BYK

TECHNICAL INFORMATION

ADDITIVES FOR PVC PLASTISOL APPLICATIONS

PVC-TI 8

A member of ALTANA

Contents

Introduction

PVC plastisols are used in numerous applications, ranging from floorings and wall coverings, vinyl, printing inks, and textile applications to dip coatings, tarps, and traffic cones. Our corresponding additive portfolio supports the production processes and helps optimize material properties.

Note

To ensure the best appearance and full functionality, please open in Adobe Acrobat.

Viscosity depressants

Why use viscosity depressants?

It is important to adjust the viscosity for each type of manufacturing process. This ensures consistent processing and high product quality.

Viscosity (η) is the key factor in describing flow behavior. In most plastisol systems, viscosity is not a constant. It depends on a variety of parameters. To a great extent, it determines the usability and user-friendliness of the PVC plastisol.

The three most important factors encountered in PVC plastisol formulating are:

1. **Raw material properties**
2. **Temperature parameters**
3. **Rheology.**

Rheology is the interrelationship between viscosity and shear forces, which can be very complex.

The most important rheological parameter from the application standpoint is the mechanical stress the liquid system is exposed to.

Shear rate calculation example

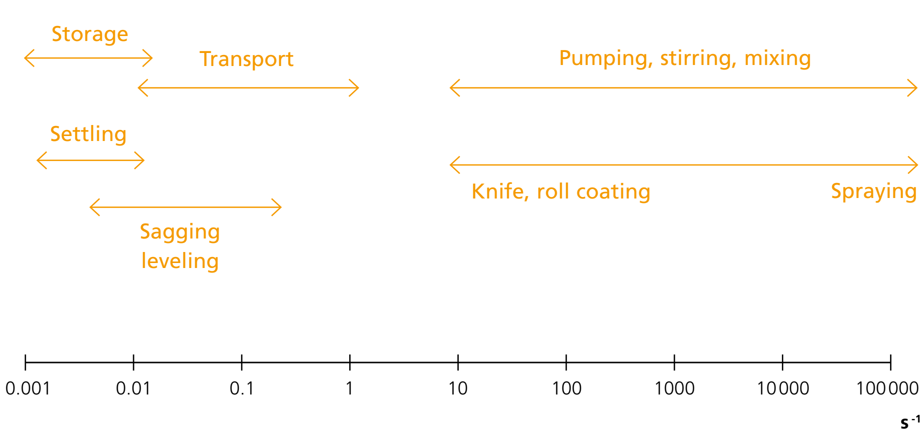
$$\text{Shear rate} = \frac{\text{Line speed x Conversion factor}}{\text{Coating gap}}$$

Speed	25 m/min	82 ft/min
Coating gap	0.1 mm	2.5 mils
Conversion factor	~ 16.7	~ 127

$$\text{Shear rate} = \frac{25 \text{ x } 16.7}{0.1} \qquad \frac{82 \text{ x } 127}{2.5}$$

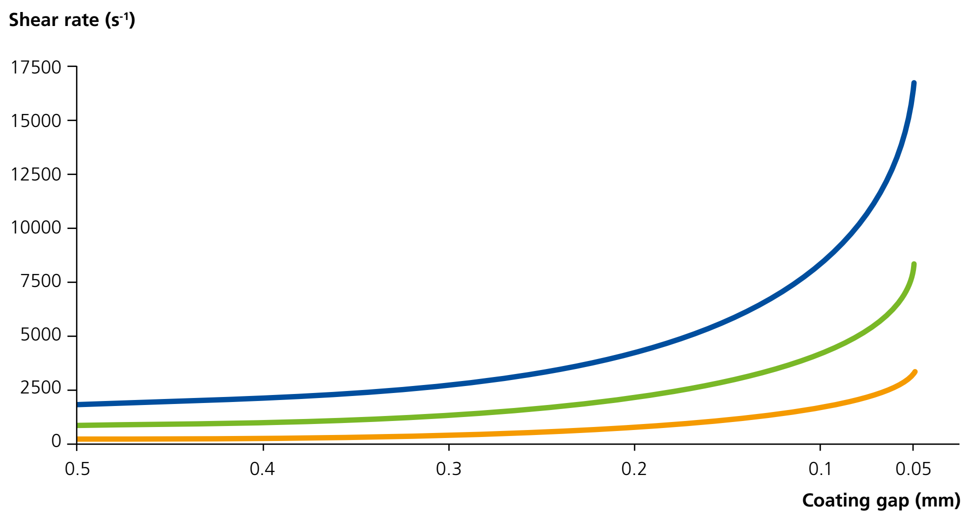
$\sim 4170\ s^{-1}$ $\qquad \sim 4170\ s^{-1}$

Typical shear ranges



G.01

Shear rate dependent on coating gap



Line speed (m/min) 10 25 50

G.02

How do viscosity depressants work?

BYK's viscosity depressants work in two steps:

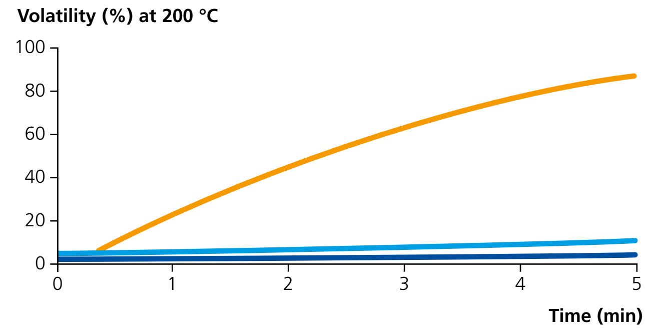
1. The mixtures of aliphatic hydrocarbons or carboxylic derivatives are specially developed to reduce the viscosity in the liquid phase of the PVC plastisol.
2. The special wetting and dispersing components adsorb onto the particle surfaces, reducing the interactive forces between them and preventing reagglomeration.

Viscosity depressants allow for easier movement of the particles. This stabilizes the viscosity and storage behavior of the whole system (G. 04).

Product volatility

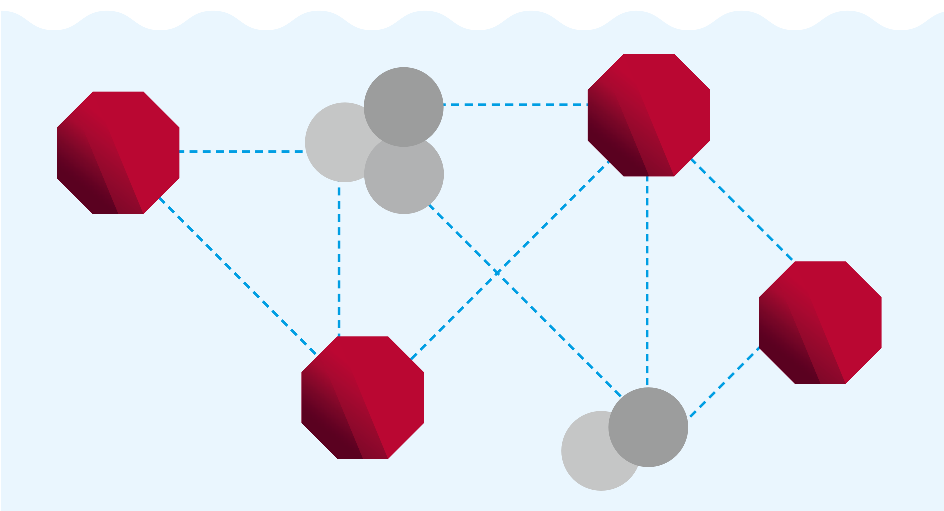
Additives of the VISCOBYK-5000 series and BYK-1160 series are low-volatile viscosity depressants. During production, the process emissions are reduced significantly compared to conventional viscosity depressants (G. 05). These additives perform similarly to primary plasticizers in regard to their low volatility.

