stirring to incorporate the additive homogeneously. This applies particularly to waterborne and radiation-curing coatings in which the additives disperse more slowly than they do in organic solvents.
Chemistry of surface active additives

Eliminating the defects described above depends largely on the surface activity of the additives. Substances are said to be surface active if they reduce the surface tension of a liquid by concentrating at the interface to form a new but less energetic boundary surface. Further explanations of surface tension are given in the "Technical Background Substrate Wetting Additives".

In solventborne formulations, which by nature exhibit low surface tension, silicone oils and modified siloxanes are surface active.

Modified siloxanes are a particularly versatile group of substances and are found in diverse forms in the TEGO range of products. Modified siloxanes are derived from low molecular weight polydimethylsiloxanes by replacing individual methyl groups with very diverse organic side chains. These increase compatibility with binders. The organic side chains are frequently polyethers, or, less commonly, long chain alkyl groups. Modified siloxanes are considerably more soluble and binder-compatible than polydimethylsiloxanes.

The most important type of modification is with polyethers. As a rule, polyethers are manufactured from ethylene oxide and/or propylene oxide. The higher the ethylene oxide content, the more hydrophilic the resulting product is. Even water-soluble siloxane compounds can be obtained. Basically, the property profile of modified siloxanes depends on the silicone content, the structure of the siloxane backbone and the organic side chains. Modified siloxanes are used successfully as slip and flow additives.

The crosslinkability of TEGO® Rad products and the durability of their surface effects are based on incorporating reactive acrylic groups in the modified siloxane. During radiation-curing the additive is polymerized into the molecule and thus cannot migrate. This technique achieves extreme release effects but overcoatability and overprintability are impaired. The mobility of the slip and flow additives is a prerequisite for overcoatability and unimpaired adhesion in multicoat finishes.

The use of surfactants:
- improves substrate wetting
- improves flow
- generates a uniformly textured surface
- prevents floating of pigments and matting agents
- reduces sliding resistance
- improves scratch resistance

There is no clear delineation between slip and flow additives and their effects are therefore considered together. Usually they are modified polysiloxanes with a wide range of molecular weights from 1,000 to 15,000 g/mol. To be effective in a given system, they must be compatible in the solvent (in waterborne formulations, water) but still develop their surface activity.
They must also exhibit sufficient compatibility in the binder, otherwise cloudiness or flow defects can occur in the liquid coating and/or dried film.

The best slip additives are therefore, polyethersiloxanes with high levels of polydimethylsiloxane segments, such as TEGO® Glide 410.

**Measurement of release effect**

The release characteristics of siloxane containing additives are measured by applying standardized adhesive strips to the coating surface. The prepared test specimen is aged, partly with a weight applied. The adhesive strips are then linked to a sensor and pulled off the surface at constant speed. The force required to remove the adhesive strips is measured and used to calculate the release value. The lower the pull-off force, then the stronger the release effect. Non-reactive release additives may migrate into the adhesive either over a period of time or because of the effect of temperature so that the release effect disappears.

**Recommended additives**

Non-turbid flow, particularly in clear coats, is achieved with the highly compatible TEGO® Flow 370 which is especially effective in smoothing the surface during spray application. The same additive promotes flow in coil coatings without stabilizing air. TEGO® Glide 410 achieves the greatest reduction in sliding resistance in solventborne formulations. The addition of just 0.1% on the total formulation lowers the coefficient of sliding friction by 90%. TEGO® Glide 482 has been specially developed to optimize the sliding resistance of waterborne coatings. The slip additive emulsion is much more effective here than homogeneously soluble slip additives.

If, however, a slip effect combined with intercoat adhesion is required; TEGO® Glide 450 is recommended. This polyether siloxane has been successfully used in delicate clear coats. TEGO® Glide 432 shows its strengths in radiation-curing coatings and printing inks. Its combination of substrate wetting, improvement of scratch resistance and low-foam is impressive. TEGO® Rad products, which are reacted into the coating, achieve a significantly greater slip effect in radiation-curing systems. TEGO® Rad 2300 is particularly suitable for use in clear coats and combines substrate wetting, slip, compatibility and low-foam characteristics, etc. In contrast, TEGO® Rad 2600 combines deairing characteristics and a strong release effect.
What affects friction?

If an object is pulled over and parallel to a substrate, a certain force must be overcome at the start. This initial force is termed static friction. This adhesive force prevents two touching objects moving in relation to each other.

To maintain movement, the sliding frictional force must be overcome. The sliding frictional force required ($F_R$) is proportional to the normal force ($F_N$) of the object. The various material properties involved affect the dimensionless coefficient of friction ($\mu_G$).

$$F_R = \mu_G \cdot F_N$$

There is thus a coefficient of static friction ($\mu_H$) and a coefficient of sliding friction ($\mu_G$); the former is the greater. The material properties of the substrate and of the object to be moved are reflected in the coefficients of friction. The chemical composition and the interactions arising from it as well as the surface morphology (roughness) play a role.

FAQs

How can additives improve scratch resistance?

Improving the coating’s slip and smoothness enables objects to slide past the surface. Scratches are avoided since the offending object slides away instead of penetrating the surface. The crosslinking density is not affected.

What is the effect of being able to chemically incorporate TEGO® Rad products?

The release effect becomes more durable by crosslinking into the binder matrix. The surface effects of additives which cannot be chemically bound decrease on aging.

Why are crosslinkable slip additives difficult to overcoat/overprint?

Upon curing, reactive additives are chemically incorporated in the binder matrix which impairs intercoat adhesion during overpainting/overprinting. Unimpaired adhesion requires mobility of the additives. A fresh coating applied to a film, treated with additive, must be able to dissolve the additive from the lower layer to allow problem-free adhesion. If the additive is chemically anchored, this is not possible.

What is the effect of polyether modification?

Polyether modification of flow and slip additives primarily increases the compatibility of the additives with coating systems. The siloxane component of the additive is responsible for the extreme surface activity. The modification minimizes the tendency of cloudiness and prevents undesirable side effects which are known to occur with pure silicone oils.

What are the advantages of acrylates over polyethersiloxanes as flow additives?

The acrylates barely influence the surface tension. Primers containing polyacrylates can be rewetted because the polyacrylates do not reduce the surface energy even in cured coatings formulations.
Substrate Wetting Additives

TEGO® Wet – TEGO® Twin
How well a paint wets the substrate is a determining factor in the quality of a coating. How can wetting during application be improved? Which is the best additive for a particular problem? What is the mechanism behind it? We are often asked these and similar questions which reflect the importance manufacturers of coatings and printing inks attach to the subject of wetting. Hardly a surprise, as a homogeneous, continuous film cannot form if wetting is inadequate during application or drying.

There is no categorical answer to the questions raised above; possible defects must be considered individually. A more detailed approach requires the properties of the substrate and the coatings to be considered.

The interfacial tension of a liquid/air interface is termed surface tension.

To bring a molecule from inside a liquid to the air interface requires energy. The force acting on the surface of a liquid phase (interfacial tension) causes liquids to strive for the minimum surface area.

Figure 1: Water skater supported by surface tension

Figure 2: Wetting on a low energy substrate as displayed on the left with substrate wetting additive
The work required to increase an interfacial area $A$ by unit amount is termed interfacial energy $W$. It is proportional to the size of the additional unit and can be formulated as a differential:

$$\sigma = \frac{dW}{dA}$$

The quotient $\sigma$ is defined as surface tension. It has the dimensions of energy per unit area ($J/m^2$) and is therefore the work required to obtain a new surface.

The SI unit for the surface tension is $N/m$. The surface tension of ready-to-use coatings naturally depends not only on the solvent used but also on the other constituents. Nonetheless, the surface tension is an important parameter.

### The measuring technique

In the best known technique for measuring surface tensions of liquids, the du Noüy Ring Method, a platinum-iridium ring is placed into the liquid so that the surface is completely wet. Upon slowly withdrawing it, a lamella is formed which constitutes an increase in the surface of the liquid. The maximum force required to pull this lamella is a direct measure of the static surface tension as it corresponds to the energy necessary to increase the surface of the liquid (lamella). This measuring technique is shown on our homepage (video “Measurement of static surface tension”).

### Surface tension of various liquids

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Surface tension (mN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>73</td>
</tr>
<tr>
<td>Alkyd resins</td>
<td>33 – 60</td>
</tr>
<tr>
<td>Butyl glycol</td>
<td>30</td>
</tr>
<tr>
<td>Toluene</td>
<td>29</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>22</td>
</tr>
<tr>
<td>n-Octane</td>
<td>21</td>
</tr>
<tr>
<td>Octamethyltrisiloxane</td>
<td>17</td>
</tr>
<tr>
<td>Hexamethylsiloxane</td>
<td>16</td>
</tr>
<tr>
<td>Isopentane</td>
<td>14</td>
</tr>
</tbody>
</table>
This method is suitable for investigating aqueous solutions containing surfactants or of waterborne or solventborne clearcoats. Pigmented systems do not give reliable data as the presence of pigments impairs lamella stability so that the values of surface tension appear to be too low. Insoluble additives, such as defoamers, can also cause misleading results.

The dynamic surface tension can be determined using a bubble pressure tensiometer in which gas bubbles are generated at a defined pressure and introduced into the liquid under investigation via a capillary. In this process, the pressure required to generate the new interface of the liquid passes through a maximum which is directly related to the dynamic surface tension. This method evaluates the mobility of the surfactant in the medium since the surfactants must orient as quickly as possible at the newly formed interface to maintain the surface tension at a constant low level. When applying coatings, during printing processes for example, substrate wetting agents must be able to orient quickly to the new interfaces which are formed very rapidly. That is why measuring surface tension under these dynamic conditions is also useful.

Unfortunately, the results from pure aqueous solutions of surfactants cannot be transferred directly to coatings systems. It is therefore advisable to check the effect of wetting agents in the coating or, at least, relevant binders.

Laws governing wetting of the surfaces of solids

In contrast to the surface energy of the liquid phase of the paint, that of the substrate cannot be measured directly. A number of indirect methods have been developed; one of the most important being measurement of the contact angle of various test liquids on the substrate.
Wetting of solids by liquids is influenced by the surface tension of the components involved. Thomas Young established a formula in 1805 which characterizes the surface tension at the three phase contact of a droplet on a solid.

Young’s equation assumes all forces are in equilibrium and, strictly speaking, only applies to the case of thermodynamic equilibrium. Nevertheless, it forms the basis for a qualitative description of all wetting phenomena. In general, the following rules, confirmed in practice, apply:

- a substrate with high surface energy is easily wet out
- a liquid with a low surface energy is good at wetting
- wetting is ideal if the surface energy of the liquid is significantly less than the surface energy of the substrate

The most widely used method for improving wetting is the addition of substrate wetting additives to the liquid phase. These surface active compounds attach themselves preferentially to the phase boundary where they reach a higher concentration than in the bulk phase.

Evonik offers substrate wetting additives which, when used in even minimal amounts, substantially lower the surface tension of the liquid coating so that even difficult substrates can be wet out.

### How to improve wetting

Wetting can be influenced by the substrate surface and via the formulation of the coating. In principle, a solid surface always wets out well if the surface tension of the liquid is low compared to the free surface energy of the substrate. Substrates with low surface energies include polyethylene, polypropylene and Teflon; examples of high energy surfaces are metals, metallic oxides and glass. Cleaning of metallic substrates removes grease and increases their surface energy. Corona treatment of the surface of plastics has a similar effect: a more energetic surface zone is generated by oxidation. Not only the material, but also its surface texture plays a role and this can be utilized in some cases.

### Contact angle

The contact angle between a liquid and a solid is widely used as a criteria to evaluate the wettability. The term wetting is considered to mean the formation of a liquid/solid interface in place of the original solid surface/gas interface.
The task of all substrate wetting additives is to reduce the surface tension of the liquid phase. As surfactants, their interfacial concentration is increased by at least a factor of 100 compared to that of the volume phase. The reason for this strong adsorption is their chemical structure. As amphiphilic substances, surfactant molecules combine at least a hydrophilic and a hydrophobic part. This structure is also responsible for their preferential orientation at the interfaces: the hydrophobic part is forced out of the volume phase. The hydrophilic part points towards the water phase. This arrangement of the surfactant molecules forms a new low energy coating surface which can easily wet the low energy surface of the substrate.

How do silicone surfactants behave in waterborne, solventborne and uv-curing coatings?

Short chain polyether siloxanes are used primarily to reduce surface tension in waterborne coatings. The reason is the high surface tension of water which is the main solvent in such systems.

The structure of a siloxane surfactant is shown schematically in fig. 9. The polyether modification substantially influences the compatibility and tendency to foam of surfactants. The length of the silicone chain determines the interfacial activity of the substrate wetting additive. The higher the siloxane content in the molecule, the stronger the reduction in surface tension.

The differences in molecular structure are reflected in product recommendations:

TEGO® Wet 240 particularly suitable for waterborne formulations, fine atomization during spray application

TEGO® Wet 270 outstanding anti-cratering effect, additional flow promotion

In completely waterborne systems, the effectiveness of short-chain siloxanes is completely sufficient; whereas in solventborne and uv coatings, a longer siloxane chain is advantageous.

Siloxane-Gemini surfactants

Gemini surfactants are distinguished chemically by a combination of two hydrophobic side chains and two ionic or polar chains separated by a spacer. Gemini surfactants are interesting because of their particularly high surface activity and their different aggregation characteristics compared to classic surfactants.
Using this clever combination, researchers at Evonik have succeeded in linking Gemini surfactant chemistry with silicone chemistry. The advantages are the characteristics of Gemini technology combined with the performance and low surface tension of siloxanes.

With siloxane-based multi-functional surfactants, Evonik has opened a new door to substrate wetting without foam.

The effect of these products is particularly advantageous in waterborne formulations. TEGO® Twin products have also proved to have interesting and beneficial effects in solventborne systems.

TEGO® Twin 4000 and TEGO® Twin 4100 are two powerful products with very different application properties.

### Typical applications of individual products

The optimum surface active substrate wetting additive for a particular application is decided, in the final analysis, by the requirements of the users of coatings and printing inks. Basic research, user experience and practical testing have played their part in developing additives which, because of their special characteristics, provide the right solution to many challenges.

The products currently offered by Evonik comprise the following classes of chemical substances:
- polyether-modified siloxanes
- siloxane multi-functional surfactants
- alkoxylates (silicone-free)

For all these classes of substances, there are specific areas of application.

Short chain, polyether-modified siloxanes are similarly effective in reducing static surface tension. They are almost universal aids for difficult to wet and contaminated substrates in diverse areas of application (see also “Contamination test” video). On capillary substrates, such as wood, they greatly improve pore wetting by the coating. Their particular advantage is the ability to customize properties such as compatibility, low foam and anti-cratering effects via polyether modification and siloxane chain length.

Low molecular weight polyether-modified siloxanes, such as TEGO® Wet 270 and TEGO® Wet 240 reduce the surface tension in waterborne systems more strongly than hydrocarbon-based surfactants or higher molecular weight polyether siloxanes. This makes them ideal substrate wetting additives for coating many critical substrates. TEGO® Wet 270, with its relatively high silicone content, has excellent anti-cratering properties and is outstanding at improving wetting of wood substrates. TEGO® Wet 240, specially developed for spray paints, provides optimum atomization during application without affecting the slip characteristics of the dried finish.

**Reduction in surface tension of a waterborne binder by surfactants**

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>Surfactant surface tension (mN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High molecular silicone surfactant</td>
<td>31</td>
</tr>
<tr>
<td>TEGO® Wet KL 245</td>
<td>21</td>
</tr>
</tbody>
</table>

**Spreading of 0.05 ml of a 0.1% aqueous solution on a PVC sheet**

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>Wetted area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High molecular silicone surfactant</td>
<td>5</td>
</tr>
<tr>
<td>Organic wetting agent</td>
<td>20</td>
</tr>
<tr>
<td>TEGO® Wet KL 245</td>
<td>160</td>
</tr>
</tbody>
</table>

![Figure 10: Waterborne clearcoat on a critical substrate, optimized with TEGO® Twin 4100](image-url)
Substrate wetting additives occasionally lead to the incorporation of foam since the more effective a surfactant is at reducing surface tension, the greater the tendency to foam. With Evonik’s proprietary know-how, our researchers have been able to extend the existing range of TEGO products with the addition of the multi-functional surfactants TEGO® Twin 4000 and 4100. This new type of product provides a combination of outstanding reduction in surface tension and pronounced defoaming properties. TEGO® Twin 4100 is a highly compatible, foam inhibiting multi-functional surfactant imparting good recoat properties.

The TEGO® Wet 500 series, a silicone- and solvent-free class of surfactants offers advantages particularly in printing inks since they reduce dynamic surface tension significantly. The TEGO® Wet 500 range of products is also foam inhibiting and degassing in waterborne coatings and printing inks. TEGO® Wet 505 is the most hydrophobic surfactant in this class of products. It acts as a deaerator and wets pigments. Within this group, the hydrophilic TEGO® Wet 510 is the most effective as far as substrate wetting and promoting flow are concerned.

At the end of the day, however, the specific use of the coating defines which additive is best for solving problems.

**Outlook**

The importance of substrate wetting additives is growing and goes hand in hand with the development of eco-friendly coatings formulations based on new raw materials and application concepts. Additives with optimized performance tailored to solve specific problems are being developed to make application more secure and broaden the application window.

**FAQ:**

Which additives remove craters in waterborne coatings?
TEGO® Twin 4100 and TEGO® Wet 270 are particularly suited to reduce surface tension and eliminate craters. They are also highly capable in completely wetting inhomogeneous substrates such as wood.

Which additive achieves the best result with spray application?
Tego Wet 240 has been specifically developed for particularly fine mist and outstanding atomization. The small droplets substantially improve substrate wetting.

Which substrate additive is the preferred choice for reducing dynamic surface tension?
TEGO® Wet 500 is the additive of choice for reducing dynamic surface tension in dynamic processes such as printing. Furthermore, the product does not stabilize foam.

How can defoaming be combined with wetting?
TEGO® Twin 4100 based on the unique siloxane multi-functional technology combines wetting properties with foam inhibition as required in low-VOC coatings. Despite high activity, recoatability is good.

<table>
<thead>
<tr>
<th>Characteristics of substrate wetting additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate wetting additive</td>
</tr>
<tr>
<td>TEGO® Wet 500 series, si-free</td>
</tr>
<tr>
<td>TEGO® Wet 240, contains si</td>
</tr>
<tr>
<td>TEGO® Twin 4100</td>
</tr>
</tbody>
</table>
Wetting and Dispersing Additives

TEGO® Dispers
Optimal dispersion and stabilization of pigment particles is a significant factor in determining the end properties of lacquers, paints or printing inks. The pigments and fillers of the formulation must be ground to small-sized particles, wetted and uniformly distributed as stably as possible. Only then can color intensity, gloss, hiding power, lightfastness and weathering resistance be maximized. Pigment dispersion and stabilization, which requires time and energy, is hardly possible without suitable wetting and dispersing additives.

**What occurs during dispersion?**

Pigment dispersion can be broken down into three steps which occur partly consecutively and partly concurrently: wetting, dispersion and stabilization.

### Wetting

Wetting the pigment particles is essential for them to be finely distributed in a liquid. Air entrapped in the pigment powder must be fully removed and the pigment particle completely surrounded by the liquid medium. The processes involved in wetting a solid are approximately described by the Young equation:

\[
\gamma_s = \gamma_{sl} + \gamma_l \cdot \cos \Theta
\]

or

\[
\frac{\gamma_s - \gamma_{sl}}{\gamma_l} = \cos \Theta
\]

where
- \(\gamma_s\) : free surface energy of the solid
- \(\gamma_{sl}\) : Interfacial energy solid/liquid
- \(\gamma_l\) : Surface tension of the liquid
- \(\Theta\) : Contact angle solid/liquid

With spontaneous wetting or spreading, the contact angle is zero so that the cosine term is 1. This occurs when:

\[
\gamma_s - \gamma_{sl} = \gamma_l
\]

For the liquid to wet the solid, the surface tension of the liquid must be lower than that of the solid. A liquid with lower surface tension wets pigments better than one with higher surface tension. An additive which promotes wetting must therefore primarily reduce the surface tension of the liquid.
However, wetting and dispersing additives do not only lower the surface tension of the liquid. As their pigment affinic groups cause them to be adsorbed onto the pigment surface, they also alter the boundary surface. The surface tension is no longer that between pigment and liquid but between additive and liquid.

Wetting and dispersing additives lower the surface tension of the liquid and the interfacial tension between pigment and liquid so that wetting is promoted in two ways.

**Dispersion**

The pigment particles are now wetted by the surrounding binder solution and their surface coated with the surface-active additive. The additive reduces the interactions between the pigment particles and lowers the viscosity of the millbase. This allows higher pigment loadings to be achieved, which is particularly important for the mechanical dispersion process. Millbase formulations which have been optimized in this manner are suitable for all modern grinding equipment such as dissolvers, bead mills and three-roll mills.

In the dispersion process itself, the pigment agglomerates are broken up into primary particles and smaller pigment aggregates. Usually aggregates cannot be broken up. The primary particles in aggregates are so strongly bound surface to surface that it is practically impossible to break them apart. Account is taken of this in pigment manufacture and the proportion of aggregates specifically controlled. Their amount can affect the color tone of a pigment.

Every dispersion process to break up aggregates and agglomerates requires energy. The work needed is given by:

\[ dW = \gamma \cdot dA \]

where
- \( W \): interfacial surface energy
- \( \gamma \): surface tension
- \( A \): interface area

This equation indicates that, for an increase of the surface \( dA \) during dispersion (by breaking up agglomerates), an energy input \( dW \) is needed which is proportional to the surface tension \( \gamma \). The smaller the surface tension, the greater the increase in surface area for a particular amount of energy applied. Equally, for a particular change in surface area in the presence of a dispersing additive (that is at reduced surface tension) less dispersion energy is needed.
Stabilization

In the dispersion process, the aggregates (fig. 1a) are broken up into primary particles and smaller agglomerates. Formation of primary particles results in an increase of the boundary area with the liquid medium (fig. 1b). The higher the interfacial tension, the more strongly will a solid attempt to reduce the interfacial area. The particles, therefore, reagglomerate to form so-called flocculates (fig. 1c). The term flocculate indicates an agglomerate occurring in suspension. Dispersing additives suppress the formation of flocculates.

To stabilize the fine distribution of particles, the additive molecules must be firmly adsorbed onto the pigment surface. This means that the additive molecules require groups or segments which can interact strongly with the pigment surface by ionic bonding, dipole interactions or hydrogen bridges. Depending on whether the formulation is water- or solventborne, various mechanisms are possible.

Dissociation of the adsorbed additive molecules into bound anions and freely moving cations forms an electrochemical double layer around the pigment particles. Each pigment particle is situated in a solution of oppositely charged ions which are relatively firmly bound to the pigment. Both attractive and repulsive forces depend on the interparticle separation. With a strongly pronounced double layer, repulsion predominates and the dispersion is stable. If the electrochemical double layer is disrupted, for example by addition of an electrolyte, attractive forces dominate and the dispersion breaks up. Electrostatic interactions can be quantitatively described by the zeta potential, ζ, which is a measure of the potential at the shear layer of a moving particle in a dispersion. As ζ approaches zero, the tendency of the particles to agglomerate increases.

Solventborne paint systems cannot be stabilized electrostatically. Particle flocculation is instead preferably prevented by steric stabilization. Polymeric additives with pigment-affinitive groups are used. These groups attach themselves to the pigment surface and thus ensure adsorption of the additive. The polymer segments are responsible for compatibility in organic systems. They also stabilize the dispersion by protruding into the solvent. If the pigment particles come too close, the polymer segments interpenetrate and their mobility is reduced, thus lowering the entropy. The pigment particles surrounded by the polymers move away from each other to balance this entropy loss.

With the complex demands made of wetting and dispersing additives, it is useful to combine electrostatic and steric effects. This is often known as electrosteric stabilization.

Modern wetting and dispersing additives for waterborne application use electrosteric stabilization. Only such additives can fulfill the high demands made on stabilization and durability.

Figure 1: Schematic representation, (a) agglomerated, (b) dispersed, (c) flocculated pigments
A further possibility of preventing pigment particles approaching each other and thereby flocculating is "controlled flocculation". In this, the structure of the additives allows them to mutually interact. The individual additive molecules adsorb onto the pigment surface and by interaction with each other form a three-dimensional network. This network causes a change in the rheological properties: at rest, the viscosity is very high so that the pigments can no longer easily precipitate. The different mobility of the pigments, which is also partly responsible for flooding and floating, is prevented by pigments binding to flocculates of the same color (fig. 3).

However, the three-dimensional network can compromise the flow of the coating and thus reduce gloss. Controlled flocculation is therefore mainly used in solvent-borne primers and fillers. This method is not used for waterborne coatings; a similar effect can be achieved there with associative thickeners.
Structure of wetting and dispersing additives

Wetting and dispersing additives are amphiphilic compounds, i.e. they are both hydrophilic and lipophilic. Their special molecular structure allows them to enable or facilitate dispersion of pigments and fillers in the solvent. In addition, they should stabilize the dispersion.

Wetting and dispersing additives can be classified in different ways. In the literature, there are assignments according to chemical structure or separation into ionic and non-ionic products. Other classifications are made by field of application, waterborne or non waterborne, or by pigment type, organic or inorganic. A classification by molecular size is also possible:

Wetting agents are of low molecular weight and dispersing additives are of high molecular weight. Because of the complexity of amphiphilic substances, which contain unique functional groups, it is not easy to develop a simple model. The boundaries are not fixed as the desired multifunctionality necessitates deliberate combinations of different wetting agent components.

In principle, every wetting agent has one or more “adhesion groups” which can dock with the pigment and a more-or-less long segment which can be solvated. This general principle is shown in the following simplified schematic diagram:

Figure 4: Schematic diagram of the structure of surfactant compounds with various types of head groups
The number of adhesion groups is among those properties important for the effectiveness of a wetting and dispersing additive. Adhesion groups are functional groups which have a special affinity for pigment surfaces. If there is only one adhesion group per molecule of dispersing additive, replacement by a solvent molecule leads immediately to complete removal of the additive molecule from the surface. This leads to flocculation of the pigment. Additives with several functional groups cannot so easily be removed and therefore show especially high performance.

The type of adhesion group depends on the particular pigment surface: Organic pigments usually contain aromatic groups so that dispersing additives, which contain, for example, phenyl or naphthyl units, are particularly suitable for long-term stabilization of dispersions. Inorganic pigments can also be split into chemical classes. With a few exceptions these are oxides, oxyhydroxides, sulphides, silicates, sulphates or carbonates. These pigments are characterized by polar molecular structures so that their interaction with acid groups, such as carboxy, phosphate or sulphate, are particularly strong.

Carbon blacks are a special case. The surface area of these pigments is many times greater than that of organic or inorganic pigments. On the one hand, a much larger amount of dispersing additive is needed to cover the surface effectively. On the other hand, carbon black has neither a classic organic/aromatic nor an inorganic/crystalline structure. Experience has shown that nitrogen-containing dispersing additives are the most successful.

Oligomeric and polymeric dispersing additives are particularly suited for steric stabilization. It has been found that block- and graft-copolymers are better than homo- or copolymers with a random statistical distribution. Pigment affinic groups are incorporated in the additive depending on the type of pigment and the application (fig. 5).

Modern high performance polymeric wetting and dispersing additives suitable for all types of pigments have multiple occurrences of all types of adhesion groups, e.g. TEGO® Dispers 755 W.

![Figure 5: Copolymers for steric stabilization](image-url)
The function of wetting and dispersing additives

Wetting and dispersing additives lower the viscosity of a coating formulation. However, that is not their only effect. This class of additives has a marked effect on a whole series of different, essential characteristics of the formulation.

Color intensity

The color intensity is a measure of the ability of a pigment to absorb incident light and impart color to a medium. It has practical importance in coloring white base paints: the stronger the color of a tinting agent, the more economical it is. The color intensity of such a preparation depends significantly on the absorbing power and the average particle size of the pigment. The smaller the pigment particles, the greater their effective surface area and consequently the higher their absorbing power. A higher absorbing power is associated with higher color intensity. To ensure that the small pigment particles remain finely distributed and do not clump together to form larger flocculates, they must be stabilized. Dispersing additives are necessary for this.

Hiding power

The hiding power of a coating is its ability to cover the color or the color difference with the substrate. How well the substrate is hidden depends on the coating thickness, the color of the substrate and on the scattering power of the pigment and the refractive index of the pigment with the surrounding medium (usually the film forming agent). In a coating with strong hiding power, the pigment particles scatter the light so strongly that it hardly reaches the substrate. If residual light is reflected from the substrate, it is so strongly scattered that it does not reach the eye. For a coating to scatter the light optimally, an even, fine distribution of the pigment stabilized by dispersing additives is essential.

Flocculation

Flocculation is the reagglomeration of already dispersed particles. In the dispersion process, energy is taken in to break up the pigments and form new surfaces. This is, however, an unstable state and flocculation can occur at any time during manufacturing, storing and applying a paint.
Pigments also tend to flocculate after the paint has been applied to a surface – carbon black with its high surface area is particularly susceptible. If this occurs, a substrate cannot be evenly coated in black. Dispersing additives inhibit flocculation of the pigment particles.

**Gloss**

Light falling on a surface can be reflected directly (specular reflection) or diffusely. High gloss is obtained when the surface is very smooth and the diffuse component of the reflection is small. Pigment particles or flocculates which protrude from the surface interfere with the specular reflection. Flocculated pigments also affect leveling. Poor leveling decreases the gloss further. Since wetting and dispersing additives inhibit flocculation, they increase the gloss of a coating.

**Flooding and floating**

These phenomena occur with mixed pigments when the density and/or the particle sizes of the pigments are markedly different.

With its high density, titanium dioxide tends to concentrate at the bottom of the drying paint film. Organic colored pigments have significantly lower density than titanium dioxide and, therefore, concentrate in the upper part of the film. This vertical flooding, also known as floating, causes the film to appear more colored than desired. Flooding can be made visible by rub-up tests.

Horizontal flooding occurs by separation of the color pigments in the drying film and originates from solvent flows: particles with lower density are entrained with the solvent flow and islands with different pigmentation result. These so-called Bénard cells are clearly visible.

This unwelcome separation of pigment particles can be prevented if they are associated with each other in a controlled manner by suitable dispersing additives which induce controlled flocculation.
Evaluation of wetting and dispersing additives

**Particle size**

The primary criterion which decides the quality of a dispersion is the particle size distribution. By measuring the particle size or the size of the largest particle, the endpoint of a dispersion process can be very well established. The grindometer is the simplest method of measuring the maximum particle size of inorganic pigments. A sample of the millbase is brushed onto a grindometer. Large particles are moved by the doctor blade and produce stripes in the draw down. The size of the largest particles can be read directly from a scale.

With a little practice, the grind guage allows quick and simple measurement of the maximum particle size. However, the particle size distribution cannot be measured in this way. The grindometer is of no use for binder-free dispersions which dry very quickly or for particle sizes less than 5 µm.

Very small particles and particle size distributions can be studied with more sophisticated measuring methods such as laser diffraction or ultrasound. However, because of their high cost, these methods are generally unsuitable for routine use in the laboratory.
Whether or not the desired particle size has been reached can be easily determined using secondary indices. Thus, with organic pigments, the color intensity is dependent on the particle size. By measuring the color intensity at various times during dispersion, changes in color intensity can be followed and the end point of the dispersion determined.

**Color intensity**

To determine the color intensity, a sample of the millbase is let down in a suitable paint formulation. Assessment is made by comparison with the same amount of a standard millbase optically or using a spectrophotometer. The amount of millbase is adjusted until both samples have the same optical properties. The relative color intensity of the sample as a percentage of the standard is calculated from the various amounts used. This method is very time-consuming but delivers meaningful comparative data and is used mainly by pigment manufacturers.

An absolute value can be obtained by a method based on a theory by Kubelka-Munck, involving the ratio of reflectance and transmission. The sum of the reflectance values over the complete wave range gives a value for the color intensity. In practice, however, this method has a systematic error as it is based on the assumption of an infinite film thickness and a constant degree of reflection. It is not suitable for qualitative assessment of a pigment batch.

**Color intensity according to Kubelka-Munck:**

\[
FS = \frac{K}{S} = \frac{(1-R)^2}{2R}
\]

with
- FS: Color intensity
- K: Absorption coefficient
- S: Scattering coefficient
- R: Reflection at infinite film thickness (no change in the degree of reflection)

**Rub-Up**

The Rub-Up test is used to test the stabilization of pigment particles. It allows the compatibility of pigment concentrates, tendency to flocculation of pigment particles and flooding phenomena to be determined. A part of the wet, but already
drying, film is rubbed with a finger or brush. If the pigment particles have demixed or are strongly flocculated, the mechanical rubbing re-establishes a homogeneous distribution. In a drying film, the viscosity has already increased strongly and the re-established homogeneous distribution of the pigment particles is thereby stabilized. The extent of pigment separation or flocculation is obtained from the color difference between the rubbed and non-rubbed film. The color difference is usually quoted as the separation of the color chromaticity, ΔΕ, which is dimensionless. If ΔΕ is less than 0.5, no color difference is visible, between 0.5 and 1.0 the color difference is only slightly visible, but a ΔΕ larger than 1 is not acceptable.

**Viscosity**

The viscosity of a millbase must be suitable for the dispersion unit. If the millbase viscosity is too high, the unit can be damaged. If it is too low, insufficient shear force will be transferred to break up the pigment agglomerates. Viscosity is also an important indicator of the stability of a pigment concentrate. If it alters during storage, the pigments are usually inadequately stabilized.

The dynamic viscosity of a millbase can be quickly and simply determined using a Brookfield viscometer. This method can, however, only be used for quality control. Millbases show pseudoplastic flow behavior. Changes in their viscosity are dependent on the applied shear energy. To obtain an exact picture of the rheological behavior of a millbase, a complete flow curve must be obtained using a rotational viscometer which can measure the viscosity of the millbase at different shear rates.

Such a flow curve provides information about the rheological behavior of the material from manufacture through transport to application. Interactions in the dispersion can also be quickly detected.

**If problems still occur**

In spite of innovative and high performance wetting and dispersing additives, pigment dispersion is not easy. Unexpected problems often occur especially with waterborne formulations. We will be happy to give help and advice to enable you to utilize the full effectiveness of our additives.

**Literature:**

1. DIN 55987: 1981-02
Rheological Additives

TEGO® ViscoPlus
Panta Rhei – Greek for everything flows – certainly applies to paints and coatings. From manufacture through storage and processing to drying or curing after application, many different demands are made on a coating or printing ink, related to its flow properties. Characteristics which are affected include:

- settling/sedimentation (important for storage stability)
- brushing resistance
- spattering
- sprayability
- sagging
- flow

In solventborne formulations, the flow properties can be completely regulated via the molecular weight of the dissolved binder. In waterborne formulations, the binder is in the form of dispersed polymer particles so that regulation of the flow behavior by changing the molecular weight is not possible. Rheological additives (thickeners) must therefore be used to adjust the flow properties of waterborne coatings and printing inks.

Rheology

Rheology (Greek: rheos = flow or streaming, logos = word/science) is the study of deformation and flow of substances. Flow is the continuous deformation of a material under the influence of external forces. Various rheological measuring methods can be used to characterize coatings.

The quantities measured in rheological investigations are forces, deflections and velocities. Viscosity is the resistance of a liquid to forced, irreversible change of position of its volume elements.

Energy must be supplied continuously to maintain the flow of a liquid. Viscosity $\eta$, the most frequently used rheological parameter, is calculated from the shear rate $\dot{\gamma}$ and the shear stress $\tau$. Basic rheological parameters are explained in terms of the two-plate model (fig. 1).

The upper plate of area $A$ is movable and the lower plate stationary. The plates are separated by a distance $h$ which is filled with liquid. When a certain force $F$ is applied the upper plate reaches a velocity $v$ which is related to the shear stress.
The two characteristic values, shear stress, \( \tau \), and shear rate, \( \dot{\gamma} \), can be derived from the two-plate model. The shear stress has the dimensions of pressure and is defined as the shear force \( F \) [N] per shear area \( A \) [m\(^2\)] where the force is parallel to the surface. The unit is the Pascal (Pa) which is the same as N/m\(^2\).

Shear stress (\( \tau \)) = \( \frac{F}{A} \) Pa

The shear rate (\( \dot{\gamma} \)) or velocity gradient is obtained from the velocity \( v \) [m/s] and the plate separation \( h \) [m]. The units are second\(^{-1}\).

Shear rate (\( \dot{\gamma} \)) = \( \frac{v}{h} \) s\(^{-1}\)

Although the term viscosity is often used in connection with coatings, the term flow behavior would surely be better. Usually coatings show a flow behavior in which they become thinner, that is to say, the viscosity value drops under the influence of shear forces. This phenomenon, known as pseudoplasticity, will be dealt with in more detail later.

Application properties of coatings are associated with different shear rates (fig. 2). When stirring (dispersing), low viscosities are necessary but storage should preferably take place at high viscosity so that the pigments are prevented from settling out. For spray application, the paint should have as low a viscosity as possible but as soon as the paint is on the surface it should assume a high viscosity to prevent sagging on vertical substrates.

Viscosity describes the frictional forces in a system and thus the resistance of a liquid to flow. The viscosity is a measure of the viscous flow of a liquid. The larger the viscosity, the less flowable the liquid. The (shear) viscosity (dynamic viscosity) is obtained as the ratio of shear stress \( \tau \) to shear rate \( \dot{\gamma} \). The units are Pa \( \cdot \) s\(^{-1}\).

Viscosity (\( \eta \)) = \( \frac{\tau}{\dot{\gamma}} \) [Pa \( \cdot \) s\(^{-1}\)]

If the viscosity of a substance is constant at different shear rates, it is said to exhibit ideal or Newtonian behavior. Newtonian flow is generally found only with low molecular weight liquids such as water, solvents and mineral oils. In practice, most shearable systems have flow properties which depend on the shear rate.

If the viscosity decreases with increasing shear stress, the flow behavior is said to be intrinsically viscous, shear thinning or pseudoplastic. Most coatings and polymer solutions show pseudoplastic behavior.

Bingham fluids are viscoplastic but their flow properties are linear. After a minimum shear stress, they reach the yield point, \( \tau_y \), and begin to flow. Below this point they behave as an elastic body.

Examples are ketchup and certain wall
paints. These liquids only begin to flow when a particular stress is reached. This occurs, for example, if a loaded paint roller is pressed against a wall and rolled. At that moment, the shear force is sufficient for the paint to become liquid and wet the wall. As long as the paint is on the roller without any force applied it behaves like an elastic solid and does not drip from the roller.

Materials whose viscosity increases with increasing shear stress are shear-thickening or dilatant. Dilatant behavior is shown by, for example, dispersions with high solids content or high polymer concentrations. Shear-thickening behavior is not usually found in paints and coatings as it can lead to problems with processes involving pumping or stirring.

Flow behavior can be shown diagrammatically in two ways: as a flow curve or a viscosity curve. A flow curve shows the dependence of shear force $\tau$ on shear rate $\dot{\gamma}$ (fig. 3) and a viscosity curve shows how the viscosity $\eta$ depends on the shear rate $\dot{\gamma}$ (fig. 4).

Rheological additives can be roughly separated into inorganic and organic thickeners or thickeners for solventborne or waterborne coatings.

Examples of modified inorganic thickeners for solventborne and waterborne systems include:
- bentonite
- synthetic lattice-layer silicate
- pyrogenic silica (sometimes organically modified)

Examples of organic thickeners for solventborne or waterborne systems include:
- polyureas
- cellulose derivatives
- polyamides

Examples of organic thickeners for waterborne coatings include:
- associative thickeners
- non-associative thickeners

This list is not intended to be comprehensive.

Associative thickening involves non-specific interactions of hydrophobic endgroups of a thickener molecule both with themselves and with components of the coating. The thickener produces a reversible, dynamic network of thickener molecules and other components of the coating. The thickening effect is caused by interactions of the hydrophobic end groups of the thickener with other components of the formulation.
Non-associative thickening is thickening by an entanglement of water-soluble, high molecular weight polymer chains. The effectiveness of a thickener is mainly determined by the molecular weight of the polymer. Formulations thickened non-associatively have pseudoplastic rheology with highly elastic properties. This produces good stabilization against settling out and low sagging even with high build coatings. Non-associatively thickened systems often have limited flowability. The high molecular weight of the thickeners can sometimes lead to compatibility problems such as depletion flocculation.

Associative thickeners also consist of hydrophilic water-soluble or water-emulsifiable polymer components and can simultaneously act in a non-associative manner. Both thickening modes are exhibited by associative thickeners, albeit to different extents. Table 1 shows thickeners commonly used for waterborne coatings and the way in which the thickening is produced.

**Overview of different classes of thickener and the method by which they thicken**

<table>
<thead>
<tr>
<th>Thickener</th>
<th>Associative thickening</th>
<th>Non-associative thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane thickeners “HEUR”</td>
<td>yes</td>
<td>negligible</td>
</tr>
<tr>
<td>Polycrylate thickeners</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Hydrophobically-modified polyacrylate thickeners “HASE”</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Hydrophobically-modified polyether thickeners “HMPE”</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Cellulose ethers</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Hydrophobically-modified cellulose ethers “HMHEC”</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

HEUR: Hydrophobically modified Ethylene Oxide Urethane Rheology modifier
HASE: Hydrophobically modified Alkali Swellable Emulsion
HMPE: Hydrophobically Modified PolyEther
HMHEC: Hydrophobically Modified Hydroxy Ethyl Cellulose

Polyurethane thickeners belong to the associative category. The molecular weight of polyurethane thickeners is from one to several powers of 10 lower than that of non-associative thickeners. Non-associative thickening can therefore be ignored.

**Chemistry of polyurethane thickeners**

Polyurethane thickeners are water-soluble or water-emulsifiable polymers with a segmented structure. The middle section consists of one or more hydrophilic segments while the end-groups are hydrophobic. Linking of the middle segments with each other and with the end-groups occurs mainly via free hydroxyl groups of the segments with mono- or poly-isocyanates forming the urethane structures which give their name to this class of products. The molecular weights of typical polyurethane thickeners lie between 15,000 and 100,000 g/mol.
Polyurethane chemistry opens up many possibilities for synthesizing thickeners with differing property profiles.

This can be achieved by, for example, varying:

- the type of hydrophobic end group
- the molecular weight of the thickener
- the hydrophilic character of the middle section by the choice of isocyanate and the molecular weight of the polyethylene glycol
- the middle section with hydrophobic dialcohols
- the branching of the thickener molecule by reaction with polyisocyanates or polyalcohols
- the branching of the middle section by reaction with alkyl epoxides during manufacture of the polyethylene glycol

Further variations are possible during the formulation of the thickener as a waterborne preparation. Substances high in hydrophobic components require emulsifiers or solvents as formulation aids. The structure of the emulsifier co-determines the applicational properties of the thickener. A suitable choice of emulsifier allows the property profile of the thickener to be adjusted.

**Mode of action of polyurethane thickeners**

The associative thickening action of polyurethane thickeners can be explained as follows: interactions of the thickener molecules with each other and with the surface of dispersion and pigment particles produce a network (fig. 5).

Although the simplified model in fig. 5 is helpful in explaining associative thickening clearly, the actual mechanisms of thickening by polyurethane thickeners are more complex.

Investigations on solutions of polyurethane thickeners in water show that the thickener molecules are present in monomolecular form only in highly diluted solutions. With increasing concentration, the thickener molecules associate with each other to form loop micelles. The block-like structure of the thickener favors this phenomenon:
the hydrophobic components of the molecule orient towards the interior of the micelle, the hydrophilic middle segments form the outer loop-shaped sheath.

At even higher concentrations, mutual interaction of the loop micelles results in two phase systems consisting of a free-flowing phase with low thickener content and a thickener gel. In the free flowing phase, the thickener molecules are dissolved individually or are present as loop micelles. The thickener gel consists of associates of thickener molecules. The cohesion of the gels is thought to stem from bridging and entanglement mechanisms by the micelles (fig. 6 and 7).

If the concentration of thickener in aqueous solution is raised still further, the two phase system changes into a single phase thickener gel.

In paints, polyurethane thickeners are usually used at concentrations at which two-phase systems have been observed in aqueous solutions. It is therefore probable that the polyurethane thickener is also present in paints as a two-phase system. The thickener gel interacts via the hydrophobic groups with the surfaces of the pigments and binders. A refined model of the mechanism of associative thickening by polyurethane thickeners is shown in fig. 8.

Polyurethane thickeners form a temporary network. The linkage points of the network consist of thickener molecules and thickener micelles adsorbed on the pigment or binder surfaces. It is characteristic that the linkage points of the network are constantly breaking and reforming. The system is thus highly fluid which explains the good flow and leveling characteristics of associatively-thickened paints.

The strength of the network and the resultant rheological properties of the system can be controlled via the hydrophobicity of the end groups. Long hydrophobic end groups exert strong interactions and ensure efficient thickening. To achieve comparable thickening with shorter end groups, significantly higher concentrations are required.

The length of the hydrophobic group influences not only the strength of the associative effect but also the kinetics of exchange and thus the rate at which the associative linkage points break and reform. When shear stress is applied to paints, the associative linkage points are broken. If the thickener is unable to reestablish the disrupted linkage points immediately, the associative network is weakened. There is then a shear-rate-dependent loss in viscosity.
Long hydrophobic end groups possess a slow rate of exchange; i.e. the viscosity of thickeners with long hydrophobic end groups diminishes slowly under shear stress. The formulation becomes pseudo-plastic. Short hydrophobic end groups exhibit a fast rate of exchange so that thickeners with such groups are effective even at high shear rates and result in formulations with Newtonian rheology.

Test methods

Measuring viscosity with the absolute viscometer

In absolute viscometers, the geometry of the measuring cell is known and the shear surface and plate separation are therefore also known. The shear stress, shear rate, and thus the viscosity can be calculated from the shear force and speed. The absolute viscometer is usually used to take measurements over a range of shear rates. The results are presented in flow curves or viscosity curves. Typical absolute viscometers are cone and plate or two-plate rotational viscometers (fig. 9).

Measuring viscosity with the relative viscometer

The volume of the sample is unknown; shear rate and shear stress cannot be quantified. Relative viscometers are suitable for comparative measurements of systems with similar rheology. In the coatings industry, relative viscometers of the Brookfield or Stormer spindle type are commonly used, usually at constant shear force.

Leveling

Leveling, the flow behavior in a horizontal position, is determined with a leveling doctor blade. In this method, the coating is applied as five double lines with increasing film thickness from 100 to 1000 µm on a Leneta sheet. The proportion of lines which have coalesced is quoted according to a scale of 0 (no leveling) to 10 (very good leveling). It is also common practice to visually compare a dried paint film with a standard (fig. 10). The paint is usually applied in a manner resembling subsequent application conditions.
Sagging

Sagging, the flow behavior in a vertical position, is determined with a sagging doctor blade. Ten stripes of the paint are applied using the doctor blade in thicknesses of 75 to 300 µm on a Leneta sheet. Immediately after application, the card is lifted into a vertical position so that the stripes lie parallel to the horizontal. The stripes with the lowest film thickness are at the top. After drying, the stripe at which the paint starts to sag is given on a scale of 0 to 10: 0 meaning that all stripes sagged and 10 meaning that no stripes sagged (fig. 11).

Alternatively, it is possible to determine at which film thickness sagging starts to occur by applying the paint, in various thicknesses or as a wedge, to a vertical surface.

Brushing resistance

Brushing resistance is determined by applying a specified amount of paint to a test surface and assessing the resistance felt on distributing the paint with a brush.

Spattering characteristics

The spattering characteristics can be determined by applying a specified amount of paint uniformly on a previously conditioned roller and rolled several times over a grid. The paint spray thrown from the roller is collected on a black card under the grid. The test card is compared with a standard tested at the same time.

These test methods are shown in a video on our Homepage entitled “Various methods for measuring viscosity”.

FAQs

For which paint formulations is TEGO® ViscoPlus suitable?
TEGO® ViscoPlus is only recommended for thickening waterborne coatings. The thickening effect is based on the interactions of the additive with pigment and binder particles. Thus, TEGO® ViscoPlus can basically be used in all waterborne emulsion paint formulations. The main areas of application are architectural coatings, wood finishes, printing inks and leather coatings.

Can all TEGO® ViscoPlus types be combined with each other?
All TEGO® ViscoPlus types can be combined with each other. If the required rheology cannot be achieved with one thickener, a combination of types with differing rheology profiles is recommended.

How can a rheology profile be finely adjusted?
If the required rheology profile cannot be achieved with one thickener, several thickeners can be combined. All TEGO® ViscoPlus types can be combined with each other. The rheology of the combination always lies between the profiles of the types used.

Can I combine TEGO® ViscoPlus with thickeners which have a different chemical composition?
Basically, combinations with the polyacrylate or cellulose ether thickeners commonly used in waterborne paints are possible. However it is recommended that...
the compatibility of the thickener in the formulation is checked.

How do the various TEGO® ViscoPlus types differ?
The thickeners differ in the rheology they produce in the application system:

<table>
<thead>
<tr>
<th>TEGO® ViscoPlus</th>
<th>Rheology</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEGO® ViscoPlus</td>
<td>Newtonian</td>
</tr>
<tr>
<td>TEGO® ViscoPlus 3000</td>
<td>Newtonian</td>
</tr>
<tr>
<td>TEGO® ViscoPlus 3010</td>
<td>Newtonian with high thickening at high shear rates</td>
</tr>
<tr>
<td>TEGO® ViscoPlus 3030</td>
<td>pseudoplastic</td>
</tr>
<tr>
<td>TEGO® ViscoPlus 3060</td>
<td>strongly pseudoplastic</td>
</tr>
</tbody>
</table>

What are the advantages of combining TEGO® ViscoPlus with polyacrylate thickeners?
Combination with polyacrylate thickeners enables the elastic viscosity of the paint to be increased. This leads to improved stability against settling and better sagging characteristics. Leveling is, however, frequently impaired.

What are the advantages of combining TEGO® ViscoPlus with cellulose ethers?
Combinations of cellulose ethers with polyurethane thickeners are usually encountered in architectural coatings with a high PVC. The cellulose ether imparts water retention to the paint and thus a sufficiently long open time. In addition the elastic viscosity of the paint is increased. Stability to settling and sagging characteristics are also improved. In many cases, however leveling and gloss are impaired by the cellulose ether.

What is the procedure if the rheology of a paint needs to be set using a combination of thickeners with differing rheology profiles?
With a pseudoplastic thickener, the rheology should initially be adjusted to a specified target value using low to medium shear rates. A Newtonian thickener is then added until the desired viscosity is achieved at high shear rates. The Newtonian thickener can also affect the viscosity at low to medium shear rates which should therefore be rechecked. If necessary the dosage of pseudoplastic thickener must be further adjusted.

Which types of binder can best be thickened with TEGO® ViscoPlus?
For a thickener network to form, the thickener must associate with hydrophobic surfaces. Effective thickening can be obtained with emulsifier-stabilized emulsions based on acrylates and styrene acrylates. Thickening with hydrophilic vinylacetate copolymers is less pronounced.