Volatility behavior



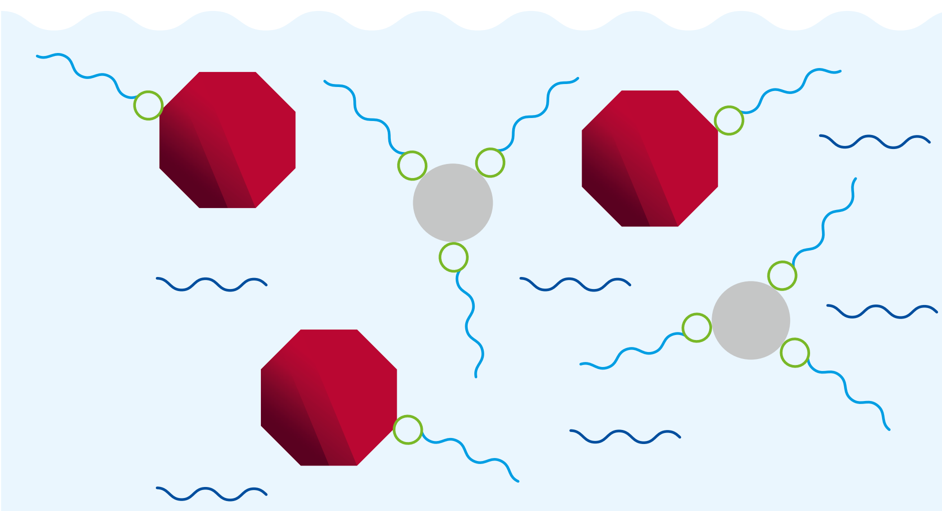
Conventional viscosity depressants and secondary plasticizers **G. 05**
VISCOBYK 5000 series and BYK-1160 series Primary plasticizer

Plastisol without viscosity depressants



PVC resin Solid Interactive forces **G. 03**

Plastisol with viscosity depressants



PVC resin Solid **G. 04**
Wetting and dispersing additive Aliphatic hydrocarbons/carboxylic acid derivatives

Emission test methods

To determine the VOC (volatile organic compounds) of building materials (e.g. cushion vinyl floorings), the analytical laboratory of BYK uses the following instrumentation:

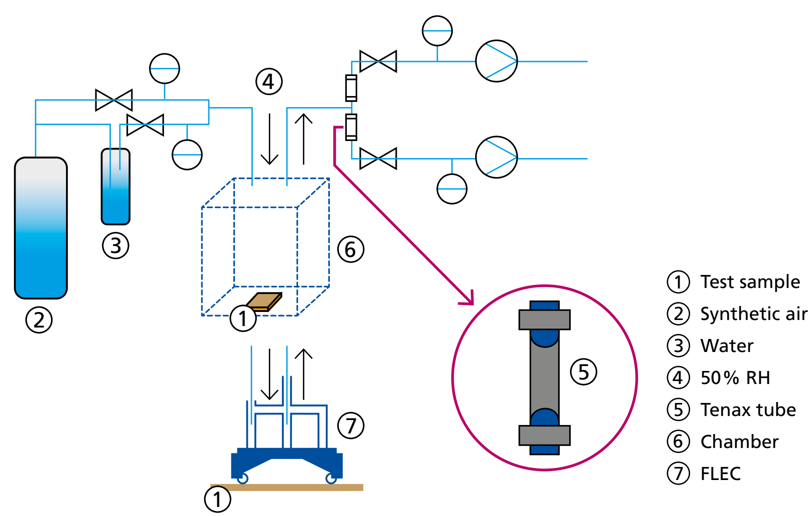
Nord test (chamber method)
This test specifies a procedure for the determination of VOC emissions from building materials in a small, ventilated climate.

FLEC test (field laboratory emission cell)
FLEC is a small piece of equipment that is easy to handle and easy to clean. It was designed to measure VOC emitted from smooth and even surfaces. It can be used for emission testing in the laboratory and at building sites. The FLEC system is widely used due to its measurement flexibility.

With both types of test equipment, the sample material's emissions are collected in a Tenax tube (G. 06). The quantity and quality can be determined by the use of analytical equipment, such as the gas chromatograph and mass spectrophotometer.

The air velocity over the test material's surface area can be 50 to 100 times greater with the FLEC equipment than with the Chamber method.