Why does the PVC influence the thickening effect of TEGO® ViscoPlus?
For a network to form, the thickener must associate with the hydrophobic surface of the binder particles. In paints with a high PVC, too few binder particles are available to form a strong thickener network.

How does the pH-value affect the thickening performance of TEGO® ViscoPlus?
In the typical range of pH for emulsion paints, the pH does not affect the thickening performance of TEGO® ViscoPlus.

Can a paint be made thixotropic using TEGO® ViscoPlus?
At high shear, the static viscosity of the pseudoplastic TEGO® ViscoPlus 3030 and 3060 falls. After the shear force is removed, the viscosity prior to shear is spontaneously reinstated. Thixotropy, in the sense of time-delayed increase in static viscosity, cannot be obtained with TEGO® ViscoPlus.

What are the ecological advantages of TEGO® ViscoPlus?
All grades are free of volatile organic compounds (VOC) and of alkylphenol ethoxylates (APE). No organotin catalysts are used in their manufacture.

Literature:
Hydrophobing Agents

TEGO® Phobe
Because of their pore and capillary structure, mineral building materials absorb moisture on contact with water. This often leads to visible and invisible damage caused either by the water itself or by processes in the walls which are initiated or enhanced by water.

Examples of facade damage caused by water are:
- growth of algae, fungi or spores
- salt efflorescence
- frost damage
- loss of insulating effect
- flaking off of coatings

An effective method of protecting walls which are exposed to weathering is by treating the surfaces with materials which are impenetrable to water or are water repellent (hydrophobic materials).

Hydrophobicity

Hydrophobic means water-hating. A surface is described as hydrophobic if it is not or is not fully wetted by water droplets. A parameter characterizing the hydrophobicity of a surface is the contact angle.

It can be determined by applying water droplets to the surface (fig. 2) and using contact-angle measuring equipment which measures the tangent at the substrate/liquid/air boundary. The result is quoted as the interior angle of the liquid droplet with the substrate. Surfaces with contact angle greater than 90 degrees are classified as hydrophobic. If the contact angle is less than 90 degrees, they are said to be hydrophilic. A video “Measurement of contact angle” can be found on our homepage.
Chemistry of hydrophobing agents

Silicone-based hydrophobing agents

Chemistry of silicone products
The fundamental building blocks of silicones are chlorosilanes, produced by the Rochow synthesis method, which are condensed to higher siloxanes by hydrolysis or alcoholysis. The number of chlorine substituents gives the number of valences available for condensation. Chlorosilanes are classified into four types depending on their degree of chlorination.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Abbreviation</th>
<th>Reactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochlorosilane</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>Dichlorosilane</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Trichlorosilane</td>
<td>T</td>
<td>3</td>
</tr>
<tr>
<td>Quatrochlorosilane</td>
<td>Q</td>
<td>4</td>
</tr>
</tbody>
</table>

Different types of silicone hydrophobing agents are obtained depending on the types of units reacting together.

Silicones have a very high spreadability; they attach very readily to surfaces. The hydrophobic effect involves orientation to the wetted surface. The oxygen atoms of the siloxane chain orient themselves to the surface while the alkyl (usually methyl) groups point away from the surface thus producing a hydrophobic surface (fig. 3). The ability of silicones to bond via Si-O-Si links to siliceous surfaces gives a system which is long-lasting.

Siliconates

Siliconates are highly alkaline solutions. After application, they initially react with atmospheric carbon dioxide (CO₂) to form silanols which then react together to produce a silicone resin. Methyl- or propyl-potassium silicates are used almost exclusively. Reaction with CO₂ also produces potassium carbonate as a by-product which is deposited as a salt on the surface. Because the potassium carbonate formed is water soluble, siliconates are used for interior use, e.g. for hydrophobing plasterboard.

Figure 3: Activity of silicones on mineral substrates
Silanes

Silanes are used for hydrophobing mineral materials. Silanes are manufactured by reacting chlorosilanes with alcohol, usually methanol or ethanol. The low molecular weight of silanes is both an advantage and a disadvantage. Compared with higher molecular weight silicones, they are much smaller and can therefore penetrate noticeably better. The disadvantage is their high volatility and the associated possible loss during application.

Upon curing, a silane reacts first with moisture from the air or the building material to give a silanol which, in a subsequent condensation step, crosslinks with itself and the substrate. The speed of the condensation reaction of silanes is strongly affected by the temperature and alkalinity of the substrate. Higher temperatures and high pH favor the condensation reaction. Among the alkoxysilanes, types with methyl groups have the highest reactivity. As methanol is formed as a by-product of the reaction, the more inert ethoxysilanes are increasingly used. The reaction of the silane can be accelerated by suitable catalysis.

Polydimethylsiloxanes

Polydimethylsiloxanes are higher molecular weight linear condensation products of D- and M-units. They have a lower penetrating power than oligomeric siloxanes. Polydimethylsiloxanes are mainly used as hydrophobing agents in coatings and plasters, for example in silicate paints, siloxane-modified coatings. Amino-modified polysiloxanes in these formulations produce good hydrophobing combined with a high water-beading effect.

Silicone resins

The use of hydrophobing agents based on silicone resins gives rise to the names silicone resin paints and silicone resin plasters. Compared with organic resin binders silicone resins have a relatively low molecular weight of between 2,000 and 3,000 g/mol. The residual reactivity in the resin enables the resin to crosslink by a condensation reaction. The water repellent effect is already fully developed immediately after drying. Silicone resins are also used as hydrophobing agents in silicone-silicate formulations.
Waxes

Waxes both as dispersions in organic solvents and as aqueous emulsions have limited penetrating power. Hydrophobing with waxes is therefore mainly a surface effect. As a result of this, hydrophobing with waxes is of limited durability as the wax layer is eroded by the effects of water and weathering. Additionally, the thermoplasticity of the waxes leads to a higher dirt uptake by the surfaces.

Polyfluorocarbon compounds

Surfaces treated with polyfluorocarbon compounds are particularly hydrophobic and also have oil repelling (oleophobic) properties. The high cost of these products and their poor biodegradability limits their use to special niche applications.

Facade protection theory

The protection of a facade against moisture by appropriate treatment is a very important factor for maintaining a building. At first sight, sealing the facade with a waterproof coating seems to be the best solution to protect surfaces against moisture. On closer consideration, however, it is apparent that there are numerous origins of water in a facade.

For example, cracks or other defects in the coating of the facade, rising moisture, damage in roof drainage or dampness from the interior contribute to entry of moisture and transport of salts into the masonry. It is important for a facade to have functioning “moisture management”. This involves two parameters which can be measured by standardized methods:

1. Protection of the facade from direct ingress of water through the facade surface (Permeability for water to DIN EN 1062-3).
2. Maintenance of the porous structure of the facade thus allowing a moist or wet wall to dry. (Water vapor transmission rate to EN ISO 7783).

Water permeability, w-value (EN ISO 1062-3)

The water permeability, often called capillary water absorption, describes the amount of water which can be absorbed by capillary suction by a square meter of building material within a certain time interval. In EN ISO 1062-1, there are three classes of capillary water uptake. Building materials in the best (class 3) have a maximum of 0.490 kg capillary water uptake on one square meter in 24 hours.
Water vapor transmission rate (permeability) (V-value or $s_d$-value)

The water vapor transmission rate is determined by EN ISO 7783. The V-value describes the amount of water vapor in grams which can diffuse in one day from a coating area of one square meter. More often than the water vapor transmission rate, the diffusion equivalent thickness of air ($s_d$-value) is given. The $s_d$-value, which can be calculated from the V-value, describes the thickness of an imaginary layer of still air which has the same resistance to water vapor diffusion as the coating. EN 1062-1 divides the $s_d$-value into three classes. Coatings with an $s_d$-value less than 0.14 m are assigned to the best class (class 1) and have very good water vapor transmission.

The relationship of these parameters to each other is given in Künzel’s facade theory. Optimally formulated facade coatings have coordinated w- and $s_d$-values and will lose water as water vapor can be taken up faster than rain. This property is fulfilled by paints where the product of w-value and $s_d$-value is at the most 0.1 kg/(m $\cdot$ $\sqrt{h}$). Ideally formulated paints have a low capillary water uptake (class 3) and very high water vapor transmission rate, characterized by a low $s_d$-value in class 1. Figure 4 shows quantitatively the relationship of w- and $s_d$-values to each other. The yellow area shows the region in which the product of w- and $s_d$-values is 0.1 kg/(m $\cdot$ $\sqrt{h}$) or smaller. The extent to which individual facade coating systems fulfill this condition is shown by the colored areas.

### Water permeability classes, w-value, (EN ISO 1062-1)

<table>
<thead>
<tr>
<th>Class</th>
<th>Water uptake</th>
<th>w-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>low</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>II</td>
<td>medium</td>
<td>0.1 – 0.5</td>
</tr>
<tr>
<td>I</td>
<td>high</td>
<td>&gt; 0.5</td>
</tr>
</tbody>
</table>

### Water vapor transmission rate, $s_d$-value (EN ISO 1062-1)

<table>
<thead>
<tr>
<th>Class</th>
<th>Water vapor diffusion</th>
<th>$s_d$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>high</td>
<td>&lt; 0.14</td>
</tr>
<tr>
<td>II</td>
<td>medium</td>
<td>0.14 – 1.40</td>
</tr>
<tr>
<td>III</td>
<td>low</td>
<td>&gt; 1.40</td>
</tr>
</tbody>
</table>

Figure 4: Facade protection theory according to Künzel
The most important parameter affecting \( w \)- and \( s \)-values is the pigment volume concentration (PVC). The pigment volume concentration describes the volume ratio of the powder-form pigments and filler to the total including the binder in the dried coating film. It is calculated from the following formula.

\[
PVC = \frac{\sum V_{\text{pigments}} + \sum V_{\text{fillers}}}{\sum V_{\text{pigments}} + \sum V_{\text{fillers}} + \sum V_{\text{binders}}} \cdot 100\% \]

The PVC for a formulation with a small amount of binder and thus a correspondingly large proportion of pigments and fillers is a high value. Such formulations are indicated by the terms “formulations with high PVC” or “weakly bound formulations”. Conversely, formulations with a high proportion of binder and low amounts of pigments and fillers are called “formulations with low PVC” or “strongly bound formulations”. Clear coats have, according to the formula, a PVC of zero and theoretically a paint formulated with no binder has a PVC of 100%. In practice, paints are found with extremely low amounts of binder up to a PVC of 90 to 95%.

If the PVC of a formulation is altered step-wise over the complete PVC range, a PVC range is reached in which the film has a high tension. This can lead to cracks in the coating. That point is known as the critical PVC, and in this region the paint undergoes a change between a binder excess at low PVC to binder deficiency at high PVC. Paints with binder excess at low PVC are termed sub-critically formulated. This means that the formulation contains an excess of binder which will fill all cavities between pigments and fillers.

Formulation of paints which satisfy the requirements of Künzel’s facade protection theory

The most important parameter affecting \( w \)- and \( s \)-values is the pigment volume concentration (PVC). The pigment volume concentration describes the volume ratio of the powder-form pigments and filler to the total including the binder in the dried coating film. It is calculated from the following formula.

\[
PVC = \frac{\sum V_{\text{pigments}} + \sum V_{\text{fillers}}}{\sum V_{\text{pigments}} + \sum V_{\text{fillers}} + \sum V_{\text{binders}}} \cdot 100\% \]
Neither super-critical formulation nor sub-critical formulation can give low water uptake and high water vapor transmission. Only formulations with hydrophobing agents simultaneously offer very good water permeability and water vapor transmission rates. The various formulation concepts and coating types are described below.

Sub-critical formulations have very good water permeability characteristics (\(w\)-value). The binder excess and corresponding continuous film provides protection against water penetration. However, the film strongly reduces the water vapor transmission rate which leads to high \(s_2\)-values. In practice, too low a water vapor transmission rate can allow the evaporating moisture from the walls to produce a water vapor pressure under the coating which can cause defects in the coating such as blistering.

In contrast, super-critically formulated, open-pore coatings have very good water vapor transmission rates. However, their porosity leads at the same time to high capillary water uptake which means that super-critical formulations do not offer adequate protection from the moisture.

**Formulation concepts for facade paints and plasters**

**Silicone resin paints and plasters**

The best protection for facades is offered by paints with low water uptake and good water vapor transmission. For this, silicone resin paints and plasters offer advantages over emulsion paints and plasters, as they satisfy both requirements. Silicone resin paints and plasters are super-critically formulated, i.e. with high PVC. The resulting open microporous structure produces excellent water vapor transmission allowing wet walls to dry out. This avoids damage to buildings such as loss of insulating effect, attack by mold or damage to the paint by blistering or flaking. Dry masonry is also an effective contributor to a healthy and pleasant indoor environment.
The addition of silicone resin emulsions produces protection against water, for example, driving rain. The silicone resin coats the open pores without closing them. Thus water vapor transmission is preserved but the hydrophobic coating efficiently prevents water from penetrating into the pores.

Silicone resin coatings offer the most effective protection for buildings. TEGO® Phobe 1650 is one of the newest generations of silicone resin hydrophobing additives. Formulations incorporating the waterborne silicone resin emulsion TEGO® Phobe 1650 effectively prevent capillary water uptake by the coated masonry. Further advantages of TEGO® Phobe 1650 include its high effectiveness in small amounts, excellent early water resistance and low dirt pick-up by the coating. Addition of the polysiloxane TEGO® Phobe 1401 or TEGO® Phobe 1505 produces an additional water beading effect. For this, an added quantity of 1 to 2% is recommended.

According to European Standard (EN 1062-1), facade coatings are grouped according to their w-values (EN 1062-3) and s<sub>v</sub>-values (EN ISO 7783-2) each into three classes. With silicone resin paints, the highest demands can be achieved with w-value in class 3 (lowest water uptake) and s<sub>v</sub>-value in class 1 (highest water vapor permeability).

**Exterior coatings based on nanohybrid binders**

Hybrid binders of an acrylate dispersion and an amorphous silica are relatively new commercial products. These binders allow paints to be formulated which, despite having a high binder content, are more open to water vapor transmission than similar coatings based on pure polymer binders, that is with lower PVC. Compared with conventional dispersions, nanohybrid binders have the advantage that the amorphous silica imparts thermoplasticity to the coating film and makes it less susceptible to dirt pick up. Formulating silicone resin paints with nanohybrid dispersions combines the low dirt pick-up properties of the hydrophobicity of silicone resin coatings, offering an effective combination of water protection and breathability.
of the latter with the good properties of the former. A three-fold combination of a conventional binder with a nanohybrid dispersion and the silicone resin TEGO® Phobe 1650 has proved particularly effective.

Siloxane facade paint with water-beading effect

Since the end of the 1990s, facade paints with marked water beading effect have become established. Such coatings are characterized by a very strong water-beading effect with a contact angle between water/coating of more than 140°. This is often associated with a low dirt pick-up as well as a self-cleaning effect. Experience in various regions of the world has shown that environmental influences such as air pollution, climate or type and frequency of rain have a decisive effect on self-cleaning ability.

The water-beading effect is obtained by using a special hydrophobing additive, TEGO® Phobe 1505, and a special surface texture of the coating. This desired micropimple structure is obtained by using highly crystalline quartz or calcium carbonate filler with a particle size between 15 and 20 micrometers and a narrow particle size distribution. Surface-active water-soluble materials in the coating reduce the water-beading effect and, in choosing raw materials, care must be taken to ensure that they are low in surfactant. As with silicone resin paints, siloxane paints have very low water uptake and excellent water vapor transmission.

| Guiding formulation for a silicone resin paint based on nanohybrid dispersion |
|-----------------------------------------------|-----------------|----------------|
| Item | Component | Amount by weight | Ingredient/Effect |
| 1 | Water | 14.8 |  |
| 2 | TYLOSE® MH 30000 YP2 | 0.2 | Cellulose thickener |
| 3 | TEGO® Foamex 855 | 0.3 | Defoamer |
| 4 | ACTICIDE® MBS | 0.4 | Biocide |
| 5 | DOWANOL® DPnB | 3.2 | Coalescing agent |
| 6 | TEGO® Dispers 755 W | 1.3 | Wetting and dispersing additive |
| 7 | AMP90° | 0.4 | Neutralizing agent |
| 8 | KRONOS® 2190 | 22.5 | Titanium dioxide |
| 9 | OMYACARB® 5 GU | 6.0 | Calcium carbonate |
| 10 | OMYACARB® 2 GU | 6.0 | Calcium carbonate |
| 11 | AICA® "TG" | 4.0 | Mica |
| 12 | SIPERNAT® 820 A | 3.2 | Aluminum silicate |
| 13 | TEGO® Phobe 1650 | 7.5 | Hydrophobing additive |
| 14 | COL.9* DS 1200 X | 15.0 | Nanohybrid binder |
| 15 | ACRONAL® A 684 | 10.5 | Acrylate binder |
| 16 | COLLACRAL® LR 8990 (1:1 in Water) | 2.7 | Polyurethane thickener |
| 17 | TEGO® Foamex 855 | 0.4 | Defoamer |
| 18 | ACTICIDE® MKB | 1.6 | Film preserving agent |
| | | 100.00 | |

| Guiding formulation for a siloxane coating with water-beading effect |
|-----------------------------------------------|-----------------|----------------|
| Item | Component | Amount by weight | Ingredient/Effect |
| 1 | Water | 29.70 |  |
| 2 | TEGO® Foamex 825 | 0.10 | Defoamer |
| 3 | SURFYNOL® E 104 | 0.25 | Wetting and dispersing additive |
| 4 | WALOCEL® XM 6000 PV | 0.30 | Cellulose thickener |
| 5 | ACTICIDE® MB5 | 0.10 | Biocide |
| 6 | KRONOS® 2044 | 20.00 | Titanium dioxide |
| 7 | SIBELITE® M 3000 or CALCIMATT® | 32.00 | Quartz Calcium carbonate |
| 8 | Ammonia 25 % | 0.15 | Neutralizing agent |
| 9 | TEGO® Phobe 1505 | 2.40 | Hydrophobing additive |
| 10 | ACRONAL® S 790 | 15.00 | Styrene acrylate binder |
| | | 100.00 | |
Silicate paints and plasters

Silicate paints and plasters contain water glass, usually in combination with polymer dispersions as binders. The ability of water glass to react with silicate substrates and form a strong chemical bond makes silicate systems very attractive for coating the most common mineral substrates found outdoors. This property, known as silicification, makes silicate paints very durable. The high proportion of inorganic components gives the silicified coating a mineral appearance and excellent water vapor transmission. A disadvantage however is the high capillary water uptake of such formulations. This can be reduced by using hydrophobing agents specially suited to silicate paints, for example TEGO® Phobe 1505 or 1401.

Silicone-silicate paints

These are a variant of silicate paints in which the binder is a three-fold combination of emulsion, silicone resin and water glass. In terms of values for capillary water uptake and water vapor diffusion, they are similar to other silicate paints but have the advantage of lower dirt pick-up.

Guiding formulation for a dispersion silicate paint

<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
<th>Amount by weight</th>
<th>Ingredient/Effect</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>BETOLIN® V 30</td>
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<td>Thickener</td>
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<tr>
<td>3</td>
<td>TEGO® Dispers 735 W</td>
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<td>Wetting and dispersing additive</td>
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<tr>
<td>4</td>
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</tr>
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<td>5</td>
<td>TEGO® Foamex 825</td>
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<td>Defoamer</td>
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<td>6</td>
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<td>KRONOS® 2310</td>
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</tr>
<tr>
<td>8</td>
<td>OMYACARB® 5</td>
<td>30.00</td>
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</tr>
<tr>
<td>9</td>
<td>PLASTORIT® 000</td>
<td>5.00</td>
<td>Talc</td>
</tr>
<tr>
<td>10</td>
<td>TEGO® Phobe 1401</td>
<td>4.00</td>
<td>Hydrophobing additive</td>
</tr>
<tr>
<td>11</td>
<td>ACRONAL® S 559</td>
<td>6.00</td>
<td>Styrene acrylic binder</td>
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<tr>
<td>12</td>
<td>White spirit</td>
<td>1.50</td>
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</tr>
<tr>
<td>13</td>
<td>BETOLIN® K 28</td>
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<td>Potassium water glass binder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.00</td>
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</table>

Guiding formulation for a silicone-silicate paint

<table>
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<th>Component</th>
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<th>Ingredient/Effect</th>
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<tr>
<td>1</td>
<td>Water</td>
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</tr>
<tr>
<td>2</td>
<td>BETOLIN® V 30</td>
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<td>Thickener</td>
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<tr>
<td>3</td>
<td>TEGO® Dispers 715 W</td>
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<td>Wetting and dispersing additive</td>
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<td>BETOLIN® Q 40</td>
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<td>Coalescing agent</td>
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<td>13</td>
<td>BETOLIN® K 28</td>
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<td>Potassium water glass binder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>
**Emulsion paints with silicate character**

Because of their formulation with quartz flour or other mineral fillers, emulsion paints with silicate character are particularly open-pored or capillary active and thus permeable to water vapor.

**Emulsion paints and plasters**

Using polymer dispersions as binders in emulsion paints and plasters prevents water uptake by the coating. If water beading is needed, this can be achieved by adding TEGO® Phobe 1401 and TEGO® Phobe 1500 N.

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**Guiding formulation for a dispersion paint with silicate character**

<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
<th>Amount by weight</th>
<th>Ingredient/Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>14.70</td>
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</tr>
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<td>2</td>
<td>TYLOSE® MHB 10.000 YP2</td>
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<td>Cellulose thickener</td>
</tr>
<tr>
<td>3</td>
<td>TEGO® Dispers 715 W</td>
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<td>Wetting and dispersing additive</td>
</tr>
<tr>
<td>4</td>
<td>TEGO® Foamex 825</td>
<td>0.30</td>
<td>Defoamer</td>
</tr>
<tr>
<td>5</td>
<td>KRONOS® 2310</td>
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<td>6</td>
<td>OMYACARB® 5</td>
<td>10.00</td>
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<td>Talkum AT 1</td>
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<td>Talc</td>
</tr>
<tr>
<td>8</td>
<td>SIKRON® Feinstmehl SF 3000</td>
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<td>Quartz</td>
</tr>
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<td>9</td>
<td>ACTICIDE® MBS</td>
<td>0.20</td>
<td>Biocide</td>
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<td>TEGO® Phobe 1401</td>
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<td>Hydophobing additive</td>
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<td>White spirit</td>
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<td>12</td>
<td>DOWANOL® DPnB</td>
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<td>DESAVIN®</td>
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<td>Plasticizer</td>
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<tr>
<td>14</td>
<td>ACRONAL® S 559</td>
<td>21.00</td>
<td>Styrene acrylate binder</td>
</tr>
</tbody>
</table>

100.00
Hydrophobing additive for impregnation and primers

Impregnation is performed on building materials when it is not intended to coat them further. The aim of impregnation is to reduce the water uptake of a building material without otherwise altering its characteristics such as porosity or appearance. The impregnating agent must not impair water vapor and carbon dioxide permeability. Impregnation with siloxane products can be achieved with TEGO® Phobe 6010 for solvent-based impregnation or TEGO® Phobe 6510 and 6600 for water-based impregnation. Impregnation should not be used for materials which have little or no absorbency.

Primers are used to reduce the absorbency and consolidate the substrate. For this, the primer must be able to penetrate the substrate adequately. Otherwise, too much material would remain on the surface and consolidation of the substrate would not be sufficient. Adhesion problems might arise with subsequent coats. The right primer can have a decisive influence on the durability of the complete coating system.

Effective priming protects the coating from infiltration of salts and water which can damage the building. If the top coat is damaged, the primer must additionally protect the building material from further damage by water penetration.

With siloxanes of the TEGO® Phobe 6xxx series, Evonik offers products for formulating solvent- and water-borne primers.

Test methods

**Determination of water vapor permeability by the wet cup method**

Evonik uses a gravimetric method from EN ISO 7783-2 to determine the water vapor permeability by comparison with an inert carrier material. The substrates are polyethylene frits with a diameter of 60 mm. The coating material is applied to the frit with a flat brush in the amount per
Determination of water vapor permeability by the dry cup method

The dry-cup method is another way of measuring the water vapor permeability. Preparation of the sample is the same as that for the wet-cup method. However, in the dry cup method the weighing dish is filled with phosphorous pentoxide (P₂O₅) to produce an internal humidity of 0% and the glass is then kept in a standard climate of 23°C and 50% relative humidity. The water vapor diffusion is thus in the opposite direction.

Comparison of wet- and dry-cup methods has shown that the wet-cup method is more accurate.

Measurement of capillary water uptake

The capillary water uptake is measured by Evonik from EN 1062-3. The test specimens are calcium sandstone blocks with an area of 115 x 70 mm = 0.008 m² and a thickness of 20 mm. The blocks are prepared by scrubbing them free of dirt with water and then drying for 24 hours at 50°C.

The correct amount of coating is then poured onto the block and distributed with a flat brush ensuring that the sides are coated as well. The amount of coating material is based on the recommended amount used in practice. If there are no recommendations as to the amount to be used for a given area, Evonik uses a total of 400 ml/m² applied in two coats. Care must be taken to ensure that all the pores of the block are closed. The coated block is kept overnight in a standard climate (23°C, 50% relative humidity) followed by drying for 24 hours at 50°C.
The test samples are placed on foam in a water-filled tray (fig. 5). The level of the water must reach the underside of the samples and from time to time the water level is checked and water replenished if necessary. After 24 hours, the blocks are removed from the water bath, placed on paper, blotted and weighed. DIN EN 1062-3 specifies a fourfold watering of the block. In the first watering, water-soluble components of the coating are washed out. For classification of EN ISO 1063-1, the result of the fourth watering is taken and specified as the \( w_{24} \)-value, e.g. \( w_{24} = 0.5 \text{ kg/(m}^2 \cdot \sqrt{\text{h}}) \)

The method of measuring the capillary water uptake can also be seen on our internet site.

**Determination of the contact angle**

The contact angle describes the wettability of a substrate by a liquid, predominantly water in the case of exterior paints. To determine the contact angle, a water droplet with a specified volume is placed on the coating. Using an optical method, the angle of the tangent of the drop to the substrate is measured. High contact angles indicate poor wetting and consequently good water beading. In contrast, low contact angles indicate good wetting and poor water beading. The contact angle can change during the course of the measurement. In particular, with fresh paints which have not been exposed to water or weathering, the contact angle decreases during the course of the mea-
surement. The reason for this is that emulsifiers and other water-soluble components are dissolved out of the paint film and these lower the interfacial tension of the water droplet. If the coating is irrigated for 24 hours prior to the measurement, higher and more stable values of the contact angle are obtained. When comparing results of contact angle measurements, it is therefore always necessary to know details of the pre-treatment.

No statements about the capillary water uptake can be made from the contact angle of a coating.

**Dirt pick-up**

In addition to the technical properties of a coating, it is also important that it retains its appearance over a long period of use. One obvious visible aspect of an exterior coating is its soiling characteristics. This can be tested in several years of outdoor weathering but the tendency of an exterior coating to soil can be simulated in a fast test developed by Evonik. Using a converted washing machine, test samples of coatings are sprayed with a dirt dispersion and then dried. This is repeated several times. The dirt dispersion used contains both organic and inorganic matter such as would typically be found in highly polluted urban or industrial areas. The results of the soiling test are specified as delta L of the sample before and after the test. Experience shows that this soiling test produces results which would otherwise only be obtained by several years of outdoor weathering tests.
FAQs

Vertical tracks which differ from the original color are caused by rain. How can this sensitivity to sudden rain of a recently applied silicone resin paint be improved?
We offer TEGO® Phobe 1650, a silicone resin with early water resistance. That means that the hydrophobic effect of TEGO® Phobe 1650 develops very quickly after application. According to the method for determination of capillary water uptake, EN 1062–1, coatings must reach their full effectiveness after the fourth exposure to water. TEGO® Phobe 1650 actually achieves this after only two exposures.

Does the silicone resin in silicone facade paints affect the sd value and is the PVC of the coating altered?
The amount of silicone resin has practically no effect on the $s_d$-value. Investigations have shown that silicone resins do not behave like binders in their effect on wet abrasion resistance or $s_d$-value. In calculating the PVC, silicone resins should therefore not be incorporated into the calculation as binders.

We have found that our silicone resin paints show a strong increase in viscosity after storing for 5 to 6 months. How can we prevent this?
The order of addition during the manufacture of the paint plays an important role. After manufacturing the millbase, the silicone resin emulsion should be added first and the binder dispersion only added after further stirring.

How much silicone resin do I need to formulate a silicone resin paint?
There is no clear rule as to how much silicone resin a formulation must contain. More important than the quantity used is that the formulation must fulfill the physical demands made on it, such that it achieves class 3 in permeability of water and class 1 in water vapor transmission rate. Older formulations contain up to 10% silicone resin emulsion to satisfy these demands. With the newest generation of silicone resin emulsions, similar properties can be reached with only 4 to 7%.
In choosing the silicone resin, it should be noted that, by definition, silicone resin paints must be made hydrophobic with a silicone resin. Even if linear polysiloxanes can produce a similar hydrophobing effect they cannot, by definition, be used to hydrophobe silicone resin coatings.

How do silicone resin paints behave with respect to dirt pick-up?
The claim that silicone-containing coatings with a high water-beading effect are self-cleaning has not been shown in practice. On the contrary, silicones in coatings tend to promote soiling of the surface. As silicones are necessary to reduce the capillary water uptake, it is necessary to find the best compromise amount. With the most recent generation of silicone resins, between 4-7% produces a good balance between dirt pick-up and capillary water uptake.

What is the difference between a silicone resin and a silicone oil?
In terms of chemical structure, silicone resins and silicone oils differ in the way the molecules are branched. Silicone oils (also known as polysiloxanes) have a linear structure composed of M- and D-units. Silicone resins are branched and contain T- and/or Q-units. Silicone resins which contain only T- and Q-units have a very closely meshed resin network and high hardness. If they also contain D- and/or M-units, the resin forms a more open network with lower hardness. The real physical difference between a silicone oil and a silicone resin is the film forming properties. Silicone oils do not form films; that is to say that from an emulsion or solution they dry to an oily layer. In contrast, silicone resins form a non-tacky soft to hard silicone resin film.

How is a silicone resin defined?
Silicone resins are silicone structures that contain branching T- and/or Q-units. They can also contain linear components of D- and M-units. Depending on the amount of linear components, customized resins with high or low hardness can be formulated.

Should silicone resin hydrophobing additives be regarded as binders?
Silicone resin paints are formulated with an organic binder dispersion and a silicone resin. Often the amount of binder dispersion is in the region of 8 to 20% and that of the silicone resin between 4 and 10%. If the amount of silicone resin in the formulation is altered and coating properties such as water vapor transmission or wet abrasion resistance compared with a formulation in which the organic binder has been altered by a similar amount, it is noticeable that both formulations do not change in the same way. Raising the amount of organic binder leads to a higher water vapor diffusion resistance and a higher wet abrasion resistance; whereas these two properties remain virtually unchanged for changes in silicone resin. This indicates that the silicone resin is not behaving as a binder. It is therefore questionable if the silicone resin should be included as a binder when calculating the PVC.

Can I improve the wet abrasion resistance of a coating by using silicone hydrophobing additives?
Investigations have shown that silicone hydrophobing materials have only a slight effect on wet abrasion resistance.

Can I impart especially good cleaning properties to a matte interior paint by adding silicone resins?
Producing a hydrophobic paint surface by adding silicone resin is not sufficient to impart good cleaning properties to a coating. Whether or not a coating can be cleaned easily is determined by the overall formulation. A silicone hydrophobing additive can nevertheless contribute to the cleanability of the coating.

Can I make deductions about the capillary water uptake of a paint from the contact angle?
The contact angle and the capillary water uptake refer to two fundamentally different things. The contact angle describes the wettability of a coating surface by water. High contact angles indicate poor wettability and a concomitant water beading effect. The capillary water uptake describes the capillary hydrophobicity of a coating. It is quite possible for a coating to have high (and consequently unfavorable) capillary water uptake even though the beading effect is very strong.
Co-Binders
TEGO® AddBond – TEGO® VariPlus
Adhesion is a key topic in coatings systems. The demands made on adhesion-promoting products are highly sophisticated. Besides excellent compatibility with other formulation components, such resins must be able to optimize adhesion on all types of substrates. TEGO® AddBond products provide formulators with a range of polyester resins which improve adhesion of solventborne, waterborne and radiation-curing coatings and printing inks regardless of the way they dry or cure. The resins can be used in physically drying, oxidatively drying, heat-curing and radiation-curing systems.

How are polyester resins manufactured?

TEGO® AddBond resins are polyester resins with a special structure. They are manufactured by the polycondensation of special-purpose carboxylic acids and polyols (fig. 1). Aqueous secondary dispersions are obtained by neutralizing carboxyl groups with amines (fig. 2). Such solvent-free dispersions have a good storage life. The TEGO® AddBond resins are resistant to hydrolysis. They always contain free carboxyl and hydroxyl groups. Their hydrophilic and hydrophobic characteristics are designed to make a maximum contribution to improving adhesion and enhancing corrosion protection.
What do polyester resins achieve?

With the exception of TEGO® AddBond LTH, which is a solid resin, all other products in the TEGO® AddBond range are supplied as solutions (table 1). Since TEGO® VariPlus 3350 UV is also a polyester resin, it is listed here. This resin is dissolved in tripropylene glycol diacrylate, a UV-reactive solvent. TEGO® AddBond DS 1300 is an aqueous secondary dispersion which does not contain any organic solvents. All other products are dissolved in an organic solvent.

TEGO® AddBond resins contribute to improved adhesion on numerous substrates. They are effective on metals, minerals and various plastics and are thus often used in primers or one-coat finishes. They also improve intercoat adhesion so they are highly recommended for use in multicoat finishes. In effect-finishes, they improve cohesion within the film. The adhesion promoting properties of TEGO® AddBond products, complemented by excellent resistance to hydrolysis, significantly improve the anti-corrosion performance of coatings. TEGO® AddBond resins help to enhance gloss, flexibility and hardness.

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<table>
<thead>
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<tbody>
<tr>
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<tr>
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</tr>
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<td>TEGO® AddBond LTW-B</td>
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<tr>
<td>TEGO® AddBond DS 1300</td>
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<td>TEGO® AddBond HS</td>
</tr>
</tbody>
</table>

\(^1\) 60% in xylene  \(^2\) solid resin

Table 1

---

Figure 3: Use of TEGO® AddBond LTW in coil coatings
TEGO® AddBond resins are used as co-binders in numerous paints and lacquers such as can coatings and coil coatings, automotive OEM or refinish coatings, industrial coatings, anti-corrosion paints, road marking paints, printing inks, adhesives, hot embossing foils and UV coatings.

Figs. 3 to 7 show typical examples of applications. TEGO® AddBond LTW and LTW-B improve adhesion of can coatings and coil coatings (fig. 3). These resins exhibit a flexibilizing effect and enhance the coating’s processing properties.

An additional important area of application is automotive OEM or refinish coatings. TEGO® AddBond LTW and LTW-B are widely used in solventborne finishes. TEGO® AddBond 1270 is used in brake disc lacquers. TEGO® AddBond DS 1300 is used, for example, to improve the adhesion of waterborne paints on plastic fenders (fig. 4).

TEGO® AddBond products are also used in anti-corrosion paints, TEGO® AddBond LTH and LTW in solventborne coatings, and TEGO® AddBond DS 1300 in waterborne coatings (fig. 5).

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### Areas of application of TEGO® AddBond resins

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<td>+</td>
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</table>

+ recommended use   o possible use   – limited use
TEGO® AddBond products improve adhesion in numerous paints and lacquers for plastics substrates such as polyamide, polyvinylchloride, polycarbonate, ABS, ABS/polycarbonate, Noryl or HIPS. The TEGO® AddBond products LTH, LTW, LTW-B, 2325 and 1270 are recommended for solventborne finishes, DS 1300 and 1270 for waterborne finishes and TEGO® AddBond LTH and TEGO® VariPlus 3350 UV for radiation-curing coatings. The flexible TEGO® AddBond LTW ensures good substrate wetting, improved adhesion and excellent cohesion of effect pigment finishes (fig. 6). Because of its high compatibility with acrylic resins and reactive thinners, TEGO® VariPlus 3350 UV is recommended for use in radiation-curing coatings, printing inks and adhesives (fig. 7). TEGO® AddBond LTH is also used in some UV formulations. Both resins enhance not only adhesion but also reduce volume shrinkage during curing.

Figure 4: Use of TEGO® AddBond DS 1300 in automotive finishes
Figure 5: Use of TEGO® AddBond LTH in anti-corrosion paints
Figure 6: Use of TEGO® AddBond LTW in plastic coatings
Figure 7: Use of TEGO® VariPlus 3350 UV in UV printing inks
Numerous coatings and printing inks are available commercially. Physically-drying coatings, air-drying paints, stoving enamels and radiation-curing systems are used in diverse fields and applied to very different substrates. TEGO® VariPlus resins are frequently used to enhance the property profile of such systems. These non-saponifiable, neutral, hard resins have a low molecular weight, low inherent color and exhibit good light and heat resistance. Their outstanding compatibility with the most important main binders and their good solubility in the solvents commonly used in these systems make them highly versatile.

**How are ketone-aldehyde resins and the special resins derived from them manufactured?**

Ketone-aldehyde resins are manufactured by an aldol condensation of a ketone with an aldehyde. The resulting chemical structures and their properties depend substantially on the ketone used. If acetophenone or trimethylcyclohexanone are used, resins with exclusively keto groups are obtained (fig. 1). It is possible to manufacture ketone resins containing hydroxyl groups by using suitable reaction conditions and cyclohexanone.

![Figure 1: Typical structures of TEGO® VariPlus resins based on ketone-aldehyde chemistry](image)
Another possibility for obtaining alcohol groups is by hydrogenating the keto group. In this way, the ketone-aldehyde resin TEGO® VariPlus AP is made into the polyol resin TEGO® VariPlus SK (fig. 2). The polyurethane-polyol resin TEGO® VariPlus 1201 TF is manufactured by reacting the hydroxyl groups of TEGO® VariPlus SK with a special light-resistant polyisocyanate using an organotin-free catalyst.

Resins for waterborne applications can be manufactured by various means. Water-insoluble resins, for example, are rendered water-dispersible by neutralization of the carboxyl groups. These polyurethane-polyol dispersions are resistant to hydrolysis (fig. 3).

Another method ensures water-compatibility by incorporating polyether chains. This enables TEGO® VariPlus UC to be used to manufacture a water-soluble polyetherketone resin which is also soluble in organic solvents.

**How do ketone-aldehyde resins and special resins derived from them perform?**

As a result of their chemical structure and the production process, the ketone-aldehyde resins are very light in color and transparent compared with natural resins. The inherent color and resistance to light and heat of the special resins obtained by chemical modification of the ketone-aldehyde resins are also substantially improved. The solubility of TEGO® VariPlus resins in organic solvents is very good. The polarity determines the solubility in very polar (alcohols) or very non-polar (aromatic-free white spirit) solvents. With one exception, all TEGO® VariPlus resins are hard solids. The glass transition temperature ranges from -47°C to +130°C. While most resins are supplied as solids, TEGO® VariPlus 1201 TF is supplied in an organic solvent. As an aqueous secondary dispersion with excellent stability, TEGO® VariPlus DS 50 is free from organic solvents. TEGO® VariPlus UC is the only solvent-free, liquid resin with a low glass transition temperature of -47°C.
As a result of the optimized process, the formaldehyde content of products based on acetophenone is below the limits of detectability.

Because of their low molecular weights and high softening or melting temperatures, resins in the TEGO® VariPlus range are not film-forming. They are thus combined with other binders to improve the properties of coatings.

TEGO® VariPlus resins influence in all sorts of ways the properties of solvent-borne, waterborne and radiation-curing coatings, printing and other inks as well as of adhesives:

- faster drying and set times
- lower VOC content
- higher hardness
- higher gloss
- improved adhesion
- improves ability to be used in primers
- better heat resistance
- better chemical resistance
- better mechanical resistance
- better corrosion protection
- better block resistance
- higher pigment loading and higher color intensities through improved pigment wetting
- lower pigment paste viscosities

### Physical properties of TEGO® VariPlus resins

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<th>Tg (°C)</th>
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\(^1\) solid resin

Figure 4: Use of TEGO® VariPlus 1201 TF in printing inks
Areas of application of TEGO® VariPlus resins

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+ recommended use
o possible use
– limited use

Besides their widespread use in printing inks (rotogravure, flexographic, screen printing, uv and specialist printing processes) and hot embossing foils, TEGO® VariPlus resins are proven co-binders in coatings and adhesives. They are used in wood finishes, coatings for plastics, anti-corrosion paints, concrete paints, road marking paints, industrial finishes, packaging coatings, paper coatings, writing inks, pigment pastes, liquid adhesives and hot melt adhesives.

Figures 4 to 7 show typical applications. TEGO® VariPlus 1201 TF imparts printing inks with very good adhesion, excellent gloss, and good block resistance during rapid drying. Because of its very good pigment wetting, it is also used in pigment pastes to achieve high color intensity and good transparency.

Ballpoint pen pastes owe their special rheological properties to the unique structure of TEGO® VariPlus SK. This resin prevents drying out and leakage of the ink while ensuring rapid setting after writing.

Figure 5: Use of TEGO® VariPlus SK in ballpoint pen pastes
Used as a resin in the top coat of hot embossing foils, TEGO® VariPlus CA has a positive influence on a range of properties such as gloss, flexibility and fastness. It is also used in the adhesive film of these coated foils because it enhances adhesion.

Because of its high glass transition temperature and special chemical structure, TEGO® VariPlus DS 50 improves the resistance of waterborne coatings for plastics to water, solvents and chemicals as well as their film hardness and gloss. Substrate adhesion is also optimized.

TEGO® VariPlus TC has proved itself as a grind paste resin in pigment concentrates because of its universal solubility in organic solvents, compatibility with binders and excellent pigment wetting. TEGO® VariPlus UC represents a new generation of pigment paste resins developed specifically for solventborne, extremely high-solids pigment concentrates with high pigment loadings. TEGO® VariPlus UC W 40 makes this resin accessible for use in waterborne (including universal) pigment preparations.
Silicone resins and silicone combination resins

An important reason for the wide application and commercial success of silicone resins are properties such as:

- thermal stability
- weathering resistance
- maintaining elasticity at low temperatures
- low surface tension
- hydrophobicity, surface activity
- release and lubricating properties

These properties make silicone resins and silicone combination resins widely applicable in areas such as impregnation of concrete, high-temperature resistant coatings or weather resistant exterior coatings. These binders are used in the form of solutions, liquid resins and emulsions.

General introduction and manufacture of silicone resins

Silicones are organic silicon compounds known as polyorganosiloxanes. This product group can be defined simply as follows:

- they are polymers
- silicon is directly bonded to carbon
- there is at least one oxygen atom connected to the silicon

The silicones occupy a hybrid position between inorganic and organic compounds, specifically between silicates and organic polymers. The siloxane link (Si-O-Si), also found in silicates, is responsible for the “inorganic” character. The organic properties arise from the direct link between silicon and carbon.

The starting point for manufacturing silicone resins are the chlorosilanes which are obtained on a large scale by the Müller-Rochow synthesis. In this, very pure silicon (>98%) is reacted at 280°C in the presence of catalysts and promoters with chemicals such as methyl chloride or phenyl chloride in a fluidized bed reactor (fig. 1).
The composition and number of the structural units and the functional groups on the silicon atom determine the structure, processing, and complex properties of the silicone resins. Table 1 shows the structural elements for forming polyorganosiloxanes.

### Table 1

<table>
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<th>Functionality in terms of hydrolyzable groups</th>
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<tr>
<td>R₂-SiX₂</td>
<td>difunctional (form chains)</td>
<td>R₂SiO₂/2</td>
<td>D</td>
</tr>
<tr>
<td>R₃-SiX</td>
<td>monofunctional (chain breaking or terminating)</td>
<td>R₃SiO₁/2</td>
<td>M</td>
</tr>
</tbody>
</table>

Silicone resin manufacture by Evonik

Chlorosilanes, the starting materials for silicone resins, are generally reacted with water or alcohols (methanol or ethanol) to produce resin intermediates with molecular weights (MW) between 1,000 and 3,000 g/mol. These have many OH- and/or OR- end-groups and no longer contain chlorine. During hydrolysis/alcoholysis of the silane mixture, a dense network of three-dimensional and cyclic structures is formed. Because of this complexity, precise chemical structural formulas cannot be given. In general, silicones are described in terms of their different substituents and reactive groups (fig. 3).

Various techniques have been developed for further modification of the resin intermediates. All Evonik silicone resins are manufactured using a common reaction scheme. First, resin intermediates with well-defined molecular weight and containing almost exclusively SiOR- rather than SiOH-reactive groups are produced. These are crosslinked further with polyalcohols to produce single phase products with a long shelf life.

Crosslinking of SILIKOPHEN® and SILIKOFTAL® silicone resins

### Chemical Reactions

Equations (1) and (2) describe the reaction of chlorosilanes with water and alcohol. They occur only during the manufacture of the resin intermediate. Reactions (3) to (6) take place both during resin manufacture and also during curing. Reactions (4) to (6) are particularly important during manufacture as they lead to an increase in molecular weight.

Equations (1) and (2) describe the reaction of chlorosilanes with water and alcohol. They occur only during the manufacture of the resin intermediate. Reactions (3) to (6) take place both during resin manufacture and also during curing. Reactions (4) to (6) are particularly important during manufacture as they lead to an increase in molecular weight.
The silicone intermediates and organic components such as polyols are not compatible with each other at the beginning of the modification process. They only become compatible and homogenizable as a result of the chemical reactions. The reaction is stopped when the desired molecular weight is reached.

The partially completed modifying reaction (6) is resumed during curing. This involves further reaction of the remaining functional groups in a system which is already strongly crosslinked and for SILIKOPHEN® and SILIKOFTAL® can only occur at high temperatures. Stoving temperatures of at least 200°C are necessary to ensure complete curing.

**Crosslinking of silicone resins in the coating**

In general, various catalysts only have a limited effect on accelerating the curing reactions of SILIKOPHEN® and SILIKOFTAL® resins. The use of large amounts of catalyst to reduce burn-off temperatures is restricted as problems such as low storage stability, gelling or increased tendency to yellowing can occur. For complete curing without addition of catalyst, we recommend stoving for 30 minutes at an object temperature of 250°C (figure 5 shows the crosslinking reaction of the silicone resins).
Applications of silicone resins and silicone combination resins

**Guiding formulation for a coating based on SILIKOPHEN® P 80/X with temperature resistance to 500°C**

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount by weight</th>
<th>Ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>SILIKOPHEN® P80/X</td>
<td>42.5</td>
<td>Silicone resin</td>
</tr>
<tr>
<td>TEGO® Dispers 670</td>
<td>1.0</td>
<td>Dispersing additive</td>
</tr>
<tr>
<td>BENTONE® 38</td>
<td>0.3</td>
<td>Rheological additive</td>
</tr>
<tr>
<td>Isobutanol</td>
<td>0.5</td>
<td>Alcohol</td>
</tr>
<tr>
<td>Butylglycol acetate</td>
<td>1.2</td>
<td>Glycol ester</td>
</tr>
<tr>
<td>TEGO® Airex 900</td>
<td>0.5</td>
<td>Deaerator</td>
</tr>
<tr>
<td>HEUCODUR® 9-100</td>
<td>6.0</td>
<td>Black pigment</td>
</tr>
<tr>
<td>HEUCOPHOS® ZPO</td>
<td>6.0</td>
<td>Corrosion protection pigment</td>
</tr>
<tr>
<td>MICA TM</td>
<td>17.0</td>
<td>Mica</td>
</tr>
<tr>
<td>AEROSIL® 200</td>
<td>0.5</td>
<td>Pyrogenic silica</td>
</tr>
<tr>
<td>Xylene</td>
<td>24.5</td>
<td>Solvent</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

**Maximum service temperatures of binders**

<table>
<thead>
<tr>
<th>Temperature in °C</th>
<th>Polyester</th>
<th>Silicone-polyester</th>
<th>Methyl-silicone</th>
<th>Phenylmethyl-silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Illustration 1

- heat resistance as a function of pigmentation
- continuous heat resistance

Evonik offers a range of phenyl methyl silicone resins under the trade name SILIKOPHEN®. The high phenyl group content ensures excellent heat resistance as well as good compatibility with other organic resins. As with all phenylmethyl silicone resin coatings, those based on SILIKOPHEN® P resins are thermoplastic.

Illustration 1 gives an overview of the temperature stability achievable. This depends strongly on the formulation, particularly on the pigmentation. While silicone resins with ethyl or propyl groups have low temperature stability, the heat resistance is distinctly raised if phenyl or methyl groups are incorporated resulting in resins with extraordinary heat resistance up to 350°C.

Such coatings are used mainly in corrosion protection at high temperatures such as car exhausts, smoke stacks, industrial kilns and combustion chambers (fig. 6). The property profile of coatings based on SILIKOPHEN® P resins is strongly dependent on the formulation. For heat resistance up to 350°C, formulations with heat resistant inorganic colored pigments and titanium dioxide are used. The guiding formulations in tables 2 and 3 give examples for long-term temperature levels of 500 and 600°C.
SILIKOPHEN® P resins are characterized by very good pigment wetting. The films remain fully functional even after extended exposure to temperatures of 350°C but may gradually lose their gloss. The maximum thickness of such coatings should (depending on their pigmentation) be less than 25 (±5) µm, otherwise solvent blistering can be caused by alcohol liberated on stoving.

In addition to this, too high a cured coating thickness loses flexibility when exposed to long-term temperatures over 300°C. Flexibility of such high temperature coatings is obtained by using lamellar fillers such as mica or aluminum flakes. Care must still be taken to ensure the same dry coating thickness as above.

Primers formulated with zinc dust can be used for corrosion-resistant coatings up to 450°C. Coatings which maintain their protective effect up to 600°C are formulated using flake inorganic or metallic pigments such as aluminum and mica (table 3).

At temperatures above 350°C, the organic components of the resin are almost completely burned off. Aided by sintering, inorganic composites are formed which are very hard and completely chemically inert but at the same time very brittle. Burning off organic groups, especially the phenyl substituents of SILIKOPHEN® P resins, leaves microscopically small voids. The resulting matrix system is so flexible that coatings at a temperature of 600°C can be quenched repeatedly with cold water without cracking.

Coatings resistant to temperatures in excess of 700°C can be manufactured using ceramic powders. However, the entire coated surface must be heated above the melting point of the frit. Only then are permanently bonded, enamel-like coatings produced by sintering with the siloxane backbone.

High solid silicone resin SILIKOPHEN® P 80/X or silicone resin emulsion SILIKOPHEN® P 40/W can satisfy demands for a reduction in solvent emission. Table 4 gives a guiding formulation for a waterborne application based on the silicone resin SILIKOPHEN® P 40/W which can withstand continuous use at temperatures up to 500°C.