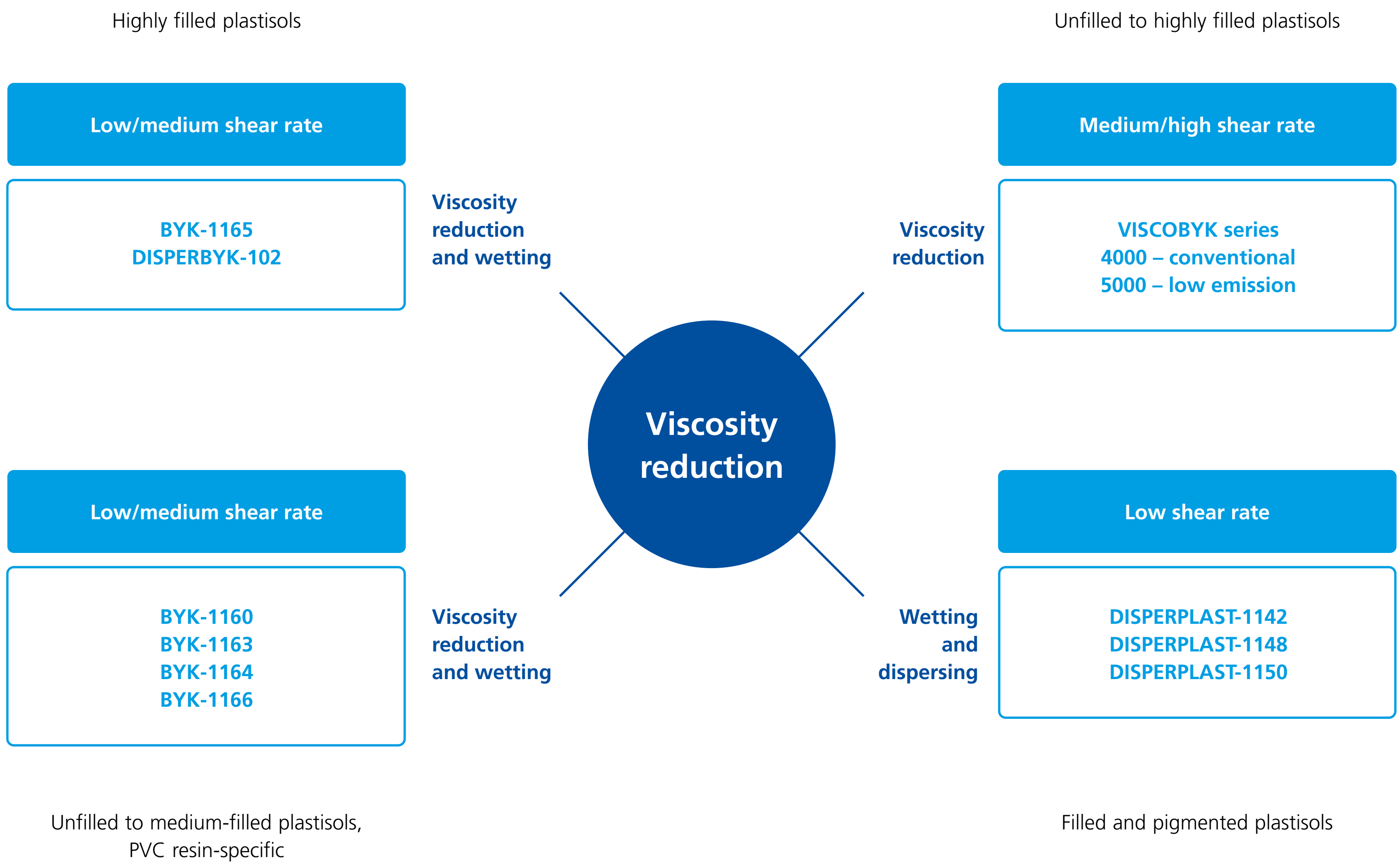
Flow chart of VOC measurement



G. 06

Additive recommendations

Overview of BYK additives for viscosity reduction



G.07

Wetting and dispersing additives

Why use wetting and dispersing additives?

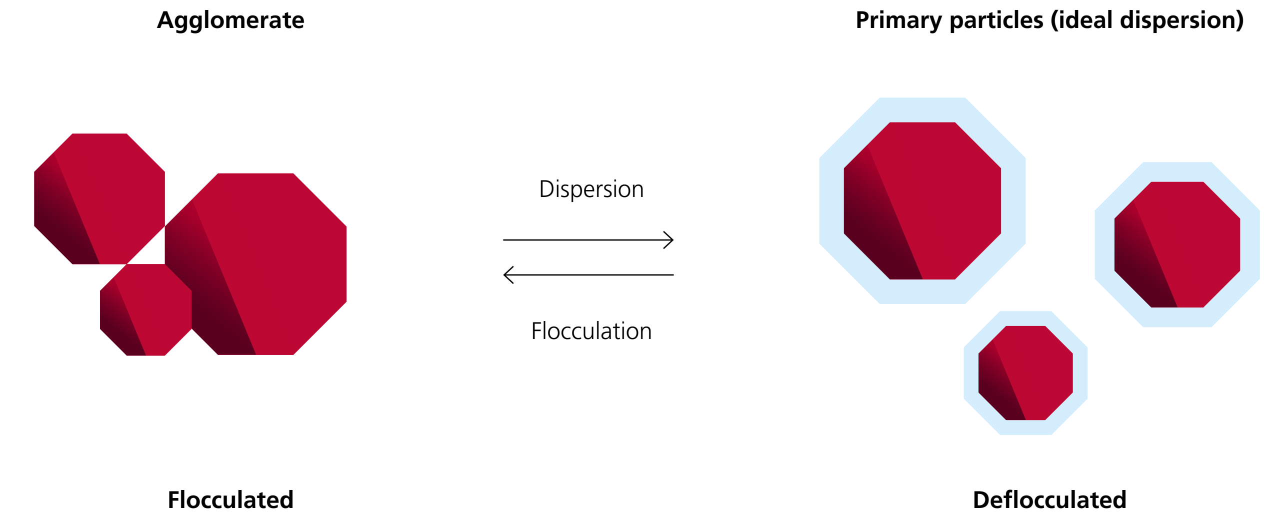
Wetting and dispersing additives correct the deficiencies that occur during the dispersion process. During the dispersion of particles in plasticizers, the interactive forces between the particles result in long dispersion times, pigment streaks, flooding and floating, and high viscosity.

During dispersion, the introduction of energy breaks down agglomerates into individual particles. If the system is not stabilized, the finely distributed particles reagglomerate and form flocculates (G. 08). Wetting and dispersing additives adsorb onto the surface of the pigment/filler particles. They then separate particles from each other and stabilize the system by forming an organic adsorption layer that is compatible with the plasticizers.

Benefits of wetting and dispersing additives

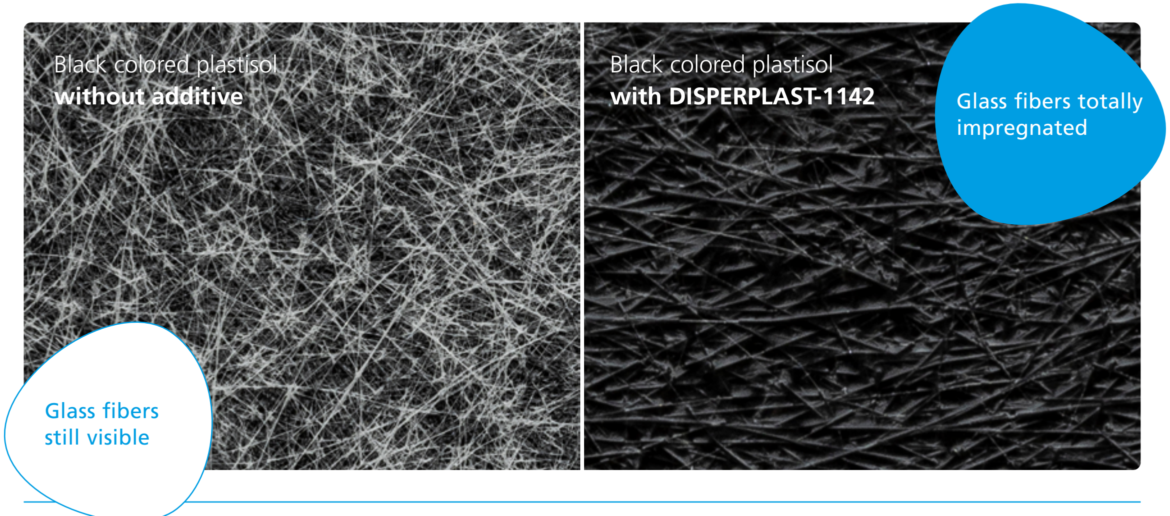
- Reduced flooding and floating
- Improved flow behavior
- Improved glass/synthetic fiber penetration/wetting
- Higher pigment loading at lower/constant viscosity
- Shorter dispersion times
- Increased throughput
- Improved color consistency from batch to batch
- Faster color matching
- Greater color strength and hiding power
- Longer storage stability of dispersions

Dispersion process



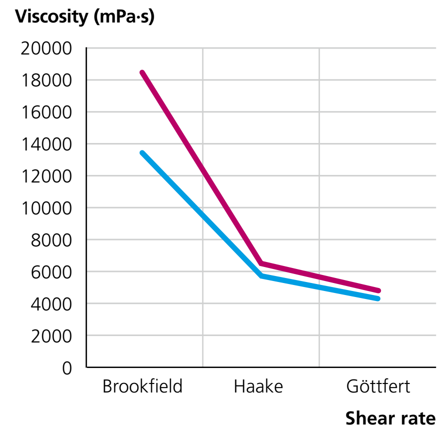
G. 08

Better penetration of glass fibers using DISPERPLAST-1142



G. 09

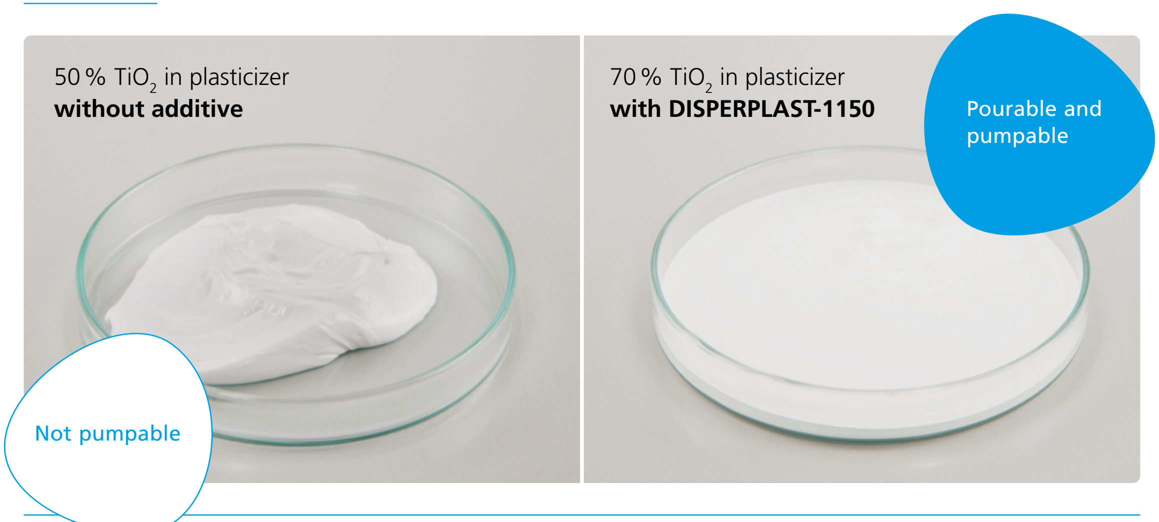
Viscosity reduction of a foamed wallcovering plastisol



Formulation:
100.0 pts PVC
65.0 pts Plasticizer
70.0 pts $CaCO_3$
20.0 pts TiO_2
4.0 pts Azodicarbonamide
3.0 pts Liquid kicker
6.0 pts VISCOBYK
0.6 pts DISPERPLAST

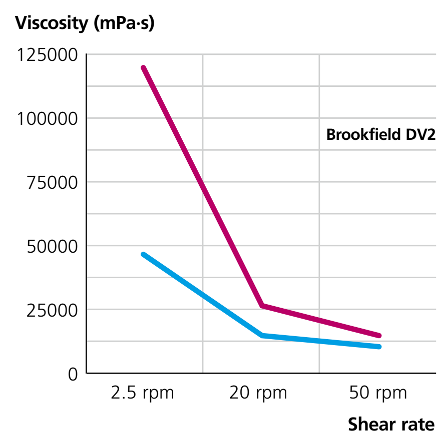
G. 11

Better handling with increased pigment loading using DISPERPLAST-1150



G. 10

Viscosity reduction of a highly filled plastisol (e.g. carpet backing)



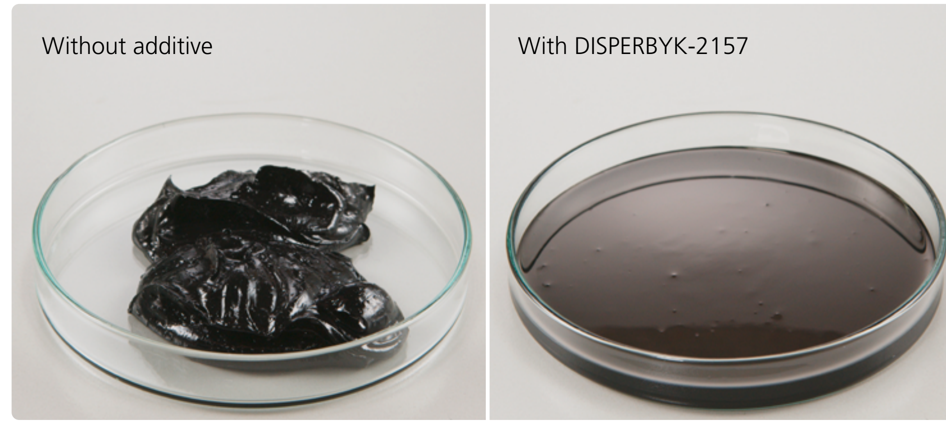
Formulation:
100.0 pts PVC
70.0 pts Plasticizer
250.0 pts $CaCO_3$
0.8 pts BYK-2616
3.2 pts Carbon black paste
1.0 pts Stabilizer
1.0 pts BYK-1165

G. 12

Viscosity reduction of a $CaCO_3$ paste with DISPERPLAST-1148 in plasticizer

G. 13

Viscosity reduction of a carbon black paste using DISPERBYK-2157



G. 14

Additive recommendations

Product	Inorganic pigments	Organic pigments	Carbon blacks	Azodicarbonamide	Low emission	Low fogging	Dispersing medium
BYK-1162					●		●
BYK-1165	●				●		
BYK-9076	○	○	●	●	●	●	
BYK-9077			●		●	●	
DISPERBYK-102	●				●		
DISPERBYK-2157	●	●	●	●	●	●	
DISPERPLAST-1142	●				●	●	
DISPERPLAST-1148	●			●	●	●	
DISPERPLAST-1150	●			●	●	●	
DISPERPLAST-I	●	●		○	●	●	
DISPERPLAST-P	●	●	●	○	●	●	

● Recommended ○ Suitable

T. 01

Air release additives

Why use air release additives?

Air entrapment is unavoidable during the production and processing of PVC plastisols. Interfacially active substances, e.g. residual emulsifiers, stabilized air bubbles, or the air release can be inhibited by high viscosity, pseudoplasticity, or thixotropy. However, air bubbles are detrimental to:

- Transparency
- Color strength
- Print definition
- Substrate wetting
- Mechanical properties, such as tensile strength and elongation
- Contact drum gelling

How do air release additives work?