**Guiding formulation for a coating based on SILIKOPHEN® P 80/X with temperature resistance to 600°C**

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount by weight</th>
<th>Ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>SILIKOPHEN® P80/X</td>
<td>52.0</td>
<td>Silicone resin</td>
</tr>
<tr>
<td>TEGO® Airex 900</td>
<td>0.5</td>
<td>Deaerator</td>
</tr>
<tr>
<td>BLANC FIXE® N</td>
<td>15.0</td>
<td>Filler</td>
</tr>
<tr>
<td>AEROSIL® 200</td>
<td>0.5</td>
<td>Pyrogenic silica</td>
</tr>
<tr>
<td>STAPA® 4</td>
<td>20.0</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Xylene</td>
<td>12.0</td>
<td>Solvent</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 3
Metals such as tin can leach out of metal cans and lead to formation of gel particles. Therefore, manufactured paints should not be stored or packaged in this type of container.

**Silicone-polyester resins/ SILIKOFTAL® HT grades**

Silicone-polyester resins combine the good properties of silicone resins (temperature resistance, weathering resistance and low surface tension) with those of polyesters (low thermoplasticity, high flexibility and good pigment wetting).

By using thermally-stable polyesters, binders can be produced with a continuous high temperature resistance of 250°C.

With silicone content below 50%, exposure to a temperature of 300°C for three hours produces strong yellowing, typical of an organic resin. With silicone content greater than 50%, the silicone component stabilizes the organic component so that no noticeable yellowing occurs. The probable reason for this is that the higher silicone content increases the inorganic content in the whole polymer thereby decreasing thermal oxidation.

By varying the polyesters and silicone resin intermediates, it is possible to produce silicone-polyester resins with different properties. Evonik offers a wide range of SILIKOFTAL® HT silicone-polyester grades which are customized for specific requirements.

The polyester content ensures good pigment wetting. Thus, for example, white coatings can be produced with gloss values greater than 90 (20° angle). Because of the resistance to yellowing, very light colors can also be formulated.

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount by weight</th>
<th>Ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>26.1</td>
<td>Dispersing additive</td>
</tr>
<tr>
<td>TEGO® Dispers 750 W</td>
<td>1.5</td>
<td>Defoamer</td>
</tr>
<tr>
<td>TEGO® Foamex K 3</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Ammonium hydroxide 25%</td>
<td>0.2</td>
<td>Base</td>
</tr>
<tr>
<td>HEUCODUR® Schwarz 9-100</td>
<td>8.0</td>
<td>Black pigment</td>
</tr>
<tr>
<td>HEUCOSIL® CTF</td>
<td>5.0</td>
<td>Corrosion protection pigment</td>
</tr>
<tr>
<td>MICA TM</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>SILIKOPHEN® P40/W</td>
<td>45.0</td>
<td>Silicone resin</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4
A further characteristic of coatings based on SILIKOFTAL® is their low thermoplasticity. As both the silicone and polyester portions are strongly crosslinked, the hardness is maintained even at temperatures around 150°C.

This is important in applications in which the hot coatings are mechanically stressed but must be scratch-resistant.

The properties of SILIKOFTAL® HT grades are particularly advantageous in decorative coatings of thermally stressed appliances such as toasters, tanning beds, fan heaters and cookers as well as the outer coatings of deep fryers, pots and pans (figs. 7 and 8).

Coatings of some household items must be resistant to detergents so that they can withstand frequent cleaning in a dishwasher without damage using surfactant-containing, strongly-alkaline cleaning agents. Resistance of a coating to detergents is generally determined by the formulation, particularly the binder used. It is an important criteria for the quality of silicone polyesters.

The most important properties of different SILIKOFTAL® HT grades are shown in table 5.

### SILIKOFTAL® grades

<table>
<thead>
<tr>
<th>Product</th>
<th>Silicone content</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>SILIKOFTAL® HTT</td>
<td>80%</td>
<td>retains hardness from room temperature to 150°C; long-term heat resistance to 250°C; good detergent resistance. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
<tr>
<td>SILIKOFTAL® HTS</td>
<td>70%</td>
<td>very good resistance to yellowing up to 220°C. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
<tr>
<td>SILIKOFTAL® HTF</td>
<td>50%</td>
<td>flexible and therefore to a limited extent may be deep drawn. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
<tr>
<td>SILIKOFTAL® HTL</td>
<td>50%</td>
<td>high gloss and low thermoplasticity. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
<tr>
<td>SILIKOFTAL® HTL 2</td>
<td>50%</td>
<td>high gloss, low thermoplasticity, good detergent resistance. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
<tr>
<td>SILIKOFTAL® HTL 3</td>
<td>30%</td>
<td>very good yellowing resistance up to 200°C, very good boiling water resistance. Currently listed under FDA 175.300 in cured solvent-free resins; conforms to BfR.*</td>
</tr>
</tbody>
</table>

*Please note that the evaluation regarding suitability for food contact may change, you can find the latest status on our website www.tego.de

Table 5
Suitable solvents for silicone-polyester resins

In unbaked form, silicone-polyesters still have a high OH-content. These polar groups interact strongly with the ester groups. In the manufacture of the resin, polar solvents are therefore used to inhibit association and thus maintain a stable viscosity. If interactions occur, such as during cooling, these associations only break up slowly upon warming.

There is a time delay in physical properties such as viscosity and conductivity reaching their final value. When formulating coatings, polar solvents such as ketones and esters are preferred to avoid clouding. The use of aliphatic solvents is not recommended.

OH content

The free OH-content of SILIKOFTAL® resins is not specified. When manufacturing these products, the emphasis is on clarity and viscosity rather than constant OH-value.

Stoving conditions and catalysts

In general, the curing reactions of SILIKOFTAL® resins are accelerated by various catalysts. The use of large amounts of catalyst to significantly reduce stoving temperatures is not recommended as it can lead to problems such as poor storage stability, gelling, brittleness and increased tendency to yellowing.

To achieve full curing without addition of catalysts, the following conditions are recommended:
- 60 minutes at 220°C
- 30 minutes at 250°C
- 15 minutes at 280°C

Silicone epoxide combination resins/ SILIKOPON® E grades

The SILIKOPON® range combines the properties of the widely applicable epoxide resins with those of silicone resins. SILIKOPON® EW and SILIKOPON® EC are for high-temperature use. Compared with pure silicone resins (SILIKOPHEN®), these silicone/epoxy hybrids offer better adhesion to metals as well as better corrosion protection and chemical resistance. A typical application is in vehicle exhaust coatings where SILIKOPON® EW or SILIKOPON® EC is used in primers and a SILIKOPHEN® resin in top coats. Such two-coat systems are temperature resistant to 550°C and have excellent corrosion resistance.

Alongside silicone/epoxy hybrid resins for use at high temperatures, SILIKOPON® EF is a further hybrid for use in topcoats in general industrial and maritime applications.
SILIKOPON® EF is used as a binder for ultra high solids applications in corrosion protection coatings for steel, coatings for wood and concrete and maritime applications such as biocide-free, easy-to-clean coatings particularly above the water line.

The special feature of the chemical crosslinking of SILIKOPON® EF lies in the dual-cure mechanism at room temperature: the nucleophilic opening of the epoxide ring (by the amine) and the hydrolysis/condensation reaction of the alkoxy groups. Both reactions occur in situ. The curing agents are aminosilanes whose amine groups react with the epoxide groups. The three alkoxy groups react in the presence of water or moisture with the free alkoxy group of the silicone resin by hydrolysis/condensation. This “double crosslinking” allows the positive properties of organic and inorganic polymers to be combined in a new class of binders. Because of the high crosslink density (see fig. 9), these coatings have a high dirt-repelling effect and are thus very effective against graffiti.

The hydrolysis/condensation reaction described in figure 9 can be strongly accelerated by catalysts. These can be tin compounds or Lewis acids and illustration 2 shows the reduction in drying time achieved by a tin compound (DOTL) and a Lewis acid (boron trifluoride/ethylamine complex).

This binder is suitable for ultra high solids, eco-friendly coatings. The particular advantage is that it permits production of isocyanate-free, 2-pack formulations with VOC content less than 250 g/l. In the case of, for example, wood clear coats, the VOC can be less than 100 g/l. The silicone/epoxy resin combination allows two-coat corrosion protection coatings to be manufactured with SILIKOPON® EF which can replace the classic three-coat systems (fig. 10).

<table>
<thead>
<tr>
<th>Effect of catalysts on the drying of SILIKOPON® EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying time/hours</td>
</tr>
<tr>
<td>SILIKOPON® EF</td>
</tr>
<tr>
<td>EF + tin catalyst</td>
</tr>
<tr>
<td>EF + Lewis acid</td>
</tr>
</tbody>
</table>

Illustration 2

Figure 9: The Dual-Cure Mechanism

![Figure 9: The Dual-Cure Mechanism](image-url)
In contrast to this commonly-used synthesis, Evonik largely replaces the polyester-polyol with a silicone base unit, a dihydroxyalkylpolydimethyl siloxane with two terminal OH groups (fig. 12).

Applications of SILIKOPUR® 8080

An application of SILIKOPUR® 8080 is the coating of leather in, for example, shoes, clothing or vehicles. The polyurethane formulation increases the slip effect and decreases creaking and squeaking of leather over the long-term.

Waterborne silicone-modified polyurethane dispersions

Under the name SILIKOPUR® 8080, Evonik offers a waterborne, N-methylpyrrolidone-free (NMP-free), silicone-modified, 1-pack polyurethane dispersion. This dispersion air-dries at room temperature.

Manufacture of SILIKOPUR® 8080

The synthesis of polyurethane dispersions usually occurs as the series of consecutive steps shown in figure 12. A diol, dimethylolpropionic acid and excess isocyanate are reacted together to form an isocyanate-terminated prepolymer. After neutralization and chain extension, it is emulsified in water.

In addition to the reduced coat thickness and hence less material needed, cost savings also accrue because of the reduced time required for coating. Further advantages arising from the high inorganic content are good char resistance and high abrasion resistance. The high crosslinking density of coatings based on SILIKOPON® EF allows this binder to be used in the flooring and industrial plant sectors.

The special properties are as follows:
- quick drying in air
- non-stick effect
- special haptics
- hydrophobic
- high flexibility even at low temperatures (-30°C)
- high elasticity of 300-400%
- good adhesion to flexible substrates
- improved abrasion resistance

Manufacture of SILIKOPUR® 8080

The synthesis of polyurethane dispersions usually occurs as the series of consecutive steps shown in figure 12. A diol, dimethylolpropionic acid and excess isocyanate are reacted together to form an isocyanate-terminated prepolymer. After neutralization and chain extension, it is emulsified in water.

Applications of SILIKOPUR® 8080

An application of SILIKOPUR® 8080 is the coating of leather in, for example, shoes, clothing or vehicles. The polyurethane formulation increases the slip effect and decreases creaking and squeaking of leather over the long-term.
As with all condensed binders, the amount of solids in SILIKOPHEN®, SILIKOPON® and SILIKOFTAL® is not exactly the same as the amount of non-volatiles. Solids contain low molecular resin components and condensed groups which are not present in the non-volatile residue after drying. Therefore, the solids content is often a few percent higher than the non-volatiles as determined by DIN 53216. In our data sheets, only the amount of non-volatiles is given as this is the parameter which is important for the user. In contrast, the material safety data sheets give the solids content which is what is important for hazardous goods classification.

Figure 13 compares the slip properties with those of a usual waterborne polyurethane dispersion.

Because of the silicone modification and the anti-stick properties and high flexibility resulting from it, SILIKOPUR® 8080 is used in release coatings for EPDM. Furthermore, the dispersion has good substrate adhesion properties on many other plastics (ABS, GFP, Nornyl, PA, PMMA, PVC, PC).

Illustration 3 shows that a 30% addition of SILIKOPUR® 8080 as co-binder to an acrylic dispersion can improve abrasion resistance of wood finishes.

---

### Abrasion resistance (CS-17 wheel, 1 kg)

<table>
<thead>
<tr>
<th>Amount of SILIKOPUR® 8080 (%)</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 abrasion cycles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000 abrasion cycles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13: Slip properties
Silica-Nanocomposites
NANOCRYL® – NANOPOX® – NANOPOL®
Because of their special properties, nano-composites are mainly used in coatings whose characteristics cannot be produced by conventional means or can only be achieved by multiple coats. Silica-nano-composites are preferred where high scratch and abrasion resistance is needed at the same time as transparency.

Silicon dioxide nanoparticles can be used in the form of liquid composites in many organic matrices in coating materials.

They:
• improve scratch and abrasion resistance
• improve barrier properties
• improve total transparency of the coating
• have no effect on the degree of gloss
• reduce shrinkage during curing
• reduce tension stress during curing
• improve adhesion on substrates with hydroxyl functions

It follows from the above properties that silica nanoparticles are favored in applications which require transparency and/or high abrasion resistance such as high performance coatings or off-shore topcoats.

**Manufacture of silica-nanocomposites**

Composites can be manufactured from silica nanoparticles and organic resins using a modified sol-gel process. Despite being 50% w/w filled, they are crystal clear.

Starting from water glass (aqueous sodium silicate solution), spherical silica nanoparticles of ca. 20 nm diameter can be cultured in an aqueous environment and their growth stopped by wet-chemical means. These particles then have their surfaces modified to permit stable transfer into an organic matrix.
Depending on the matrix which will surround it, this modification is performed with various agents and can lead to different results according to the polarity of the matrix and silica-nanoparticles.

In the first purification step, practically all free ions are removed. In a second step, after surface modification with a processing matrix, water is separated. In the third step, the processing matrix is replaced by the final matrix.

Silica-nanoparticles obtained in this way, contain, depending on the matrix, up to 50% silica in nanoparticulate form and are stable for at least six months. These products are crystal clear, completely transparent and show no sedimentation.

Free silica-nanoparticles cannot be prepared by this process as, in the absence of a surrounding matrix, they have a tendency to form agglomerates of µm size which cannot be re-dispersed. This would lead to the loss of all the desirable properties of the silica-nanocomposites, such as transparency and scratch and abrasion resistance.

In principle, a large range of different particle sizes can be produced. An average particle diameter of ca. 20 nm has however proved optimum for:
- optical clarity in coating materials
- core/shell ratio
- high amount of silica nanoparticles in the liquid composite
- storage stability

Particle size distribution is very narrow as a result of process optimization.

Use of silica-nanocomposites to improve properties

In addition to the main property of scratch and abrasion resistance while maintaining transparency, secondary properties such as barrier effects or reduced shrinkage during curing can also be found in important applications.

The particles in the cured film are statistically distributed. The distribution is, on average, identical at the surface, in the middle and at the bottom.

![Particle size distribution](image_url)

The silica phase consists of discrete nanospheres (Ø 20 nm) with an extremely narrow particle size distribution.
This is quite different from surface active products such as waxes or silicone oils which are only effective at the paint/air interface. Therefore, they only have a temporary effect on the scratch and abrasion resistance and provide protection only over a few load cycles. Current recommendations are for added amounts in the region of 0.5%, as higher quantities can lead to surface defects and incompatibilities.

In contrast, silica-nanocomposites offer permanent protection because they are firmly bound into the cured film matrix. Because they are distributed throughout the whole film, the initial recommendation is 5 to 10% w/w relative to the solids of the paint formulation. This amount greatly improves hardness, scratch and abrasion resistance in many applications.

The resistance to abrasion with steel wool is shown for two PPTTA-based coatings – the coating on the right contains 50% nanoparticles and that on the left has no additive. Both coatings were subjected to rubbing with commercial steel wool and then viewed microscopically. The left sample, which contains no nanoparticles, has sustained heavy damage. In contrast, the sample on the right containing silica-nanoparticles remains undamaged.

Addition of inorganic nanoparticles can alleviate shrinkage during curing. This is important for coating substrates which should not undergo any dimensional change during crosslinking (e.g., warping or distortion of panels, foil or filigrain components).

**Relationship pbw nanosilica/pencil hardness**

![Graph showing the relationship between pencil hardness and pbw nanosilica particles](image)
The correct choice of low-shrinkage binders on the one hand and addition of nanosilica on the other is crucial for successful formulation of clear coats. During curing, the nanoparticles achieve an even distribution of forces. Furthermore, introduction of inorganic components in amounts related to that of the shrinkable organic resins leads to smaller effects at the same film thickness.

Similarly, the so-called bending or curling effect which can occur with foils or endless products is significantly reduced by silica-nanoparticles.

As a result of the special surface modification of the nanosilica particles, the silica-nanocomposites only produce a relatively small increase in viscosity. In general, incorporation of 50% w/w nanosilica leads to a viscosity only four times higher than with the original resin.

The reason for this low increase in viscosity lies in the monodispersed silica-nanoparticles which, with their special surface modification, show different behavior to, e.g., milled silicon dioxide or fumed silica. The latter gives rise to an almost exponential increase in viscosity at higher amounts which, at these levels, would lead to a solid mass.

On substrates, such as glass and aluminum, the glassy nanoparticles facilitate adhesion since similar substances adhere well to each other. This effect is exploited in, for example, printing on high quality glass bottles. The demands made on scratch and abrasion resistance and chemical resistance of print in the cosmetics sector or on bottles for high quality spirits have grown enormously, so that the use of silica-nanoparticles can be advantageous.

Silica-nanoparticles are also suitable for applications where a barrier effect is required especially where transparency is also essential. The barrier effect in an organic transparent coating is increased by the inorganic silica particles. Diffusion of oxygen and water vapor is thus significantly lower than in an unmodified clearcoat.

The addition of silica-nanoparticles also generates a barrier effect in the cured film against solvents and can increase resistance by up to 400%.

<table>
<thead>
<tr>
<th>Relationship pbw nanosilica/loss of weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relationship pbw nanosilica/haze</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
In filler formulations containing microscale fillers or pigments, the nanoparticles can reduce settling of the fillers. This can be attributed to the loosening effect of the nanoparticles which position themselves between the microparticles and prevent close particle packing.

In the cured, filled coating, the nanoparticles can position themselves in the gaps between the filler and the pigment permitting, on the one hand, a marked increase in the absolute filler content (of particular interest for high solids coatings) and, on the other, denser packing of all inorganic components.

The slight increase in viscosity caused by the nanoparticles also plays a part. The reduction of emissions by adding the particles as an extender in formulations is also worth mentioning.

### Viscosity build-up of different SiO₂ particles in PPTTA

<table>
<thead>
<tr>
<th>Viscosity [mPa·s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>5000</td>
</tr>
<tr>
<td>10000</td>
</tr>
<tr>
<td>15000</td>
</tr>
<tr>
<td>20000</td>
</tr>
<tr>
<td>25000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SiO₂ content [wt%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

- surface modified fumed silica
- monodisperse nanosilica
The degree of gloss of the formulation is not affected by the silica-nanoparticles. Unlike surface waxes or pyrogenic silicas, which are added as matting agents, the nanoparticles do not settle out on the surface but are, as already described, distributed statistically throughout the entire film. Increased hardness, scratch and abrasion resistance can thus be achieved in coatings of all degrees of gloss.

**Use of silica-nanocomposites**

Incorporation of the liquid composites is easy. Like standard binders, the products are thoroughly stirred together with the main binder at the start of the production process. Dispersing or bead milling is unnecessary. Non-polar resins, solvents or additives are especially unsuitable as they cause the silica-nanoparticles to agglomerate or precipitate.

In general, aromatic polyisocyanates (TDI-based) are unsuitable as they rapidly lead to agglomeration, even when used in small amounts or in blends with aliphatic or cycloaliphatic polyisocyanates. Suitable alternatives are aliphatic and cycloaliphatic polyisocyanates such as VESTANAT® T1890.

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**Solvent migration via ERA (evaporation rate analysis)**

<table>
<thead>
<tr>
<th></th>
<th>EPA</th>
<th>PEA</th>
<th>TEMPEOTA</th>
<th>AMPA</th>
<th>GPTA</th>
<th>EPA + SiO₂</th>
<th>PEA + SiO₂</th>
<th>TEMPEOTA + SiO₂</th>
<th>AMPA + SiO₂</th>
<th>GPTA + SiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-Value</td>
<td>1000</td>
<td>800</td>
<td>600</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
Amino-functional resins, such as amine synergists for radical-curing UV coatings or aminoplastics for 1-pack stoving enamels, are mostly unsuitable. Compatibility should, of course, always be checked in the laboratory.

Moderately polar solvents such as xylene or toluene should not be used alone in formulations. These solvents are, however, in general very compatible when used in blends with popular solvents such as esters, ketones and alcohols.

Certain additives can result in incompatibilities with silica-nanocomposites. These manifest themselves in, for example, agglomeration, flocculation or increased viscosity of the coating formulation.

Since the times at which such events manifest themselves may be very different, storage tests at raised temperature, e.g. 50°C are recommended:

- to simulate storage at elevated temperature
- to specify a shelf-life (using the Arrhenius principle that reaction rates roughly double for a 10°C increase in temperature).

To save laboratory time when developing coatings with silica-nanocomposites, compatibility lists are available on request for the additives most commonly used with NANOCRYL®, NANOPOL® and NANOPOX®.

These lists give reliable recommendations for the compatibility of additives with the silica-nanocomposites in terms of short- and long-term shelf-life.

For markedly improved scratch and abrasion resistance, approx 5 to 10% nanoparticles by weight of the solids in a formulation are required – this corresponds to 20% NANOCRYL® and NANOPOL® or 25% NANOPOX® because the silica nanoparticle content differs depending on the form supplied.
### NANOCRYL®: products for UV-coatings

<table>
<thead>
<tr>
<th>Type</th>
<th>Monomer</th>
<th>Characterization</th>
<th>SiO₂ content [wt%]</th>
<th>Dyn. viscosity, 25°C [mPa·s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NANOCRYL® C 130</td>
<td>CTFA</td>
<td>Trimethyl propane formalacrylate</td>
<td>50</td>
<td>275</td>
</tr>
<tr>
<td>NANOCRYL® C 140</td>
<td>HDDA</td>
<td>Hexanediol diacrylate</td>
<td>50</td>
<td>175</td>
</tr>
<tr>
<td>NANOCRYL® C 145</td>
<td>TPGDA</td>
<td>Tripropylen glycol diacrylate</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>NANOCRYL® C 150</td>
<td>TMPTA</td>
<td>Trimethyl propane triacrylate</td>
<td>50</td>
<td>3,3</td>
</tr>
<tr>
<td>NANOCRYL® C 153</td>
<td>TMPEOTA</td>
<td>Ethox. Trimethylol propane triacrylate</td>
<td>50</td>
<td>1,0</td>
</tr>
<tr>
<td>NANOCRYL® C 155</td>
<td>GPTA</td>
<td>Propox. Glycerine triacrylate</td>
<td>50</td>
<td>1,75</td>
</tr>
<tr>
<td>NANOCRYL® C 165</td>
<td>PPTTA</td>
<td>Alkox. Pentaerythritol tetraacrylate</td>
<td>50</td>
<td>2,5</td>
</tr>
</tbody>
</table>

### NANOPEX®: products for coatings

<table>
<thead>
<tr>
<th>Type</th>
<th>SiO₂ content [wt%]</th>
<th>Base resin</th>
<th>EEW [g/equiv.]</th>
<th>Dyn. viscosity, 25°C [mPa·s]</th>
<th>Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>NANOPEX® C 450</td>
<td>40</td>
<td>DGEBA</td>
<td>295</td>
<td>60,000</td>
<td>aromatic</td>
</tr>
<tr>
<td>NANOPEX® C 460</td>
<td>40</td>
<td>DGEBA/DGEBF</td>
<td>290</td>
<td>45,000</td>
<td>aromatic, crystallizationfree</td>
</tr>
</tbody>
</table>

### NANOPOL®: products for coatings

<table>
<thead>
<tr>
<th>Type</th>
<th>Solvent</th>
<th>Characterization</th>
<th>SiO₂ content [wt%]</th>
<th>Dyn. viscosity, 25°C [mPa·s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NANOPOL® C 764</td>
<td>MPA</td>
<td>Methoxypropylacetate</td>
<td>50</td>
<td>20 mPa·s</td>
</tr>
<tr>
<td>NANOPOL® C 784</td>
<td>n-BA</td>
<td>N-Butylacetate</td>
<td>50</td>
<td>20 mPa·s</td>
</tr>
</tbody>
</table>
Silica-nanocomposites for various coatings systems

Customized silica-nanocomposites for each resin matrix have been developed for the different curing mechanisms in coatings.

All products are characterized by transparency, low viscosity and easy incorporation to the formulation.

NANOCRYL®, a range of silica-nanocomposites in various commonly used UV-curable acrylate monomers, has been specially developed for radical-curing UV coatings.

NANOPOX® materials are manufactured from epoxide resins and suitable reactive diluents. Some products can be heat-cured anhydrously or room-temperature cured with amines or force cured and some are suitable for cationic UV curing.

NANOPOL® is a solvent-based product which is almost universally applicable. It is equally suited for use in 1-pack stoving enamels and in 2-pack PUR or UV coatings.

Other modified products are available on request.
Application Fields

• Highlights
• Selection Tables
Alkyd paints (waterborne)

**TEGO® Dispers 653**
Solvent-free wetting and dispersing additive. Particularly good wetting and stabilization of inorganic pigments and fillers. Also recommended for organic pigments.

**TEGO® Dispers 656**
Solvent-free wetting and dispersing additive. Particularly good wetting and stabilization of inorganic pigments and fillers especially titanium dioxide. Good reduction of the grinding viscosity.

**TEGO® Foamex 883**
Defoamer concentrate with good compatibility and excellent long-term effectiveness in waterborne alkyd paints. Excellent gloss retention.

**TEGO® VariPlus DS 50**
Co-binder based on a polyurethane-polyol used to improve paint properties. TEGO® VariPlus DS 50 improves adhesion of waterborne alkyd paints to various substrates such as plastic or metal. In this application, it also prevents formation of flash rust. Increases hardness without affecting flexibility.

*All our wetting and dispersing additives are APE free.*
Emulsion-based coatings (silk to matte)

**TEGO® Dispers 715 W**
Universal wetting and dispersing additive for inorganic pigments and fillers for the production of waterborne coatings. Strong reduction of grinding viscosity and utmost viscosity stability of the resulting coatings.