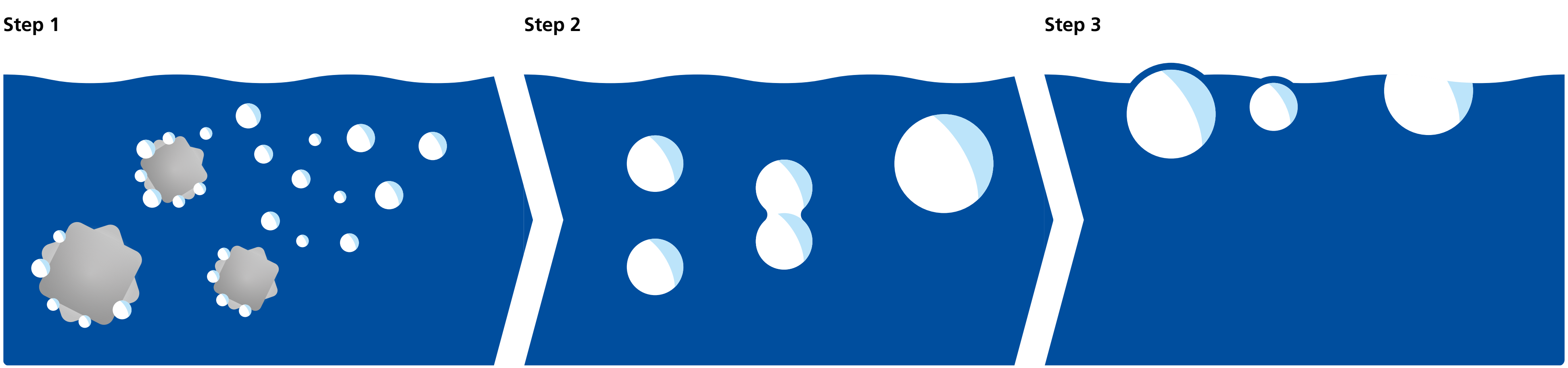
BYK's air release additives work in three steps:

1. Displacement of air from PVC resin, filler, pigment, and reinforcement
By reducing the interfacial tension between plasticizer, PVC resin, pigment, filler, and reinforcement, the trapped air is displaced into the plasticizer.

2. Smaller bubbles coalesce to form larger bubbles
Bubble-stabilizing substances are displaced by the air release additive. Smaller bubbles coalesce to form larger bubbles, which rise to the surface faster because of their higher buoyancy (Stokes' law).

3. Bubbles burst on the surface
Bubble-stabilizing substances are displaced, and the bubbles burst.

Air release additives work in three steps



G. 15

Test methods

1. Vacuum deaeration
Air is mixed into a PVC plastisol using a Dispermat before the beaker is put into a desiccator. Full vacuum is pulled without stirring until the foam reaches the top of the beaker. Then the vacuum is cut (1 cycle). The number of cycles and time required for full plastisol deaeration is measured.

2. Self deaeration
Air is mixed into a plastisol and stored for a defined time. Then the plastisol is applied by a doctor blade onto a contrast chart, gelled, and visually checked for bubbles (G. 16).

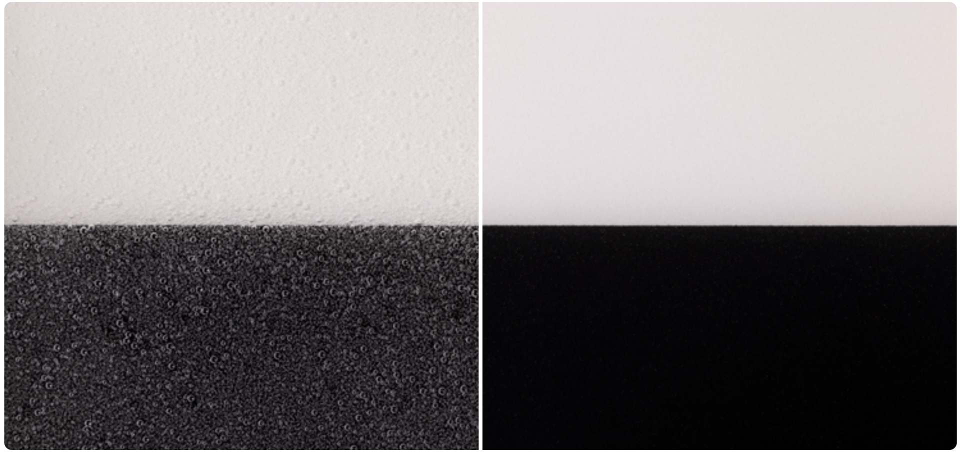
Additive recommendations

BYK-3155 and BYK-3140 are the most universal of the BYK air release additives. BYK-3105 and BYK-3140 are also recommended for low-fogging applications.

Remarks
To achieve further improvement in defoaming, a combination of an air release additive and a defoamer (e.g. BYK-A 530) is recommended.

Self deaeration effect

Without additive **With BYK additive**



G. 16

Additive recommendations

Product	Transparent	Foamed	Filled	Low emission	Low fogging
BYK-1160	○	○	○	●	●
BYK-1163	○	○	○	●	●
BYK-1164	○	○	○	●	
BYK-1166	●	●	○	●	
BYK-3105	○	●	●	●	●
BYK-3140	●	●	●	●	●
BYK-3155	●	●	●	●	
BYK-A 530	●	●	●	○	●

● Recommended ○ Suitable

T. 02

Rheology additives

Why use rheology additives?

Flow behavior is one of the most important technical properties of a PVC plastisol. To a great extent, it determines the usability and user-friendliness of the paste. In plastisols, thickeners such as fumed silica, polysulfonates, and precipitated calcium carbonate have traditionally been used.

These conventional thickeners may exhibit the following undesirable properties and limitations:

- Difficult to store and handle
- Hard to disperse properly
- High viscosity at high shear rates, which can lead to coating defects (e.g.: "spitting") during knife coating and spraying
- Poor air release due to highly pseudoplastic rheology
- Non-reproducible results
- Insufficient heat sag resistance
- Loss of thickening effect when used with an amine adhesion promoter.

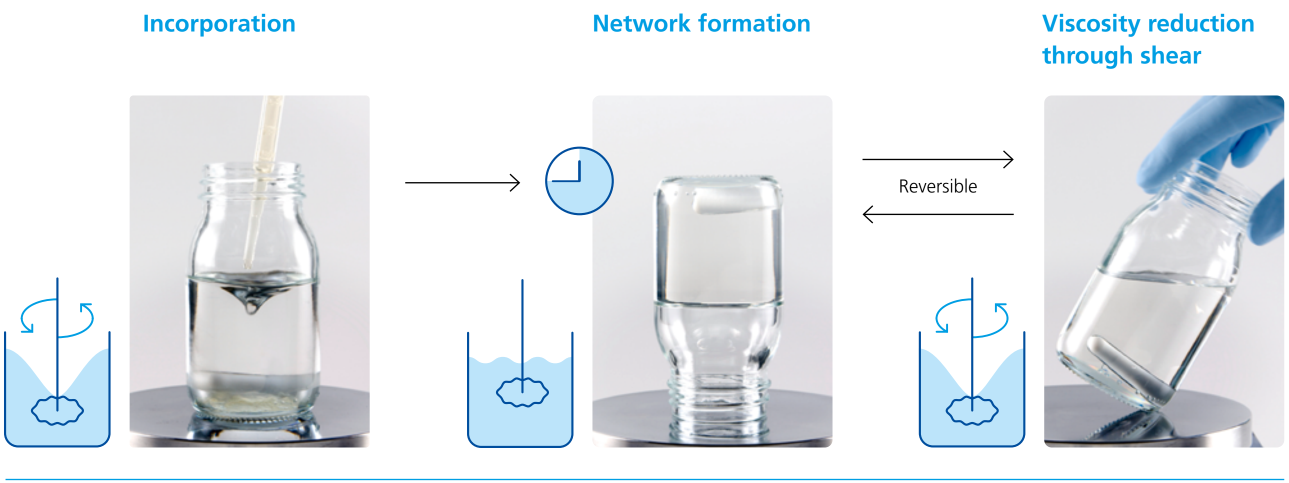
BYK's unique rheology additives allow optimum adjustment of rheological properties. In many cases, the additives are used to improve anti-settling properties during storage and to avoid sagging during application. In addition, they reduce flooding and floating of pigmented PVC plastisols by increasing the yield point.