**TEGO® Foamex 1488**
Highly efficient defoamer emulsion with good compatibility in many binders over a wide range of PVCs. Ideal for use in the letdown.

**TEGO® Foamex 8050**
Highly effective defoamer concentrate for waterborne paint systems based on a wide variety of binders such as styrene/ acrylic, acrylic and terpolymers. Also, excellent for defoaming pigment concentrates. TEGO® Foamex 8050 is formulated so it is highly effective and has good compatibility.

**TEGO® Foamex 855**
Highly effective defoamer emulsion. Eliminates foam during manufacture and application. Especially recommended for styrene acrylic and vinyl acetate based systems in the PVC ranges of 40 to 80%.

**TEGO® Foamex 883**
Highly effective defoamer concentrate with excellent long-term effectiveness. Offers very efficient defoaming for paints based on vinyl acetate copolymers over a wide range of PVCs. Recommended for the mid- to high-PVC range in styrene/ acrylic and acrylic systems.

**TEGO® Foamex K 7**
Silicone-free defoamer concentrate based on mineral oil and free of aromatics. Effective defoamer for paints with PVCs in the range 30 - 80%. Suitable for emulsion, silicone resin and silicate paints.

**TEGO® Foamex K 8**
Defoamer concentrate based on renewable raw material as an alternative to mineral oil defoamers. Combines high efficiency with the best possible compatibility over a wide range of PVCs. Suitable for use in paint formulations based on the commonly-used binders and especially in styrene/acrylic based emulsion paints.

**TEGO® ViscoPlus 3000**
Polyurethane thickener with Newtonian properties. Particularly recommended as co-thickener to reduce spattering behavior during roller application or increase brush resistance. Little effect on wet abrasion resistance.

**TEGO® ViscoPlus 3010**
Polyurethane thickener with Newtonian properties and very high efficiency in the high shear region. Especially suitable for adjusting the ICI viscosity. Particularly recommended as co-thickener to reduce spattering behavior during roller application or to increase brush resistance. Little effect on wet abrasion resistance.

**TEGO® ViscoPlus 3030**
Polyurethane thickener with pseudoplastic rheology. Recommended as co-thickener to reduce spattering behavior during roller application or increase brush resistance. Little effect on wet abrasion resistance.

**“All our TEGO® ViscoPlus products are VOC and APE free. Manufactured without addition of organotin compounds.”**
Emulsion-based coatings

**TEGO® Dispers 715 W**
Universal wetting and dispersing additive for inorganic pigments and fillers for the production of waterborne coatings. Strong reduction of grinding viscosity and utmost viscosity stability of the resulting coatings.

**TEGO® Dispers 755 W**
Highly effective pigment wetting and dispersing additive for inorganic and organic pigments. Very good color and storage stability. Good compatibility with pigment pastes. Little effect on water resistance or wet abrasion resistance of the coating.

**TEGO® Foamex 1488**
Defoamer emulsion with very high efficiency and good compatibility without impairing gloss. Universal defoamer for use in the millbase and letdown.

**TEGO® Foamex 8050**
Highly effective defoamer concentrate for waterborne coating systems based on various binders such as styrene/acrylic, acrylic and terpolymers. Also excellent for defoaming pigment concentrates. TEGO® Foamex 8050 is highly effective while still maintaining good compatibility.

**TEGO® Foamex 810**
Highly compatible defoamer concentrate with good effectiveness. Especially recommended as a millbase defoamer for sensitive paint formulations. Can also be added to clear coats and to the letdown.

**TEGO® Foamex 815 N**
Defoamer emulsion with good effectiveness and excellent compatibility without impairing gloss. Easy to incorporate at the letdown stage but also suitable for use in the millbase. The defoaming and the deaerating effect can be optimized by the use of TEGO® Foamex 810 in the millbase.

**TEGO® Foamex 823**
Universally suitable and highly effective defoamer emulsion with good compatibility. Easy to incorporate in the let-down. Very good long-term effect.

**TEGO® VariPlus DS 50**
Co-binder based on a polyurethane-polyol for improving coating properties. TEGO® VariPlus DS 50 improves adhesion on various substrates such as plastic or metal. It also prevents formation of flash rust, and increases hardness and block resistance.

*All our wetting and dispersing additives are APE free.*
**TEGO® ViscoPlus 3000**

**TEGO® ViscoPlus 3010**
Polyurethane thickener with very high efficiency at high-shear. Especially suitable for adjustment of ICI viscosity. Improves spattering, brush resistance and leveling. Good compatibility with pigment pastes.

**TEGO® ViscoPlus 3030**
Polyurethane thickener with pseudoplastic rheology. Recommended for adjusting in-can viscosity. Prevents sedimentation and syneresis. Good compatibility with pigment pastes and enhances leveling and gloss.

**TEGO® ViscoPlus 3060**
Polyurethane thickener with strong pseudoplastic rheology. Especially suitable for applying thick coats in spray application. Positive effect on leveling and gloss.

**ADDID® 230**
Solvent-free antistatic additive based on a quaternary ammonium compound. In larger quantities very effectively increases the conductivity of coatings, even without addition of conducting fillers or carbon fibers. No effect on color and therefore suitable for clear coats. 100% active substance.

**ADDID® 240**
Solvent-free antistatic additive based on quaternary ammonium compounds. Very effective increase in conductivity of coatings when used in conjunction with conductive fillers or carbon fibers. No effect on color and therefore suitable for clear coats. 100% active substance.

**TEGO® Airex 900**
Highly effective deaerator concentrate for solventborne and solvent-free coatings based on 2-pack epoxies. Added to the epoxy resin component. Very effective at preventing air inclusions and pinholes.

**TEGO® Airex 910**
Highly compatible deaerator for solventborne and solvent-free coatings based on 2-pack epoxies. Easy to incorporate and minimizes tendency of cloudiness in clear coats. Silicone-free.

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“**All our TEGO® ViscoPlus products are VOC and APE free. Manufactured without addition of organotin compounds.**
**TEGO® Airex 922**
Highly effective silicone- and solvent-free deaerator for epoxy floor coatings with very good compatibility. Also suitable for use in clear epoxy sealants. Satisfies the requirements for coatings conforming to AgBB scheme***.

**TEGO® Airex 940**
Deaerator for solventborne and solvent-free coatings based on 2-pack polyurethanes and epoxies. Excellent deaeration, easy incorporation, good compatibility and excellent overcoatability.

**TEGO® Airex 944**
Highly effective, solvent-free deaerator concentrate with low odor for use in solventborne and solvent-free 2-pack polyurethane and epoxy floor coatings. Conforms to AgBB scheme***. Good overcoatability.

**TEGO® Airex 990**
Universal deaerator for two-pack polyurethane and epoxy floor coatings. Solvent-free and suitable for use in coatings conforming to AgBB scheme***.

**TEGO® Dispers 650**
Wetting and dispersing additive for organic pigments and carbon blacks in solventborne and solvent-free epoxy floor coatings. Reduces millbase viscosity and prevents settling of pigments and fillers. Promotes leveling.

**TEGO® Dispers 652**
Wetting and dispersing additive for inorganic pigments and titanium dioxide in solventborne and solvent-free epoxy floor coatings. Reduces millbase viscosity and prevents settling of pigments and fillers. Especially suitable for glossy coatings.

**TEGO® Glide B 1484**
Flow and slip additive with deaerating properties and good compatibility for solventborne and solvent-free 2-pack epoxy- and polyurethane coatings.

**Flooring (waterborne)**

**TEGO® Airex 901 W**
Highly effective deaerator concentrate for pigmented waterborne coatings based on 2-pack polyurethanes and epoxies. Prevents micro- and macro-foam. Incorporation requires high shear.

**TEGO® Airex 902 W**
Highly compatible deaerator emulsion for waterborne coatings based on 2-pack polyurethanes and epoxies. Prevents micro- and macro-foam. Suitable for pigmented or non-pigmented systems. Easy to incorporate.

***AgBB: German Committee for Health related Evaluation of Building Products

*All our wetting and dispersing additives are APE free.
**TEGO® Dispers 650**
Wetting and dispersing additive for organic pigments and carbon blacks in waterborne epoxy floor coatings. Reduces millbase viscosity and prevents settling of pigments and fillers. Promotes leveling.

**TEGO® Dispers 652**
Wetting and dispersing additive for inorganic pigments and titanium dioxide in waterborne epoxy floor coatings. Reduces millbase viscosity and prevents settling of pigments and fillers. Particularly suitable for glossy coatings.

**TEGO® Wet 240**
Substrate wetting additive for improving substrate wetting of waterborne floor coatings. Leveling is improved particularly for 2-pack epoxy formulations.

**Hydrophobing**

**TEGO® Phobe 1401**
Universally applicable hydrophobing agent for various coating formulations. Outstanding compatibility with commonly used binders. It produces a noticeable water-beading effect. When used in silicate paints, the storage stability of the paints is also improved.

**TEGO® Phobe 1505**
Highly concentrated hydrophobing agent for formulating waterborne exterior paints and plasters with water-beading effect. TEGO® Phobe 1505 can also be used in combination with a silicone resin to formulate waterborne silicone resin paints and plasters to produce an additional water-beading effect. Use in combination with special fillers enables paints with a particularly strong water-beading effect to be formulated. Further properties of TEGO® Phobe 1505 are low VOC.
**TEGO® Phobe 1650**
TEGO® Phobe 1650 is a silicone resin emulsion for formulating waterborne silicone resin paints and plasters. Formulations with TEGO® Phobe 1650 offer excellent protection of the façade from rain and water. TEGO® Phobe 1650 offers good protection immediately after the first exposure to rain. Silicone resin paints based on TEGO® Phobe 1650 are very durable and characterized by low dirt uptake. TEGO® Phobe 1650 is cost effective and therefore offers advantages over established commercial products.

**Lipotin DB**
Wetting and dispersing additive for inorganic and organic pigments which is also suitable for binder-free pastes. Good compatibility even in low-polarity paint formulations.

**TEGO® Airex 944**
Highly effective deaerator concentrate for high solids, solventborne alkyd paints for addition to the millbase. Incorporation requires high shear.

**TEGO® Airex 931**
Universal deaerator for high solids, solventborne alkyd and acrylic paints with good compatibility. Suitable for adding to the let-down and for use in clear coats.

**TEGO® Airex 940**
Highly effective deaerator solution for solventborne alkyd paints. Suitable for addition to the millbase or let-down.

**TEGO® Glide 410**
Highly active slip and flow agent for substrate wetting and prevention of craters. In solventborne paints, very low concentrations suffice to achieve excellent slip properties.

**TEGO® VariPlus TC**
Synthetic resin for improving paint properties such as good pigment wetting. Additionally, TEGO® VariPlus TC improves adhesion of solventborne paints on substrates such as plastics and metals. Especially good at increasing the hardness without reducing the flexibility. TEGO® VariPlus TC can prolong the drying time of alkyd paints.

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**Solventborne architectural paints**

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Solventborne inks and varnishes

TEGO® Airex 900
Highly effective deaerator concentrate for solventborne flexo and gravure printing inks. Effectively prevents micro- and macro-foam and destroys existing foam. Solvent-free.

TEGO® Airex 931
Deaerator for slightly to highly polar coatings. Very high effectiveness and thus used at low addition levels.

TEGO® Dispers 670*
High performance dispersing additive for solventborne formulations. The millbase viscosity is strongly reduced making possible a high pigment loading during grinding. TEGO® Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

TEGO® Foamex N
Extremely effective deaerator concentrate for solventborne and radiation-curing pigmented printing inks. Ensures extremely rapid deaeration and breaks foam bubbles. Especially recommended for screen printing application. Solvent-free.

TEGO® Glide 410
Very strong slip additive. Especially recommended for pigmented inks.

TEGO® Glide 450
Universal flow and slip additive. Despite maximum effectiveness, very good reprintability and thus suitable for printing inks and overprinting varnishes. Solvent-free.

TEGO® Glide A 115
Highly effective slip and anti-scratch additive. Excellent flow and synergistic effects with waxes. Ideal for cellulose nitrate and polyamide-based formulations.

*All our wetting and dispersing additives are APE free.
**TEGO® VariPlus SK**
Co-binder to achieve better adhesion of printing inks on difficult substrates. This hard resin is based on a special polyol. It improves the mechanical and chemical resistance while also improving the gloss and lowering the viscosity. TEGO® VariPlus SK increases the color strength and shows broad solubility and compatibility in solventborne printing inks. Contains no solvents.

**TEGO® VariPlus TC**
Special synthetic resin to improve the pigment wetting and stabilization. When used in the grinding stage, the benefits are strongly improved pigment wetting and higher gloss of the finished ink. This product is recommended for various systems including nitrocellulose-based printing inks. Broad solubility in different solvents, TEGO® VariPlus TC is solvent-free.

**Solventborne inkjet inks**

**TEGO® Dispers 670**
High performance dispersing additive for solventborne formulations. The millbase viscosity is strongly reduced making possible a high pigment loading during grinding. TEGO® Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

**TEGO® Glide 410**
Surface active multifunctional additive, which modifies and improves the droplet formation, substrate wetting and mechanical resistance. TEGO® Glide 410 can be used in standard and eco-solvent ink jet formulations.

**Litho(offset) and letterpress printing inks**

**TEGO® Glide A 115**
Highly effective slip, antiblocking and anti-scratch additive. Provides synergistic effects with waxes.

*All our wetting and dispersing additives are APE free.*
Technical Additives for Radiation-curing Inks

**TEGO® Airex 920**
Highly compatible deaerator for UV overprint varnishes and pigmented printing inks. Effectively eliminates micro-foam without creating surface defects or creating overprint problems. Recoatable, silicone- and solvent-free.

**TEGO® Dispers 652**
Wetting and dispersing additive for inorganic pigments and matting agents. Very suitable for radiation-curing printing inks and varnishes. Solvent-free.

**TEGO® Flow 370**
Silicone-free flow and leveling additive based on polyacrylate chemistry. The surface remains heat-sealable, bondable and overprintable. The surface tension is not affected by TEGO® Flow 370.

**TEGO® Glide 432**
Extremely effective slip, flow and substrate wetting additive. Can be used almost universally. Ideally suited for radiation-curing overprint varnishes on fresh offset inks. Solvent-free.

**TEGO® Rad 2010**
Novel, radical cross-linkable slip- and substrate wetting additive with excellent price performance ratio. TEGO® Rad 2010 is low foaming to defoaming and improves the leveling. Solvent-free.

**TEGO® Rad 2011**
Novel, radical cross-linkable leveling and substrate wetting additive with excellent price performance ratio. TEGO® Rad 2011 is defoaming, highly compatible and reprintable. Solvent-free.

**TEGO® Rad 2500**
Radical cross-linkable, highly effective slip additive. Improves scratch-resistance and deaeration. Solvent-free. Particularly suitable for matt and high-viscosity overprint varnishes.

**TEGO® Wet 270**
Reprintable and glueable substrate wetting additive. Excellent reduction of static surface tension, prevention of craters. Solvent-free.
Radiation-curing flexo, silk screen and offset inks

**TEGO® Airex 900**
Highly effective deaerator concentrate. Ensures rapid deaeration and good flow. Especially for pigmented silk screen inks.

**TEGO® Airex 920**
Highly compatible deaerator for UV overprint varnishes and pigmented printing inks. Effectively eliminates micro-foam without affecting the surface or causing overprint problems. Glueable, silicone- and solvent-free.

**TEGO® Dispers 656**
Wetting and dispersing additive for inorganic pigments and fillers, especially for titanium dioxide. Effectively reduces the viscosity of the grind and the ink. Can also be used as combination additive to reduce viscosity with critical organic pigments. Solvent-free.

**TEGO® Flow 370**
Silicone-free flow and leveling additive based on polyacrylate chemistry. The surface remains heat-sealable, bondable and overprintable. The surface tension is not affected by TEGO® Flow 370.

**TEGO® Foamex N**
Defoamer concentrate for extremely powerful defoaming and deaeration of pigmented, radiation-curing printing inks.

**TEGO® Glide 435**
Low-foam slip and flow additive with excellent substrate wetting. Highly effective and solvent-free.

*All our wetting and dispersing additives are APE free.*
**TEGO® Rad 2010**
Novel, radical cross-linkable slip- and substrate wetting additive with excellent price performance ratio. TEGO® Rad 2010 is low foaming to defoaming and improves the leveling. Solvent-free.

**TEGO® Rad 2011**
Novel, radical cross-linkable leveling and substrate wetting additive with excellent price performance ratio. TEGO® Rad 2011 is defoaming, highly compatible and reprintable. Solvent-free.

**TEGO® Rad 2500**
Radiation-curing additive with a unique set of properties: slip effect, scratch-resistance and deaeration. Solvent-free.

**TEGO® Rad 2700**
Radiation-curing release additive with excellent release effect, TEGO® Rad 2700 simultaneously increases scratch resistance and promotes deaeration. Limited suitability for clears.

**TEGO® VariPlus AP**
Polyol-based co-binder works as combination partner with radiation-curing formulations. TEGO® VariPlus AP improves adhesion, pigment wetting and increases the curing speed.

**Radiation-curing inkjet inks**

**TEGO® Airex 920**
Silicone-free deaerator for compatible defoaming in the production or in the printing process. 100% active matter

**TEGO® Rad 2200 N**
Highly compatible, radically crosslinkable additive. Modifies drop formation, reduces surface tension and increases scratch resistance.
Waterborne overprint varnishes

**TEGO® Airex 902 W**
Deaerator-emulsion, combines high effectiveness against micro and macro-foam with very good compatibility. Very good long-term stability.

**TEGO® Foamex 805 N**
Solid-particle-free defoamer emulsion with excellent compatibility. Ideal for effectively defoaming coating formulations susceptible to surface defects.

**TEGO® Foamex 831**
Silicone-, solvent- and mineral oil-free defoamer with long lasting effect for use in the grind or the let-down. In compliance with all relevant European food regulatory ordinances.

**TEGO® Foamex 842**
Highly effective defoamer solution. Easy to incorporate, high gloss retention. When the defoamer-containing varnish is stored, the defoaming effect is maintained for a long time.

**TEGO® Foamex 845**
Highly effective defoamer emulsion with very good long-term effectiveness. Highly effective at preventing foam formation, destroys existing foam. Defoams even overprint varnishes with high surfactant content without affecting the gloss.

**TEGO® Glide 410**
Excellent slip and flow additive. TEGO® Glide 410 increases scratch-resistance, mar-resistance and improves flow without any negative effects on the gloss. Solvent-free.
Waterborne flexo and gravure inks

**TEGO® Glide 482**
Highly effective slip and anti-blocking additive. Increases scratch resistance and improves slip characteristics in clear and matte formulations.

**TEGO® Twin 4000**
Siloxane gemini surfactant with distinct defoaming properties and powerful surface tension reduction. This unique product distinguishes itself by outstanding substrate wetting, foam inhibition and fast foam collapsing. Even suitable for wetting on fresh litho offset prints. Solvent-free.

**TEGO® Wet 510**
Dynamic substrate wetting additive with excellent flow-promoting properties. Improves gloss and is easy to incorporate. Silicone- and solvent-free.

**TEGO® Airex 901 W**
Deaerator concentrate with high efficiency against micro-foam. Highly suitable as defoamer for the grind. Easy to combine with defoamer emulsions in the let-down. Solvent-free.

**TEGO® Dispers 653**
Very versatile wetting and dispersing additive for grinds with or without binders for waterborne flexo and gravure inks. Highly compatible with various let-down vehicles. Suitable for all types of pigments, ideal for phthalocyanine and inorganic pigments.

**TEGO® Dispers 760 W**
Highly effective wetting and dispersing additive particularly for grinds with binders for waterborne flexo and gravure inks. Gives high gloss and color strength and allows high pigment contents without thixotropy. Ideal for carbon blacks and organic pigments.

**TEGO® Dispers 765 W**
Polymeric high-performance wetting and dispersing additive for waterborne printing inks. Especially recommended for the formulation of binder-free pigment concentrates. Suitable also for binder containing grinds. Excellent reduction of viscosity, outstanding stabilization of organic and inorganic pigments and very good color development.

*All our wetting and dispersing additives are APE free.*
**TEGO® Foamex 810**
Highly effective defoamer concentrate with minimal risk of surface defects. Excellent for multi-use pigment grinds, as a grind defoamer and also in the let-down of many flexo and gravure inks. Solvent-free.

**TEGO® Foamex 822**
High compatible defoamer emulsion. Unique in that it is highly effective while also very compatible with long-lasting effect. Ideal for use in the let-down and for subsequent addition to the ink.

**TEGO® Foamex 831**
Silicone-, solvent- and mineral oil-free defoamer with long lasting effect for use in the grind or the let down. In compliance with all relevant European food regulatory ordinances.

**TEGO® Foamex 842**
Highly effective defoamer solution. Can be used in the grind and/or the let-down. Easy to incorporate. When used as grinding stage defoamer TEGO® Foamex 842 can ideally be combined with defoamer emulsions (e.g. TEGO® Foamex 845) at the let-down stage. When the defoamer-containing ink is stored, the defoaming effect is maintained for a long time.

**TEGO® Foamex 843**
Defoamer compound for a fast foam knock-down and foam inhibition. Very high effectiveness, combined with excellent compatibility. Ideal for addition at the let-down stage. Superior long-term effective. Especially designed for low viscous formulations based on acrylics and styrene acrylics.

**TEGO® Foamex 845**
Highly effective defoamer emulsion with very good long term effectiveness. Especially recommended for use in the let-down. Effectively prevents foam formation and destroys existing foam.

**TEGO® Glide 482**
Highly effective slip and anti-blocking additive. Increases scratch resistance and improves slip characteristics in clear and matte formulations.

**TEGO® Twin 4100**
Siloxane gemini surfactant with effective surface tension reduction and defoaming properties. This unique product distinguishes itself by outstanding substrate wetting on various print stocks, excellent compatibility and fast foam collapsing. Solvent-free.

**TEGO® ViscoPlus 3000**
Polyurethane thickener with newtonian rheology for adjustment of rheology for the printing process. High color development. Reduced penetration in strong absorbent substrates. Free of emulsifiers, solvents and APE. Produced without use of tin-organic substances.
TEGO® Wet 500
Foam inhibiting wetting agent with good dynamic properties. Improves wetting of a wide variety of different substrates and pigment surfaces, without side-effects. Silicone and solvent-free.

TEGO® Wet 505
Dynamic substrate wetting additive with significant degassing effect. Improves pigment wetting and remains highly reprintable. Ideal for use in the grind. Silicone and solvent-free.

Waterborne inkjet inks

TEGO® Dispers 755 W*
High-performance wetting and dispersing additive for stabilization of organic pigments and carbon blacks. Strongly reduces the viscosity and leads to more Newtonian flow behavior.

TEGO® Dispers 760 W*
Reduction of viscosity and improvement of color strength are special properties of TEGO® Dispers 760 W. It is well suited for carbon black and organic pigments.

TEGO® Foamex 805 N
High-performance defoamer with good compatibility. Well suited for use in the production process and in circulation inkjet systems.

TEGO® Glide 440
Positively Influences the droplet formation and substrate wetting of waterborne inkjet inks. Improves the mechanical resistance.

TEGO® Wet KL 245
Fully water soluble surfactant based on polyethersiloxane technology. Achieves good substrate wetting on difficult substrates like films. It can also be used to support the wetting of pigments in the grinding stage.

*All our wetting and dispersing additives are APE free.
### Solventborne wood and furniture coatings

**TEGO® Airex 910**  
Highly compatible deaerator for coatings based on unsaturated polyesters. Also suitable for curtain coater application.

**TEGO® Airex 931**  
Effective deaerator with good compatibility. Ideally suitable for spray applied, 2-pack polyurethane coating formulations. Suitable for high gloss, matte, pigmented and non pigmented wood and furniture coatings.

**TEGO® Airex 936**  
Highly effective, silicone-free deaerator for top coats and primers. Especially suitable for 2-pack polyurethane and acid-curing coatings as well as coatings based on nitrocellulose. Recommended for spray and roller application.

**TEGO® Airex 990**  
Efficient deaerator with very good compatibility. Excellently suited for use in conventional, solventborne and high solids 2-pack PU formulations. Universally applicable for all application processes. Solvent-free.
**TEGO® Dispers 610**
Controlled flocculating wetting and dispersing additive especially for inorganic pigments and fillers. Excellent for formulating primers, fillers and top coats. Suitable for a very wide range of binders.

**TEGO® Dispers 656**
Wetting and dispersing additive for inorganic pigments especially transparent iron oxide pigments. Improves wetting, stabilization and transparency of the pigments in solventborne coating formulations. Ideally suitable for the production of binder-containing, aromatic-free pigment concentrates.

**TEGO® Dispers 710**
Polymeric wetting and dispersing additive especially suitable for organic pigments and carbon blacks. Very good pigment stabilization and color development. Usable in high to medium polarity formulations and also recommended for inorganic pigments.

**TEGO® Dispers 670**
High performance dispersing additive for solventborne formulations. The millbase viscosity is strongly reduced making possible a high pigment loading during grinding. TEGO® Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

**TEGO® Flow 425**
Highly effective and compatible flow control additive. Recoatable, thus recommended not only for top coats but also for primers and fillers.

**TEGO® Glide 406**
Universal slip additive for top coats and primers. Good recoatability and flow promotion.

**TEGO® Glide 410**
Extremely effective slip additive. High surface slip and scratch resistance and anti-blocking characteristics at very low concentrations. In matte coatings, it also ensures optimum orientation of the matting agent.

**TEGO® VariPlus CA**
Co-binder used to enhance gloss, hardness and body especially in solventborne NC coatings. The 100% pure ketone-aldehyde synthetic resin is free of solvent and tin.