The rheological behavior of a PVC plastisol using a BYK rheology additive will depend on the following:

1. Polarity and amount of the emulsifiers and surfactants on the PVC resin
2. Polarity of the plasticizer type and content
3. The type and amount of solids (e.g. filler, pigment, etc.)
4. Other ingredients (e.g. stabilizer, additives)

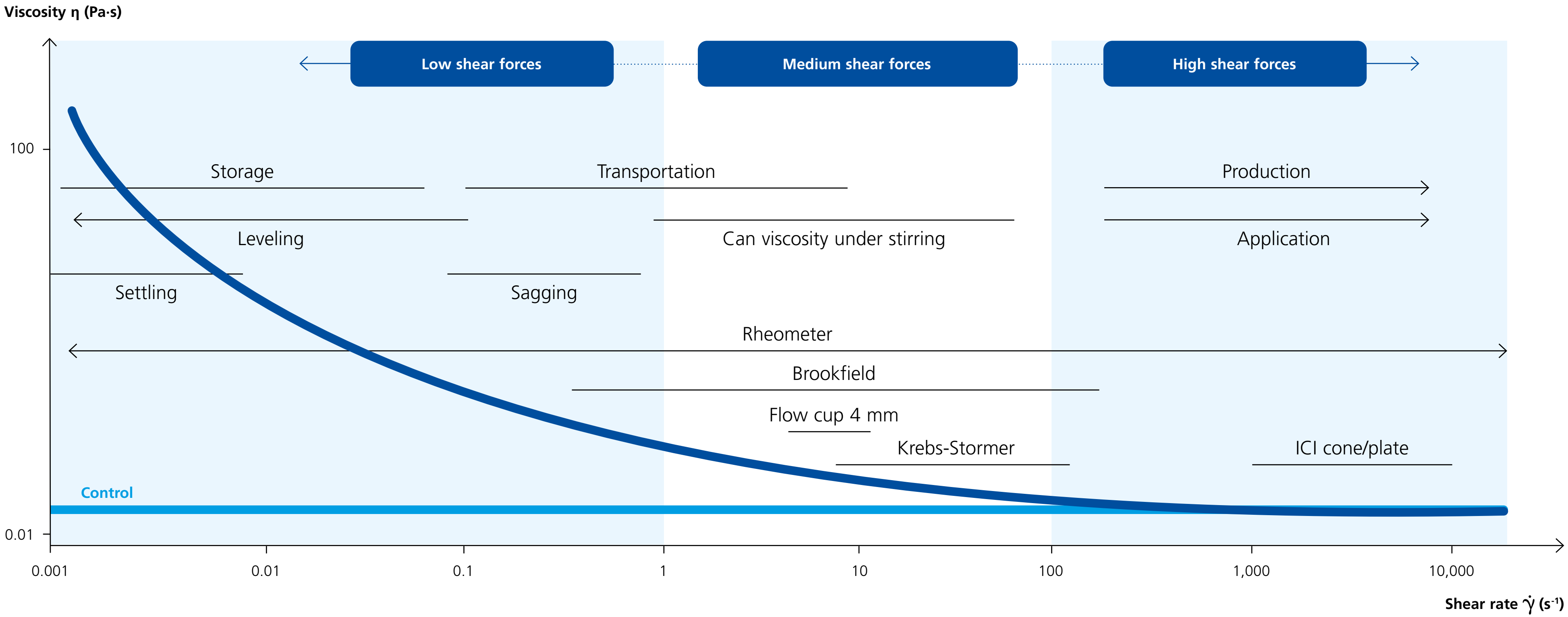
An additional major factor for the rheological behavior, however, is the dependence of viscosity on the shear rate. For many PVC plastisol applications, a relatively larger shear range must be considered. A rheological characterization over the entire shear range is best obtained by means of rotational viscometers.

Working mechanism of BYK's rheology additives



G. 17

Shear rates of typical applications/procedures



G.18

Depending on the additive and the concentration used, it is possible to create a rheology profile that is optimum for the final product. The important thing is to specifically define this profile. G. 18 shows the shear rate ranges for different industrial process steps.

Structure of the RHEOBYK-410 series

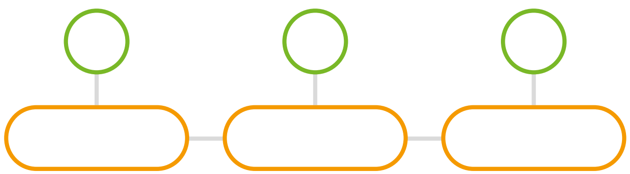
RHEOBYK-410

Urea groups   Medium polar modifying groups

G.19

Structure of RHEOBYK-7590

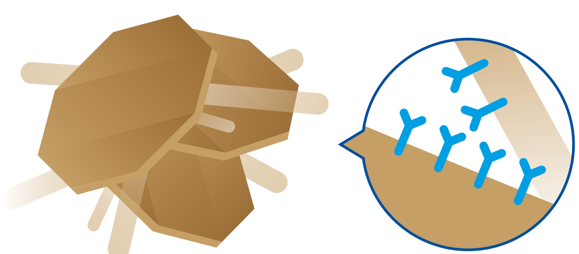
RHEOBYK-7590



Hydroxy groups   Low polar parts

G.20

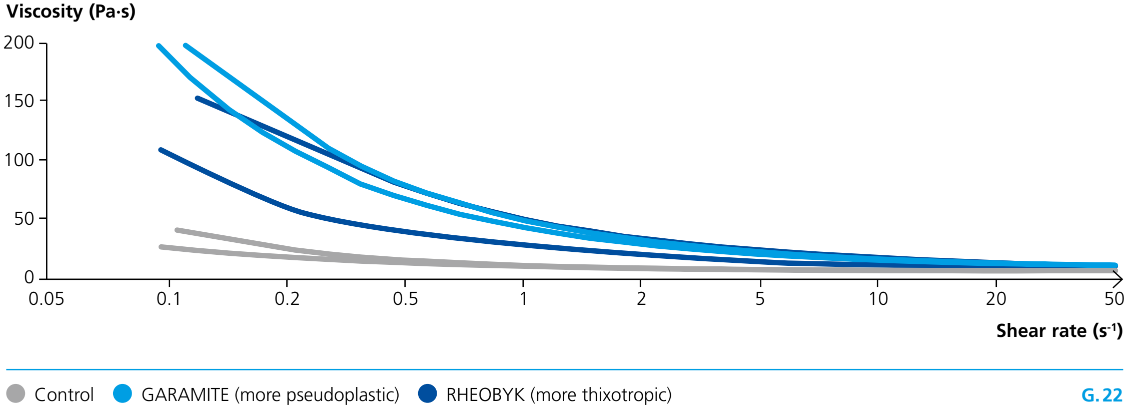
Structure of the GARAMITE series



Two types of minerals are mixed to create a unique performing clay-based additive with much faster/ easier processing properties and that is suitable for solvent-free, high-viscous systems