**TEGO® VariPlus SK**
Co-binder to increase gloss and body of solventborne 2-pack PU and NC coatings. The hard resin, based on a special polyol, also improves the dry time in 2-pack PU coatings. Free of solvents and tin.

*All our wetting and dispersing additives are APE free.*
Solventborne wood parquet and floor coatings

**TEGO® Airex 931**
Effective deaerator with good compatibility. Ideal for use in 1-pack alkyd/urethane formulations.

**TEGO® Airex 936**
Highly effective, silicone-free deaerator for top coats, base coats and primers. Highly suitable for 2-pack polyurethane-, acid catalysed or nitrocellulose coatings. Recommended for spray and roller application.

**TEGO® Airex 990**
Efficient deaerator with very good compatibility. Excellently suited for use in conventional, solventborne and high solids 2-pack PU formulations. Universally applicable for all application processes. Solvent-free.

**TEGO® Flow 425**
Highly effective and compatible flow control additive. Recoatable, thus recommended not only for top coats but also for primers.

**TEGO® Glide 100**
Combines very good flow properties and surface smoothness. Does not impair recoatability.

**TEGO® VariPlus SK**
Co-binder to improve gloss and body of solventborne 2-pack PU and NC coatings. The hard resin, based on a special polyol, also improves the dry time in 2-pack PU coatings. Free of solvent and tin.

Radiation-curing wood and furniture coatings

**TEGO® Airex 900**
Highly effective deaerator concentrate for coatings based on acrylate oligomers. Recommended for roller application. Incorporation at high-shear is recommended.

**TEGO® Airex 910**
Highly compatible deaerator for coatings based on unsaturated polyesters and acrylic oligomers. Highly suitable for curtain coater and vacumat application.

**TEGO® Airex 920**
Highly compatible universal deaerator for top coats, base coats and primers. Highly suitable for 2-pack polyurethane-, acid catalysed or nitrocellulose coatings. Recommended for spray and roller application.

**TEGO® Dispers 688**
Ideal wetting and dispersing additive for wetting the surface of matting agents thus lowering the viscosity of highly filled formulations. Yield point and thixotropy are reduced which results in improved flow and easier degassing of the coating.

*All our wetting and dispersing additives are APE free.*
TEGO® Dispers 656®
Wetting and dispersing additive for inorganic pigments and fillers, especially for titanium dioxide. Effectively reduces the grinding viscosity. 100 % active matter, solvent-free.

TEGO® Glide 100
Highly effective and compatible flow control additive. Recoatable, thus recommended not only for top coats but also for primers and fillers.

TEGO® Glide 435
Low foaming slip and flow additive with excellent substrate wetting. Promotes orientation of matting agents. Ideally suited to formulating matte top coats.

TEGO® Glide 440
Highly effective slip additive with minimal tendency to cause turbidity. Particularly suitable for glossy top coats. Improves substrate wetting, scratch resistance and leveling.

TEGO® Rad 2010
New type of radically cross-linking slip and substrate-wetting additive with excellent price/performance ratio. It destroys foam and promotes flow.

TEGO® Rad 2200 N
Radically crosslinkable, highly compatible, slip additive for increasing the surface smoothness and the scratch resistance of top coats. Substrate wetting, scratch resistance and flow are all improved.

TEGO® Rad 2011
New type of radically cross-linking flow additive with excellent price/performance ratio. Highly compatible and recoatable and therefore well suited for primers and fillers. In top-coat formulations it is an ideal partner for TEGO® Rad 2200 N and TEGO® Rad 2500.

TEGO® Rad 2500
Radically crosslinkable slip additive and deaerator. In addition to the deaerating effect, surface smoothness, scratch resistance and block resistance of the coating are improved.
**Radiation-curing wood parquet and floor coatings**

**TEGO® Airex 900**
Highly effective deaerator concentrate for coatings based on acrylate oligomers. Especially for roller application. High-shear incorporation is recommended.

**TEGO® Airex 920**
Highly compatible deaerator for top coats and primers based on acrylate oligomers. Silicone-free. Suitable for curtain coater and roller application.

**TEGO® Rad 2011**
New type of radically cross-linkable flow additive with excellent price/performance ratio. Highly compatible and recoatable and thus well suited for primers. In top coats it forms an ideal partner for TEGO® Rad 2500.

**TEGO® Rad 2500**
Radically crosslinkable slip additive and deaerator. In addition to the deaerating effect, surface smoothness, scratch resistance and block resistance of the coating are improved.

**TEGO® Wet 270**
Highly effective anti-crater additive. Recoatable, thus also suitable for primers and fillers.

**TEGO® Dispers 688**
Ideal wetting and dispersing additive for wetting the surface of matting agents thus lowering the viscosity of highly filled formulations. Yield point and thixotropy are reduced which results in improved flow and easier degassing of the coating.

**Waterborne wood and furniture coatings**

**TEGO® Airex 901 W**
Highly effective deaerator concentrate for combating micro-foam. Particularly suited for airless/airmix application coatings based on acrylate emulsions. Outstandingly effective in high build coatings.

**TEGO® Airex 902 W**
Universal, compatible deaerator emulsion for removing micro- and macro-foam. Also for waterborne 2-pack polyurethane, radiation curing and alkyd resin emulsion based formulations. Suitable for airless/airmix application. Also for curtain coating application.

**TEGO® Airex 904 W**
Efficient deaerator concentrate for effective elimination of microfoam. High performance combined with excellent compatibility. Especially recommended for airless/airmix application. Also effective in waterborne radiation-curing and 2-pack polyurethane formulations.

*All our wetting and dispersing additives are APE free.*
**TEGO® Dispers 752 W**
Wetting and dispersing additive highly recommended for transparent iron oxide pigments. Suitable for pigment concentrate production and direct grinding. Compatible with a broad range of binders.

**TEGO® Dispers 755 W**
Universal wetting and dispersing additive for organic and inorganic pigments. Highly suitable for direct grind in the binder. Particularly suited for manufacturing binder-free or binder-containing pigment concentrates.

**TEGO® Foamex 805 N**
Defoamer emulsion. Good effectiveness with minimal risk of defects. Well suited to very low viscosity and defect susceptible formulations. Ideal as a defoamer for adding to the curtain coating machine.

**TEGO® Foamex 810**
Defoamer concentrate with high effectiveness, even against micro-foam, with minimal risk of defects. Outstanding millbase defoamer. Can be used alone or in combination with defoamer emulsions. Also suitable for curtain coating.

**TEGO® Foamex 825**
Universal defoamer emulsion for use in let down and clear coats. Can be used alone or in combination with TEGO® Foamex 810. Suitable for curtain coater application.

**TEGO® Foamex 843**
Defoamer compound for rapid defoaming and effective foam break-down and inhibition especially in low-viscosity formulations. Good long-term effectiveness.

**TEGO® Glide 110**
Excellent anti-cratering additive that also improves flow and surface smoothness. Very compatible and universally applicable in waterborne, solventborne and radiation-curing wood and furniture finishes.

**TEGO® Glide 410**
Extremely effective slip additive. High surface slip and scratch resistance and anti-blocking properties at low concentrations. In matte coatings, it also ensures optimum orientation of the matting agent.

**TEGO® Glide 482**
Highly effective anti-blocking additive. Improves scratch resistance and slip in top coats.
TEGO® Twin 4100
Siloxane, multi-functional additive for effective reduction of surface tension. Very good substrate wetting and flow promotion with high compatibility. Ideal for use as an anti-crater additive while providing a foam neutral to defoaming environment. Suitable for combination with defoamers and deaerators. Solvent-free.

TEGO® VariPlus DS 50
Co-binder for improving various coating properties. This aqueous dispersion of a polyurethane-polyol improves mechanical properties such as hardness and block resistance in waterborne coating systems. Shortens dry time and at the same time improves gloss. Solvent-free.

TEGO® ViscoPlus 3000**
Polyurethane thickener with Newtonian properties and property profile which is independent of pH. Recommended for adjusting the application viscosity. Good compatibility with pigment pastes. Enhances flow and gloss. Free from emulsifiers.

TEGO® ViscoPlus 3010**
Polyurethane thickener with very high efficiency in the high-shear region and a property profile independent of pH. Especially suitable for adjusting the ICI viscosity. Additionally has good compatibility with pigment pastes. Enhances flow and gloss.

TEGO® ViscoPlus 3030**
Polyurethane thickener with pseudoplastic rheology. Performance independent of pH. Recommended for reducing sedimentation and syneresis. Good compatibility with pigment pastes and positive effect on leveling and gloss. Good storage stability.

TEGO® ViscoPlus 3060**
Polyurethane thickener with strong pseudoplastic rheology. Performance independent of pH. Highly recommended for vertical application of thick films by spraying (e.g. window frames). Promotes leveling and gloss. Good storage stability.

TEGO® Wet 270
Highly effective anti-cratering additive. Promotes flow and assists pore wetting. Recoatable, thus also suitable for primers and fillers.

TEGO® Wet 505
Silicone-free, highly compatible wetting additive for wetting wood substrates and pigments. Provides degassing effect or minimal foam stabilization. High dosing tolerance as no undesirable side effects occur. Can be added at the curtain coater.

**All our TEGO® ViscoPlus products are VOC and APE free. Manufactured without addition of organotin compounds.
**Waterborne wood parquet and floor coatings**

**TEGO® Foamex 822**
Effective and easy-to-incorporate defoamer emulsion for clear coats based on acrylate/polyurethane-copolymer emulsions or mixtures of acrylate and polyurethane emulsions. Also suitable for waterborne 2-pack PU coatings. High long-term effectiveness.

**TEGO® Foamex 825**
Highly effective defoamer emulsion for clear coats based on acrylate/polyurethane copolymer emulsion or mixtures of acrylate and polyurethane emulsions. Can be used alone or in combination with TEGO® Foamex 810.

**TEGO® Twin 4100**
Siloxane, multi-functional additive for effective reduction of surface tension. Very good substrate wetting and flow promotion with high compatibility. Ideal for use as an anti-crater additive while providing a foam neutral to defoaming environment. Suitable for combination with defoamers and deaerators. Solvent-free.

**TEGO® VariPlus DS 50**
Co-binder for improving several paint properties. This aqueous dispersion of a polyurethane-polyol improves mechanical properties such as hardness and block resistance in waterborne coating systems. Shortens dry time and improves gloss. Solvent-free.

**TEGO® ViscoPlus 3000**

**TEGO® ViscoPlus 3010**
Polyurethane thickener with very high efficiency in the high-shear region and performance independent of pH. Particularly suitable for adjusting the ICI viscosity. Also good compatibility and improves flow and gloss.

**TEGO® ViscoPlus 3030**
Polyurethane thickener with pseudoplastic rheology. Performance is independent of pH value. Recommended to avoid separation of waxes and matting agents. High compatibility. Promoting leveling and gloss.

**TEGO® Wet 270**
Highly effective anti-cratering additive. Promotes flow and assists pore wetting.
**Industrial Coatings**

**Waterborne/thin film**

**TEGO® Airex 902 W**
Highly effective and compatible deaerator emulsion for eliminating micro- and macro-foam in low and medium viscosity systems based on 2-pack polyurethane formulations. Suitable for airless/airmix application.

**TEGO® Dispers 755 W**
Polymeric solvent-free wetting and dispersing additive. Very suitable for inorganic and organic pigments as well as fillers and carbon blacks. Outstanding reduction in viscosity especially with problematical organic pigments.

Concentrates exhibit excellent color intensity and broad compatibility. Especially suitable for high-quality applications.

**TEGO® Dispers 653**
Particularly good at stabilizing inorganic pigments but also suitable for organic pigments. Pastes exhibit very good compatibility with waterborne and solventborne formulations. Suitable for aqueous and glycol-containing pigment pastes. Recommended for highly pigmented inorganic pigment pastes in combination with TEGO® Dispers 652.

*All our wetting and dispersing additives are APE free.*
**TEGO® Dispers 656**

**TEGO® Dispers 752 W**
Wetting and dispersing additive well suited for transparent iron oxide pigments. Can be used for manufacture of pigment concentrates and direct grind. Compatible with numerous binder systems.

**TEGO® Dispers 741 W**
Economical wetting and dispersing additive for direct grind and for water-based, binder-free pigment concentrates. Particularly suitable for organic and inorganic pigments but can also be used for stabilizing carbon blacks. The product is manufactured from renewable raw materials.

**TEGO® Foamex 805 N**
Silica-free, highly compatible defoamer emulsion, which is very effective but has minimal tendency to cause defects. Preferred use in low-viscosity and sensitive waterborne coating systems such as those based on polyurethane dispersions.

**TEGO® Foamex 822**
Defoamer emulsion combining good effectiveness with outstanding compatibility. Particularly suitable for coatings formulations susceptible to defects such as those based on polyurethane dispersions.

**TEGO® Foamex 843**

**TEGO® Foamex 810**
Defoamer concentrate with low tendency to cause surface defects. Highly effective even against micro-foam. Outstandingly suitable as a millbase defoamer for primers, top coats and pigment concentrates.

**TEGO® Flow 425**
Highly effective flow additive with good compatibility. Overcoatable and therefore recommended not only for top coats but particularly for primers and fillers.

**TEGO® Glide 450**
Universal flow and slip additive. Despite maximum effectiveness, very good recoatability and thus suitable for primers and top coats. Solvent-free.

**TEGO® Glide 482**
Highly effective antiblocking additive. Increases scratch resistance and slip characteristics in clear and matte formulations.

**TEGO® Wet 240**
Polyethersiloxane affects fine atomization and defect-free films in waterborne, spray-applied coating systems even at minimal film thickness. The effectiveness of TEGO® 240 is independent of co-solvent content. Solvent-free. Problem-free recoatable. Optimizes wetting on critical substrates.
**TEGO® Wet 500**
Foam inhibiting wetting additive. Promotes the wetting of a wide range of substrates and pigments without undesirable side effects. Highly compatible, recoatable without any problem and therefore ideally suited for the use in, e.g., primers, clear coats and electrodeposition coatings. Silicone and solvent-free.

**TEGO® Wet 260**
Highly effective substrate wetting additive for waterborne coating systems. Outstandingly suited for wetting plastic substrates.

**TEGO® VariPlus DS 50**
Co-binder based on a polyurethane-polyol for improving coating properties. Improves adhesion on various substrates such as plastic or metal. Can increase hardness and block resistance.

**TEGO® AddBond DS 1300**
Polyester-based co-binder for improving coating properties. Improves adhesion on various substrates such as plastics or metals.
**Highlights: Industrial Coatings**

**TEGO® Airex 901 W**
Highly effective deaerator concentrate for preventing micro-foam. Particularly suitable for airless/airmix application. Recommended for use in millbase.

**TEGO® Airex 904 W**
Effective deaerator concentrate for eliminating microfoam. Combines good effectiveness with outstanding compatibility. Recommended particularly for airless/airmix application. Particularly suitable for high and medium-low viscosity formulations based on acrylic and acrylic/polyurethane dispersions. Also effective in waterborne radiation-curing formulations as well as 2-pack polyurethane formulations.

**TEGO® Dispers 653**
Particularly good at stabilizing inorganic pigments but also suitable for organic pigments. Pastes exhibit very good compatibility with waterborne and solventborne formulations. Suitable for aqueous and glycol-containing pigment pastes Recommended in combination with TEGO® Dispers 652 for highly pigmented inorganic pigment pastes.

**TEGO® Dispers 652**
Co-dispersing additive. Combined with TEGO® Dispers 651 improves the rheology of highly-pigmented inorganic pigment pastes and also improves compatibility particularly in solventborne coatings.

**TEGO® Dispers 656**

**TEGO® Dispers 741 W**
Economical wetting and dispersing additive for direct grind and for water-based, binder-free pigment concentrates. Particularly suitable for organic and inorganic pigments but can also be used for stabilizing carbon blacks. The product is manufactured from renewable raw materials.

**TEGO® Dispers 750 W**
Polymeric, solvent-free wetting and dispersing additive. Outstanding wetting and stabilization of inorganic and organic pigments as well as fillers. Very good color strength development and color stability. Concentrates have broad compatibility with a wide variety of aqueous binders. Particularly suitable for high-quality applications.

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*All our wetting and dispersing additives are APE free.*
**TEGO® Foamex 810**
Defoamer concentrate with low tendency to cause surface defects, highly effective even against micro-foam. Outstandingly suitable as millbase defoamer for primers, top coat and pigment concentrates.

**TEGO® Foamex 843**

**TEGO® Foamex 3062**
Extremely effective defoaming concentrate for the millbase.

**TEGO® Foamex K 8**
Defoamer concentrate based on renewable raw materials as an alternative to mineral-oil defoamers. Combines high effectiveness with maximum compatibility over a wide range of PVC.

**TEGO® Flow 425**
Highly effective flow additive with good compatibility. Overcoatable and therefore recommended not only for top coats but particularly for primers and fillers.

**TEGO® Glide 450**
Universal flow and slip additive. Despite maximum effectiveness, very good recoatability and thus suitable for primers and top coats. Solvent-free.

**TEGO® Glide 110**
Outstanding anti-crater effect and high compatibility in waterborne coatings. Suitable for pigmented and clear formulations. Promotes good flow, low foaming and free of solvents.

**TEGO® Glide 482**
Highly effective antiblocking additive. Increases scratch resistance and slip characteristics in clear and matte formulations.

**TEGO® Twin 4100**
Siloxane, multi-functional additive for effective reduction of surface tension. Very good substrate wetting and flow promotion with high compatibility. Ideal for use as an anti-crater additive while providing a foam neutral to defoaming environment. Suitable for combination with defoamers and deaerators. Solvent-free.

**TEGO® Wet 270**
Highly effective substrate wetting additive with outstanding anti-crater effect. Promotes flow and is recoatable.

**TEGO® Wet 500**
Foam inhibiting wetting additive. Promotes the wetting of a wide range of substrates and pigments without undesirable side effects. Highly compatible, recoatable without any problem and therefore ideally suited for the use in, e.g. primers, clear coats and electrodeposition coatings. Silicone and solvent-free.

**TEGO® VariPlus DS 50**
Co-binder based on a polyurethane-polyol for improving coating properties. Improves adhesion on various substrates such as plastic or metal. Can increase hardness and block resistance.

**TEGO® AddBond DS 1300**
Polyester-based co-binder for improving coating properties. Improves adhesion on various substrates such as plastics and metals.
Solventborne/thin film

**TEGO® Airex 931**
Deaerator for low to high polarity coatings formulations. Very effective and therefore only small quantities required. Particularly suitable for high solids alkyd clear coats.

**TEGO® Airex 936**
Highly effective, silicone-free deaerator for top coats and primers.

**TEGO® Airex 945**
Very compatible deaerator for high solids clear coats. Additionally promotes flow.

**TEGO® Airex 950**
Highly compatible deaerator for polar, high solids clear coats.

**TEGO® Airex 962**
Universal deaerator with good compatibility.

**TEGO® Airex 990**
Compatible deaerator for conventional clear coats and high-gloss, high solids systems. Effective against micro- and macro-foam. Suitable for all spray application methods.

**TEGO® Dispers 656**

**TEGO® Dispers 670**
High performance dispersing additive for solventborne formulations. Strongly reduces millbase viscosity which permits high pigment loading during the grinding process. TEGO® Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

**TEGO® Dispers 710**
Polymeric wetting and dispersing additive for organic and inorganic pigments. Very good development of color intensity and good pigment stabilization. Particularly effective in high to moderate polarity formulations such as 2-pack polyurethane coatings. Also suitable for manufacturing pigment concentrates.

*All our wetting and dispersing additives are APE free.
**TEGO® Flow 300**
Highly compatible polyacrylate with low tendency to turbidity in solventborne coatings, especially in clears. The applied coatings show good flow and high gloss. A combination with TEGO® Glide 415 or TEGO® Glide 100 promotes brilliant surfaces.

**TEGO® Flow 370**
Polyacrylate-based silicone-free flow additive. Produces smooth flow and is very compatible in solventborne coatings. Particularly suitable for 1-pack and 2-pack coatings and coil coatings which must satisfy the highest demands with regards to appearance.

**TEGO® Glide 100**
Particularly compatible flow and slip additive for solventborne and waterborne formulations. TEGO® Glide 100 effectively prevents contamination craters in solventborne coatings.

**TEGO® Glide 450**
Universal flow and slip additive. Despite maximum effectiveness, very good recoatability and thus suitable for primers and top coats. Solvent-free.

**TEGO® Wet KL 245**
Additive for improved wetting on contaminated substrates. Highly effective even at low concentrations. Very good recoatability and very easy to incorporate.

**TEGO® Wet 270**
Universal, highly effective substrate wetting additive with outstanding anti-crater effect. Promotes flow. Solvent-free and recoatable.

**TEGO® Wet 280**
Universal substrate wetting additive with outstanding wetting properties. Particularly suitable for spray application. Promotes flow in high solids coatings. Good recoatability and is solvent-free.

**TEGO® Twin 4000**
Siloxane multi-functional additive. Highly effective in reducing surface tension and promoting flow in highly polar systems. Solvent-free.

**ADDID® 900**
Amine-modified siloxane for optimizing adhesion of coatings particularly on metallic substrates. Especially suitable for primers.

**TEGO® Hammer 501**
High molecular weight polydimethylsiloxane for generating hammertone effects particularly in alkyds. Is highly effective and is used in combination with TEGO® Wet 270 or TEGO® Glide 110 to regulate surface texture.

**TEGO® AddBond LTW**
**TEGO® VariPlus SK**
Co-binder for increasing gloss and body of solventborne 2-pack PU and NC coatings. Solvent- and tin-free.

**TEGO® VariPlus CA**
Co-binder for increasing gloss, hardness and body particularly in solventborne NC lacquers. The 100% ketone-aldehyde based synthetic resin is solvent- and tin-free.

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**Solventborne/high-build**

**TEGO® Airex 940**
Deaerator for pigmented, solventborne and solvent-free coatings based on 2-pack polyurethanes. Also suitable for epoxy systems and high solids alkyds. Easily incorporated, good compatibility and excellent overcoatability.

**TEGO® Airex 944**
Deaerator for pigmented, solventborne and solvent-free coatings based on 2-pack polyurethanes, epoxies and high solids alkyds. Excellent deaeration, easily incorporated, good compatibility and excellent overcoatability. Solvent-free.

**TEGO® Universal 962**
Universal deaerator with good compatibility.

**TEGO® Airex 990**
Compatible deaerator for conventional clear coats and high gloss, high solids systems. Effective against micro- and macro-foam. Suitable for all spray application methods.

**TEGO® Airex 991**
High performance deaerator for pigmented high solids and conventional coatings. Outstanding effectiveness against micro- and macro-foam even in high-build coatings. Especially suitable with airless, airmix and roller application.

**TEGO® Foamex N**
Extremely effective deaerator concentrate for solventborne and solvent-free coatings. Particularly effective in high viscosity millbase formulations.

**TEGO® Dispers 610**
Co-flocculating wetting and dispersing additive for inorganic pigments and fillers.

**TEGO® Dispers 700**
Wetting and dispersing additive especially for inorganic pigments. Very good pigment wetting and lowering of millbase viscosity. Also suitable for manufacturing bentone pastes.

*All our wetting and dispersing additives are APE free.
TEGO® Dispers 670*
High performance dispersing additive for solventborne formulations. Strongly reduces millbase viscosity which permits high pigment loading during the grinding process. TEGO Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

TEGO® Dispers 656*
Universal wetting and dispersing additive for radiation-curing formulations. Suitable for numerous inorganic pigments and fillers. Reduces viscosity efficiently.

TEGO® Flow 370
Polyacrylate-based silicone-free flow additive. Produces smooth flow and is very compatible in solventborne coatings. Particularly suitable for 1-pack and 2-pack coatings and coil coatings which must satisfy the highest demands with regards to appearance.

TEGO® Flow 425
Highly compatible polyethersiloxane for flow promotion. Recoatable.

TEGO® Glide 100
Particularly compatible flow and slip additive for solventborne and waterborne formulations. TEGO® Glide 100 effectively prevents contamination craters in solventborne coatings.

TEGO® Glide 410
Additive for improving surface smoothness/slip with substrate wetting properties. Anti-crater effect.

TEGO® Glide 450
Universal flow and slip additive. Despite maximum effectiveness, very good recoatability and thus suitable for primers and top coats. Solvent-free.

TEGO® Glide B 1484
Compatible slip and flow additive with deaerating properties for solventborne and solvent-free 2-pack epoxy and polyurethane coatings.

*All our wetting and dispersing additives are APE free.
**ADDID® 900**
Amine-modified siloxane for optimizing adhesion of coatings particularly on metallic substrates. Especially suitable for primers.

**TEGO® Hammer 501**
High molecular weight polydimethylsiloxane for generating hammertone effects particularly in alkyds. Is highly effective and is used in combination with TEGO® Wet 270 or TEGO® Glide 110 to regulate surface texture.

**TEGO® AddBond LTW**

**TEGO® VariPlus SK**
Co-binder for increasing gloss and body of solventborne 2-pack PU and NC coatings. Solvent- and tin-free.

**TEGO® VariPlus CA**
Co-binder for increasing gloss, hardness and body particularly in solventborne NC lacquers. The 100% ketone-aldehyde based synthetic resin is solvent- and tin-free.

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**UV**

**TEGO® Rad 2010**
New type of radically crosslinkable slip and substrate wetting additive with excellent price/performance ratio. Destroys foam and promotes flow. Solvent-free.

**TEGO® Rad 2011**
New type of radically crosslinkable flow and wetting additive with excellent price/performance ratio. Inhibits foam, very compatible and overprintable. Solvent-free.

**TEGO® Rad 2500**
Radically crosslinkable, highly effective slip additive. Improves scratch resistance and is deaerating. Solvent-free. Particularly suitable for matte and high-viscosity coatings.

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**TEGO® Flow 425**
Highly-effective flow additive with high compatibility. Overcoatable and therefore recommended not only for top coats but particularly for primers and fillers.

**TEGO® Glide 432**
Universal, highly effective slip, flow and substrate wetting additive. Solvent-free.

**TEGO® Airex 920**
Highly compatible deaerator. Eliminates micro-foam efficiently without causing surface defects or problems. Silicone- and solvent-free.
Solventborne pigment concentrates

**COLOROL F**
Wetting and dispersing additive for inorganic and organic pigments. Also suitable for binder-free pigment concentrates and bentone pastes. Concentrates also have good compatibility with low-polarity coatings formulations.

**TEGO® Dispers 656**
Universal wetting and dispersing additive for solventborne formulations. Suitable for a wide range of pigments and fillers. Especially recommended for inorganic pigments, transparent pigments and aluminium pigments. Improves gloss and compatibility in solventborne formulations.

**TEGO® Dispers 670**
High performance dispersing additive for solventborne formulations. The millbase viscosity is strongly reduced making possible a high pigment loading during grinding. TEGO® Dispers 670 is suitable for numerous organic, inorganic and carbon black pigments and leads in particular to high color strength development and transparency.

*All our wetting and dispersing additives are APE free.*
TEGO® Dispers 656*  
Universal wetting and dispersing additive for radiation-curing formulations. Suitable for a wide range of inorganic pigments and fillers. Reduces effectively the viscosity. Solvent-free.

Pigment concentrates for UV coatings

TEGO® Dispers 650*  
Outstanding stabilization of organic pigments. Good color strength and compatibility of the pigment pastes in waterborne and solventborne formulations. Recommended for aqueous and glycol-based pigment pastes.

TEGO® Dispers 652*  
Particularly good stabilization of inorganic pigments, but also suitable for organic pigments. Very good compatibility of concentrates with water and solventborne formulations. Suitable for water and glycol-based pigment concentrates. Recommended for highly-pigmented inorganic pigment concentrates in combination with TEGO® Dispers 652.

TEGO® Dispers 653*  
Particularly good stabilization of inorganic pigments, but also suitable for organic pigments. Very good compatibility of concentrates with water and solventborne formulations. Suitable for water and glycol-based pigment concentrates. Recommended for highly-pigmented inorganic pigment concentrates in combination with TEGO® Dispers 652.

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Universal concentrates (for solventborne and waterborne architectural coatings)

TEGO® Dispers 700*  
Wetting and dispersing additive especially for inorganic pigments. Very good pigment wetting and reduction of millbase viscosity. Also suitable for the manufacture of bentone pastes.

TEGO® Dispers 710*  
Polymeric wetting and dispersing additive. Particularly suitable for organic pigments and pigment blacks. Very good pigment stabilization and development of color strength. Suitable for medium to high polarity formulations. Also recommended for inorganic pigments.

TEGO® VariPlus TC  
Special-purpose ketone-aldehyde condensation resin with universal solubility and compatibility. Excellent pigment wetting when used as a grinding resin for solventborne coatings.

Pigment concentrates for UV coatings

TEGO® Dispers 656*  
Universal wetting and dispersing additive for radiation-curing formulations. Suitable for a wide range of inorganic pigments and fillers. Reduces effectively the viscosity. Solvent-free.

Pigment concentrates for UV coatings

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TEGO® VariPlus TC  
Special-purpose ketone-aldehyde condensation resin with universal solubility and compatibility. Excellent pigment wetting when used as a grinding resin for solventborne coatings.
*All our wetting and dispersing additives are APE free.

**TEGO® Dispers 652**
Co-dispersing agent. Combined with TEGO® Dispers 653, improves rheological properties of highly-pigmented inorganic pigment concentrates while also improving compatibility, particularly in solvent-borne coatings.

**TEGO® Dispers 656**
Universal wetting and dispersing additive for solventborne formulations. Suitable for a wide range of pigments and fillers. Especially recommended for inorganic pigments, transparent pigments and aluminium pigments. Improves gloss and compatibility in solventborne formulations.

**TEGO® Dispers 660 C**
Very effective compatibilizer for water-borne formulations. Improves the compatibility of pigment concentrates in base paints to reach higher color acceptance and reduced rub-out value. Also Improves as co-dispersant the storage stability of pigment concentrates. Solvent-free.

**TEGO® Dispers 662 C**
Universal compatibilizer for solventborne formulations. Improves the compatibility of pigment concentrates in base paints to reach higher color acceptance and reduced rub-out value.
Waterborne pigment concentrates

**TEGO® Dispers 650**
Outstanding stabilization of organic pigments. Very good development of color strength and compatibility of pigment concentrates. Suitable also for binder-containing pigment concentrates. Solvent-free.

**TEGO® Dispers 653**
Solvent-free wetting and dispersing additive. Particularly good wetting and stabilization of inorganic pigments and fillers. Also recommended for organic pigments.

**TEGO® Dispers 741 W**
Economical wetting and dispersing additive for aqueous, binder-free pigment concentrates. Particularly suitable for organic and inorganic pigments but can also be used for stabilizing carbon blacks. Based on renewable raw materials.

**TEGO® Dispers 752 W**
Ideally suitable for transparent iron oxides and transparent titanium dioxides. Very high pigment concentrate achievable with low viscosity. Good storage stability of the pigment concentrates and excellent clarity in wood, automotive and industrial coatings. Solvent-free.

**TEGO® Dispers 755 W**
Polymeric, solvent-free wetting and dispersing additive. Well suited for inorganic and organic pigments as well as fillers and carbon blacks. Outstanding reduction in viscosity especially with problematic organic pigments. The concentrates have excellent color strength and broad compatibility particularly in high-quality applications such as automotive finishes.

**TEGO® Dispers 760 W**
Recommended for pigment grinding with binders. Very effective reduction of mill-base viscosity even with high pigment loading. Especially suitable for pigments which are difficult to wet. In combination with TEGO® Dispers 750 W the best possible depth of color (Jetness) is achievable with carbon blacks. Solvent-free.

**TEGO® VariPlus DS 50**
Aqueous resin dispersion for the manufacture of binder-containing pigment concentrates. Improves gloss, hardness, pigment wetting, chemical and corrosion resistance of waterborne coatings.
Highlights Co-Binders

**TEGO® VariPlus SK**
Hydroxyl-containing, formaldehyde-free co-binder based on a hydrogenated ketone-aldehyde resin. The hard resin character enables hardness, gloss, block resistance and a faster touch-dry. The hyper-branched polymer structure lowers viscosity thus permitting a reduction in VOC.
**TEGO® VariPlus DS 50**
Aqueous dispersion of a hydroxyl-containing, formaldehyde-free, di-isocyanate crosslinked co-binder based on a hydrogenated ketone-aldehyde resin. The hard resin character enables the coatings’ hardness, gloss, adhesion, resistance to water and chemicals as well as block resistance to be increased.

**TEGO® AddBond HS**
Soft, special polyester co-binder used as an adhesion-promoting component for a diverse range of solventborne coatings and printing inks on numerous substrates (e.g. metals, plastics and minerals). Well-suited for use in high solids systems.

Good compatibility with numerous binders. Improves intercoat adhesion in multi-coat systems, cohesion in special effect coatings, flexibility and gloss.

**TEGO® AddBond DS 1300**
Aqueous dispersion of a widely-compatible soft special polyester co-binder used as an adhesion-promoting component for waterborne formulations on metal and plastic substrates. TEGO® AddBond DS 1300 improves the flexibility of the coating.
## Selection Tables

### Architectural Coatings, Defoaming

#### Waterborne formulations

<table>
<thead>
<tr>
<th>PVC &gt; 40%</th>
<th>Addition to the grinding stage</th>
<th>Addition to the let-down stage</th>
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<tbody>
<tr>
<td>Styrene acrylics</td>
<td>TEGO® Foamex 883&lt;br&gt;TEGO® Foamex K 8&lt;br&gt;TEGO® Foamex 8050</td>
<td>TEGO® Foamex 825&lt;br&gt;TEGO® Foamex 845&lt;br&gt;TEGO® Foamex 823</td>
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<tr>
<td>Pure acrylics</td>
<td>TEGO® Airex 901 W&lt;br&gt;TEGO® Foamex 883&lt;br&gt;TEGO® Foamex 810</td>
<td>TEGO® Foamex 8030&lt;br&gt;TEGO® Foamex 845&lt;br&gt;TEGO® Foamex 825</td>
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<tr>
<td>Terpolymers/vinyl acetate</td>
<td>TEGO® Foamex 8050&lt;br&gt;TEGO® Foamex 883&lt;br&gt;TEGO® Foamex K 8</td>
<td>TEGO® Foamex 855&lt;br&gt;TEGO® Foamex 1488&lt;br&gt;TEGO® Foamex 825</td>
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<tr>
<td>Hybrid systems</td>
<td>TEGO® Foamex 810&lt;br&gt;TEGO® Foamex 8050</td>
<td>TEGO® Foamex 815 N&lt;br&gt;TEGO® Foamex 825</td>
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<td>2-pack epoxy</td>
<td>TEGO® Airex 901 W&lt;br&gt;TEGO® Foamex 810</td>
<td>TEGO® Foamex 815 N&lt;br&gt;TEGO® Foamex 845&lt;br&gt;TEGO® Airex 902 W</td>
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</table>

<table>
<thead>
<tr>
<th>PVC ≤ 40%</th>
<th>Addition to the grinding stage</th>
<th>Addition to the let-down stage</th>
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</thead>
<tbody>
<tr>
<td>Styrene acrylics</td>
<td>TEGO® Foamex 8050&lt;br&gt;TEGO® Foamex 810&lt;br&gt;TEGO® Foamex K 8</td>
<td>TEGO® Foamex 855&lt;br&gt;TEGO® Foamex 8030&lt;br&gt;TEGO® Foamex 823</td>
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<tr>
<td>Pure acrylics</td>
<td>TEGO® Foamex 810&lt;br&gt;TEGO® Foamex 883&lt;br&gt;TEGO® Foamex K 8</td>
<td>TEGO® Foamex 825&lt;br&gt;TEGO® Foamex 1488&lt;br&gt;TEGO® Foamex 825</td>
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<tr>
<td>Terpolymers/vinyl acetate</td>
<td>TEGO® Foamex 883&lt;br&gt;TEGO® Foamex 8050&lt;br&gt;TEGO® Foamex K 8</td>
<td>TEGO® Airex 902 W&lt;br&gt;TEGO® Foamex 815 N&lt;br&gt;TEGO® Foamex 1488</td>
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<td>Acrylics-polyurethanes</td>
<td>TEGO® Airex 904 W&lt;br&gt;TEGO® Foamex 843&lt;br&gt;TEGO® Foamex 883</td>
<td>TEGO® Foamex 822&lt;br&gt;TEGO® Foamex 1488&lt;br&gt;TEGO® Airex 902 W</td>
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<td>Polyurethanes</td>
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<td>TEGO® Foamex 825&lt;br&gt;TEGO® Airex 902 W&lt;br&gt;TEGO® Foamex 822</td>
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<td>Alkyds</td>
<td>TEGO® Foamex 883&lt;br&gt;TEGO® Foamex 810&lt;br&gt;TEGO® Foamex 843</td>
<td>TEGO® Foamex 805 N&lt;br&gt;TEGO® Foamex 800&lt;br&gt;TEGO® Foamex 823</td>
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<td>2-pack epoxy</td>
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<td>TEGO® Airex 902 W&lt;br&gt;TEGO® Foamex 815 N</td>
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<td>Bitumen</td>
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<td>TEGO® Foamex 1488&lt;br&gt;TEGO® Foamex K 3&lt;br&gt;TEGO® Foamex K 7</td>
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## Solventborne and solvent-free formulations

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<th>Clear and low pigmented</th>
<th>Highly pigmented</th>
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<tr>
<td><strong>2-pack epoxy, solvent-free</strong></td>
<td>TEGO® Airex 922   TEGO® Airex 931   TEGO® Airex 910</td>
<td>TEGO® Airex 922   TEGO® Airex 900   TEGO® Airex 944   TEGO® Airex 940</td>
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<tr>
<td><strong>2-pack PU, solvent-free</strong></td>
<td>TEGO® Airex 940   TEGO® Airex 931</td>
<td>TEGO® Airex 944   TEGO® Airex 940   TEGO® Airex 990</td>
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<tr>
<td><strong>Acrylics (thermoplastic)</strong></td>
<td>TEGO® Airex 931   TEGO® Flow ZFS 460</td>
<td>n. a.</td>
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<tr>
<td><strong>Alkyds</strong></td>
<td>TEGO® Airex 944   TEGO® Airex 936   TEGO® Airex 940</td>
<td>n. a.</td>
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<tr>
<td><strong>2-pack epoxy, solventborne</strong></td>
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<td>TEGO® Airex 900   TEGO® Airex 940   TEGO® Foamex N</td>
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<tr>
<td><strong>2-pack PU, solventborne</strong></td>
<td>TEGO® Glide B 1484   TEGO® Airex 910   TEGO® Airex 940</td>
<td>TEGO® Airex 940   TEGO® Foamex 840   TEGO® Airex 990</td>
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## Architectural Coatings, Hydrophobing/Primers/Impregnation

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<tr>
<th>Hydrophobing/Primers/Impregnation</th>
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<tr>
<td>Primers/impregnation, solventborne</td>
<td>TEGO® Phobe 6010</td>
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<td>Primers/impregnation, waterborne</td>
<td>TEGO® Phobe 6510</td>
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<td>TEGO® Phobe 6600</td>
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<td>Emulsion paints/plasters</td>
<td>TEGO® Phobe 1401</td>
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<td>TEGO® Phobe 1500 N</td>
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<td>TEGO® Phobe 1505</td>
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<td>TEGO® Phobe 1650</td>
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<td>Emulsion paints/plasters with silicate character</td>
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<td>TEGO® Phobe 1500 N</td>
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<td>TEGO® Phobe 1505</td>
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<td>Silicate emulsion paints</td>
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<td></td>
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<td>TEGO® Phobe 1000 S</td>
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<td>Other coating formulations, waterborne</td>
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### Others

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<th>Solventborne-/free formulations</th>
<th>Waterborne formulations</th>
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<td>Dispersion in the direct grind</td>
<td>TEGO® Dispers 670</td>
<td>TEGO® Dispers 715 W</td>
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<td>TEGO® Dispers 656</td>
<td>TEGO® Dispers 755 W</td>
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<tr>
<td>– inorganic pigments</td>
<td>TEGO® Dispers 670</td>
<td>TEGO® Dispers 741 W</td>
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<tr>
<td></td>
<td>TEGO® Dispers 650</td>
<td>TEGO® Dispers 755 W</td>
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<td>– organic pigments</td>
<td>TEGO® Dispers 670</td>
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<td>TEGO® Dispers 650</td>
<td>TEGO® Dispers 755 W</td>
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<td>Substrate wetting/craters/contaminated substrates</td>
<td>TEGO® Glide 410</td>
<td>TEGO® Wet KL 245</td>
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<td>TEGO® Flow ATF 2</td>
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<td>TEGO® Wet 265</td>
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<td>Slip/scratch resistance</td>
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<td>TEGO® Glide 450</td>
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<td>TEGO® Glide B 1484</td>
<td>TEGO® Glide ZG 400</td>
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<td>Leveling/orange peel effect/brush marks</td>
<td>TEGO® Flow 300</td>
<td>TEGO® ViscoPlus 3000</td>
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<td>TEGO® Glide 415</td>
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<td>TEGO® Wet 280</td>
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<td>Floating/Bénard cells</td>
<td>TEGO® Glide 410</td>
<td>TEGO® Dispers 741 W</td>
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<td>TEGO® Glide B 1484</td>
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<td>TEGO® Flow ATF 2</td>
<td>TEGO® Dispers 741 W</td>
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<td>Floating/rub-up/color stability</td>
<td>TEGO® Dispers 662 C</td>
<td>TEGO® Dispers 660 C</td>
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<td>TEGO® Dispers 656</td>
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<td>TEGO® Dispers 670</td>
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### Waterborne Flexo- and Gravure Inks, (Overprint) Varnishes, Defoaming

#### Waterborne formulations

<table>
<thead>
<tr>
<th>Pigmented</th>
<th>Addition to the grinding stage</th>
<th>Addition to the let-down stage</th>
<th>Varnishes</th>
</tr>
</thead>
</table>
| Styrene acrylic resin solutions and hybrids | TEGO® Foamex 810  
TEGO® Foamex 842  
TEGO® Foamex 831* | TEGO® Foamex 843  
TEGO® Foamex 845  
TEGO® Foamex 1488 | TEGO® Airex 902 W  
TEGO® Foamex 845  
TEGO® Foamex 805 N |
| Acrylic resin solutions and hybrids | TEGO® Foamex 810  
TEGO® Foamex 831*  
TEGO® Foamex 842 | TEGO® Foamex 843  
TEGO® Foamex 845  
TEGO® Foamex 810 | TEGO® Foamex 842  
TEGO® Airex 902 W  
TEGO® Foamex 805 N |
| Casein/maleics | TEGO® Foamex 3062  
TEGO® Foamex 8050  
TEGO® Foamex 831* | TEGO® Foamex 1488  
TEGO® Foamex 845  
TEGO® Foamex 800 | TEGO® Foamex 1488  
TEGO® Foamex 822  
TEGO® Foamex 815 N |
| Acrylic/styrene-acrylic emulsions | TEGO® Foamex 831*  
TEGO® Foamex 8050  
TEGO® Airex 901 W | TEGO® Foamex 843  
TEGO® Foamex 815 N  
TEGO® Foamex 805 N | TEGO® Airex 902 W  
TEGO® Foamex 815 N  
TEGO® Foamex 805 N |
| Polyurethane/polyurethane-acrylic emulsions | TEGO® Foamex 842  
TEGO® Foamex 810  
TEGO® Foamex 830* | TEGO® Foamex 815 N  
TEGO® Foamex 800  
TEGO® Foamex 822 | TEGO® Foamex 822  
TEGO® Foamex 805 N  
TEGO® Airex 902 W |

*silicone-free
## Printing Inks and Varnishes, Others

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Selection Tables_Printing Inks page 203
# Silk Screen Inks, Defoaming, Deaeration

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| *silicone-free

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# Pigment Concentrates

## Aqueous, binder-free

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## Aqueous, binder-containing

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### Solventborne

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### Universal pastes

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## Wood Coatings, Defoaming/Deaeration

by application method

### Waterborne formulations

#### Curtain coatings

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#### Spray, roller application, brushing

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### Solventborne/radiation-curing formulations

#### Spray, roller application, brushing etc

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## Wood Coatings, Others

### Waterborne formulations

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<td>TEGO® Glide 110*</td>
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<td>TEGO® Phobe 1500 N</td>
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*only top coat

### Radiation-curing (non waterborne) formulations

| Substrate wetting/anti-crater | TEGO® Glide 432* |
|                               | TEGO® Wet 270 |
|                               | TEGO® Rad 2250* |
|                               | TEGO® Wet 280 |
| Glossy formulations Slip/scratch resistance/anti-blocking/air-draught sensitivity | TEGO® Glide 440* |
|                               | TEGO® Rad 2200 N* |
| Matte formulations Slip/scratch resistance/anti-blocking/air-draught sensitivity | TEGO® Flow 370 |
|                               | TEGO® Flow 425 |
|                               | TEGO® Glide 100 |
|                               | TEGO® Rad 2011 |
| Leveling/orange peel effect   | TEGO® Dispers 610 S |
|                               | TEGO® Dispers 656 |
|                               | TEGO® Dispers 670 |
| Floating/rub-up Floating/settling | TEGO® Dispers 688 |
| Wetting matting agent         | TEGO® Dispers 688 |

*only top coat
### Solventborne formulations

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<th>Formulations</th>
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| Substrate wetting/anti-crater                       | TEGO® Glide 410*  
|                                                    | TEGO® Glide 110*  
|                                                    | TEGO® Glide 406  |
| Glossy formulations  
| Slip/scratch resistance/air-draught sensitivity     | TEGO® Glide 410  
|                                                    | TEGO® Glide 450  |
| Matte formulations  
| Slip/scratch resistance/air-draught sensitivity/  
| orientation of matting agents                       | TEGO® Glide 410  
|                                                    | TEGO® Glide A 115  |
| Anti-blocking                                       | TEGO® Glide 410  
|                                                    | TEGO® Glide A 115  |
| Leveling/orange peel effect                        | TEGO® Glide 100  
|                                                    | TEGO® Flow 370  
|                                                    | TEGO® Flow 425  |
| Floating/Bénard-cells                               | TEGO® Glide 410  
|                                                    | TEGO® Glide 406  
|                                                    | TEGO® Dispers 610 S  |
| Floating/rub-up                                     | TEGO® Dispers 670  
|                                                    | TEGO® Dispers 656  
|                                                    | TEGO® Dispers 700  
|                                                    | TEGO® Dispers 710  |
| Sagging/settling                                    | TEGO® Dispers 630  
|                                                    | TEGO® Dispers 610  |

*only top coat
### Waterborne formulations

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### Solventborne systems

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<td>Floating/rub-up/settling</td>
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### Solventborne systems

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<td>Substrate wetting/craters/contaminated substrates</td>
<td>TEGO® Wet 270 TEGO® Wet KL 245 TEGO® Glide 415</td>
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# Leather Coatings

## Leather Coatings

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<th>Waterborne formulations</th>
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| **Defoaming/deaeration varnish** | TEGO® Airex 901 W  
TEGO® Foamex 825  
TEGO® Foamex 822  
TEGO® Foamex 800 | TEGO® Flow ZFS 460 |
| **Defoaming/deaeration, addition to the grinding stage** | TEGO® Airex 901 W  
TEGO® Foamex 810  
TEGO® Foamex 8050 | TEGO® Airex 900 |
| **Defoaming/deaeration, addition to the let-down stage** | TEGO® Foamex 825  
TEGO® Foamex 822  
TEGO® Foamex 800 | TEGO® Flow ZFS 460 |
| **Substrate wetting/craters** | TEGO® Wet 250  
TEGO® Wet KL 245  
TEGO® Wet 265 | TEGO® Glide 410  
TEGO® Wet 270 |
| **Leveling** | TEGO® Glide 410  
TEGO® Glide 440  
TEGO® Glide 450 | TEGO® Glide ZG 400  
TEGO® Glide 410 |
| **Touch and handle modification** | TEGO® Glide L 404  
TEGO® Glide L 401  
TEGO® Glide 410  
TEGO® Glide 482 | TEGO® Glide 410  
TEGO® Glide ZG 400  
TEGO® Glide 450 |
| **Anti-blocking effect** | TEGO® Glide 482  
TEGO® Glide 410 | TEGO® Glide 410  
TEGO® Glide 100 |
| **Water resistance/beading-effect** | TEGO® Phobe 1401 | TEGO® Phobe 1500 N |
| **Color strength development/ hiding power** | TEGO® Dispers 750 W  
TEGO® Dispers 760 W  
TEGO® Dispers 752 W  
TEGO® Dispers 755 W | TEGO® Dispers 710  
TEGO® Dispers 670 |
| **Pigment settling** | TEGO® Dispers 735 W  
TEGO® Dispers 760 W | TEGO® Dispers 610  
TEGO® Dispers 670  
TEGO® Dispers 710 |
| **Binder/Co-Binder** | SILIKOPUR® 8080 | |
Silicone Resins, High Temperature Resistant Coatings

### Applications from 250°C up to 600°C depending on the binder and the formulation

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<th>Ovens, chimneys, oven inserts</th>
<th>Exhaust pipes, mufflers</th>
<th>Electric and gas heaters</th>
<th>Barbecue grills</th>
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### Applications up to 250°C depending on the binder and the formulation

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<th>Iron soles, waffle irons</th>
<th>Cookware, egg cookers</th>
<th>Barbecue grills</th>
<th>Slide coatings, garden shears, screws</th>
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* recommended  ** well recommended  *** especially recommended  "depending on the formulation  "water-thinnable
## Silicone Resins, Industrial Coatings

### High Solids 2-pack isocyanate-free

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<th>Coil Coating</th>
<th>Marine Coating</th>
<th>General Industry</th>
<th>Anti-Graffiti</th>
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### Waterborne silicone modified polyurethane emulsion

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<th>Wood Coatings</th>
<th>Textile Coatings</th>
<th>Plastic Coatings</th>
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- • recommend
- •• well recommended
- •★★ especially recommended
- **water-thinnable

## Co-Binders

### Application areas TEGO® AddBond

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<th>Can Coating</th>
<th>Coil Coating</th>
<th>Automobil OEM coatings</th>
<th>Container paints</th>
<th>Floor coatings</th>
<th>Metal paints</th>
<th>Paints for packaging</th>
<th>Paints for plastics</th>
<th>Anti-corrosion coatings</th>
<th>Primer (air-drying)</th>
<th>Primer (stoving)</th>
<th>Printing Inks</th>
<th>Roadmarking paints</th>
<th>Waterborne coatings</th>
<th>Adhesives</th>
<th>Hot stamping foils</th>
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### Silica-Nanocomposites

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I would like to receive:
Please mark as indicated and state the desired product number.

Product information & samples

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<th>DATA SHEET</th>
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General information

☐ Product Overview
☐ The Big TEGO
☐ The Little TEGO

Guiding formulations
☐ for manufacturing silicone paints for heat resistance
☐ or pigment concentrates

☐ Publications regarding the following subjects:

Brochures for application field
(if available)

☐ Architectural Coatings
☐ Printing Inks and Varnishes
☐ High Solids
☐ Plastic Coatings
☐ TEGO® AddBond
☐ TEGO® VariPlus

For your order please choose a language

☐ English
☐ German

Further information you can find under www.tego.de
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