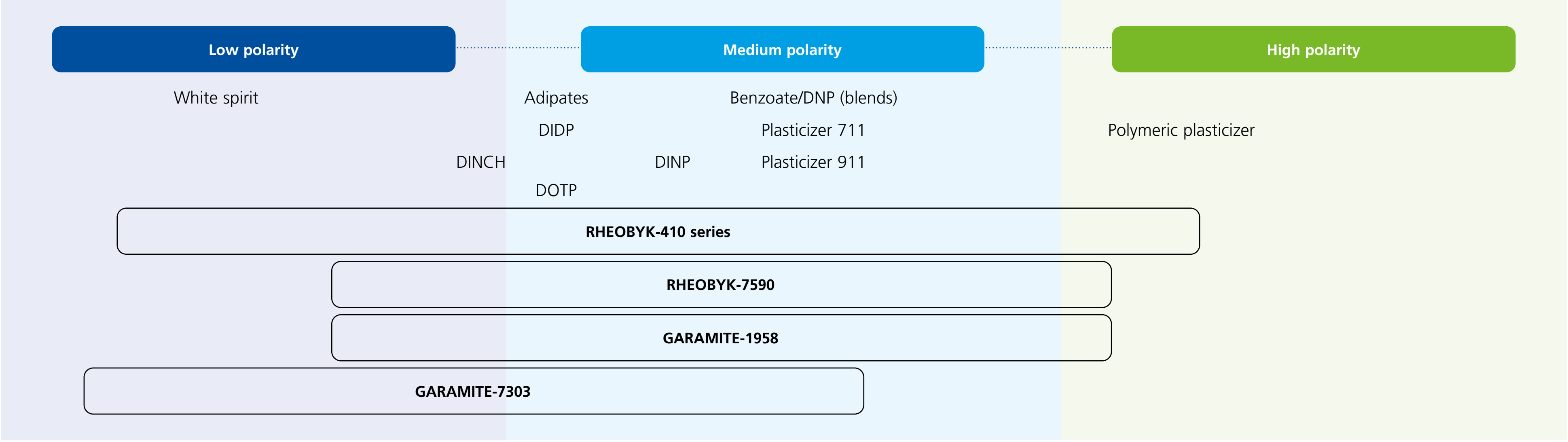
G.21

Comparison of the flow behavior of different rheology additives for PVC plastisols



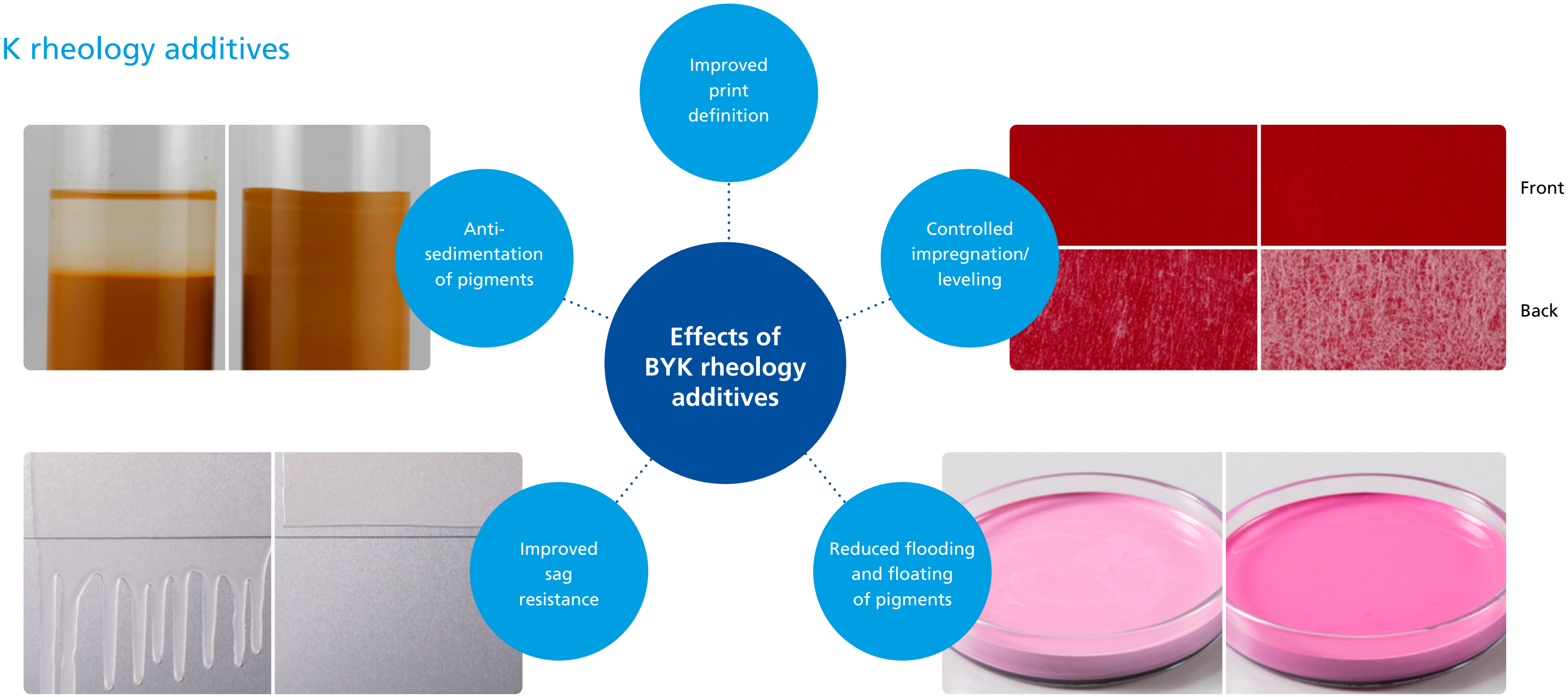
G. 22

The efficiency of rheology additives depending on the PVC plastisol polarity, e.g. the polarity of plasticizers



G. 23

Benefits of BYK rheology additives



Left = control, right = with BYK additive

G. 24

Additive recommendations

Product	Anti-settling	Sag control	Viscosity enhancement	Controlled impregnation	Reduced flooding/ floating	Chemistry	Active substance	Solvent
RHEOBYK-410	●	●	●	●	●	Modified urea	52 %	NMP
RHEOBYK-D 410	●	●	●	●	●	Modified urea	52 %	DMSO
RHEOBYK-7410 ET	●	●	●	●	●	Modified urea	40 %	Amide ether
RHEOBYK-7410 CA	●	●	●	●	●	Modified urea	47 %	Cyclic amide
RHEOBYK-7590	●		●		●	Castor oil derivative	100 %	–
GARAMITE-1958	●	●	●	●	●	Organophilic phyllosilicates	100 %	–
GARAMITE-7303	●	●	●	●	●	Organophilic phyllosilicates	100 %	–

● Recommended

T. 03

Moisture absorbers

Why use moisture absorbers?

The gelling of PVC plastisols requires high temperatures of around 170-210 °C. High amounts of moisture in the plastisol can therefore lead to surface defects like blistering, caused by the boiling of entrapped water during the gelling process. Moisture absorbers are thus used to remove water from the system and enable defect-free coatings.

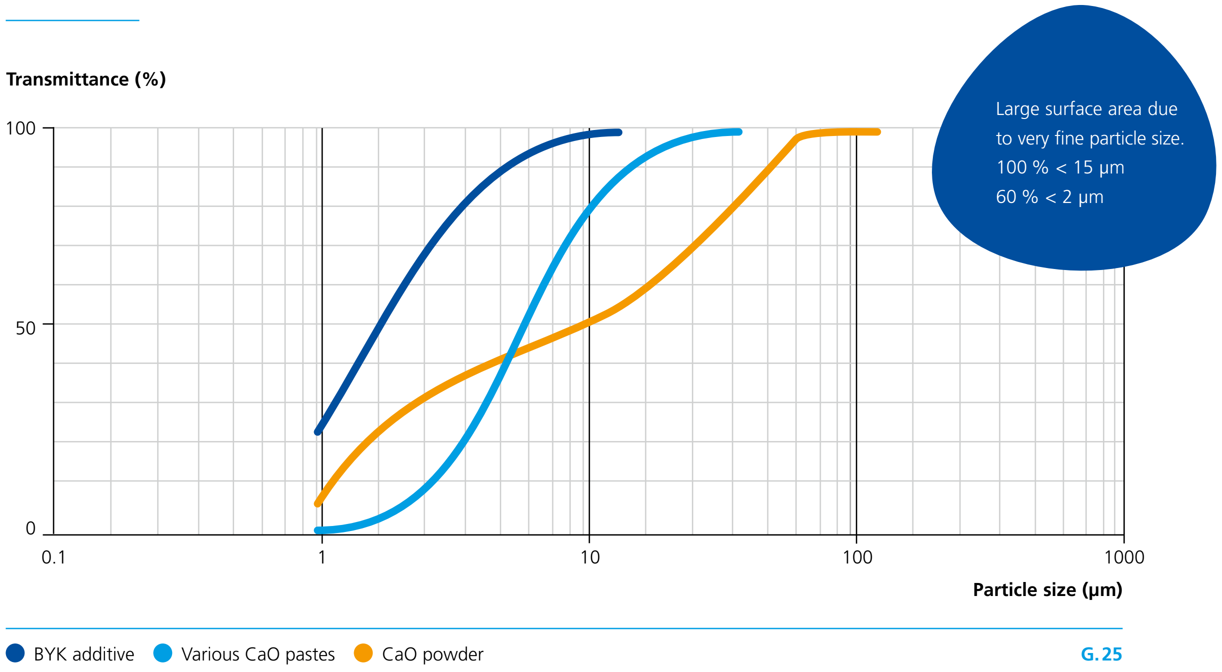
Benefits of BYK's moisture absorber

BYK's moisture absorber is a finely-dispersed, low-emission CaO paste that is pumpable and stable under normal storage conditions. The high amount of surface area provides optimal effectiveness (G. 25), so that moisture is eliminated even in large amounts in a short period of time. Utilizing a special preparation technique in combination with wetting and dispersing additives, the inorganic moisture absorber CaO is activated and stabilized. Thus, an extremely favorable dosage/effect is achieved.

Benefits

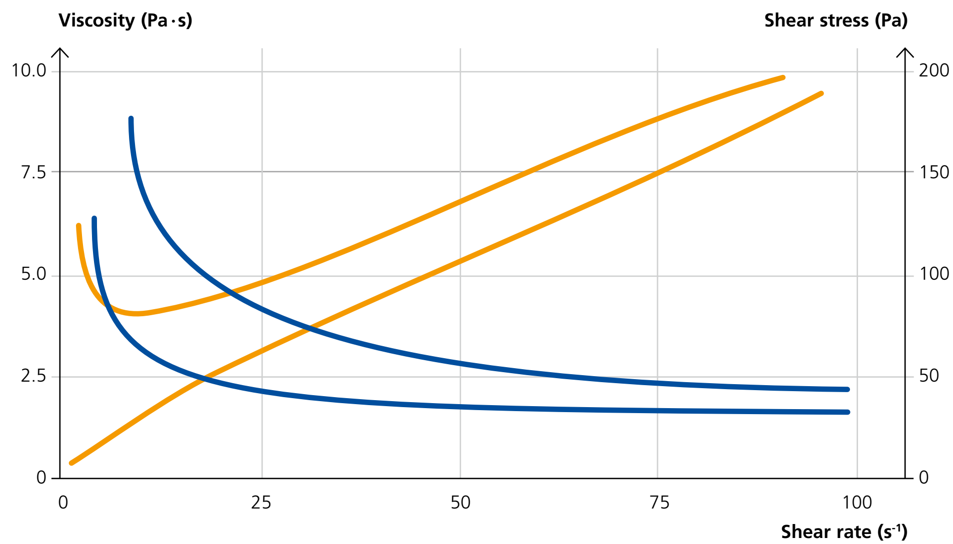
- Good storage stability (G. 26)
- Pumpable
- Dust-free
- Incorporation possible at any time during the PVC plastisol production
- Lower dosages needed compared to standard CaO moisture absorbers (G. 27)
- Prevention of surface defects such as blistering and craters during the processing of plastics, e.g. PVC, PU, and rubber (G. 28)
- Enables coating without pre-drying if moisture is present in the carrier or substrate
- Absorbs moisture carried into the system by the polymer, fillers, pigments, or reinforcement

Particle size analysis (laser diffraction)



G. 25

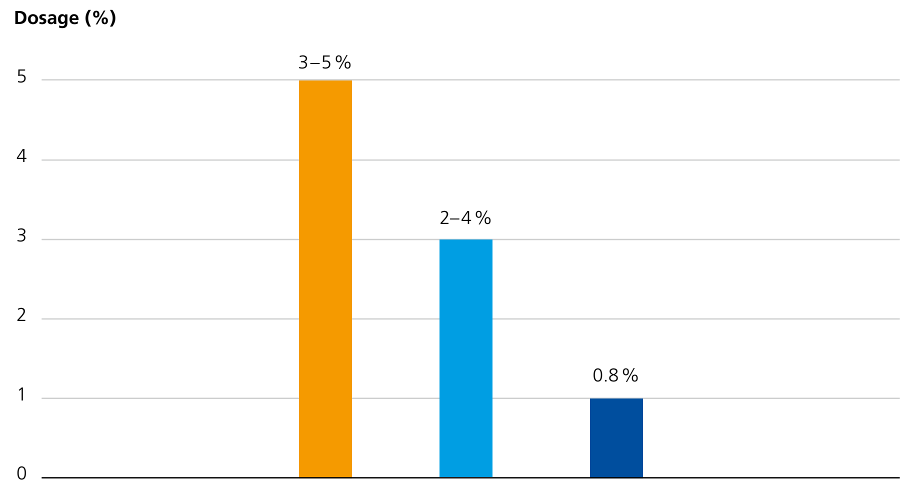
Good storage stability due to high yield point



Viscosity Shear stress

G. 26

Efficiency of BYK additive compared to other moisture absorbers

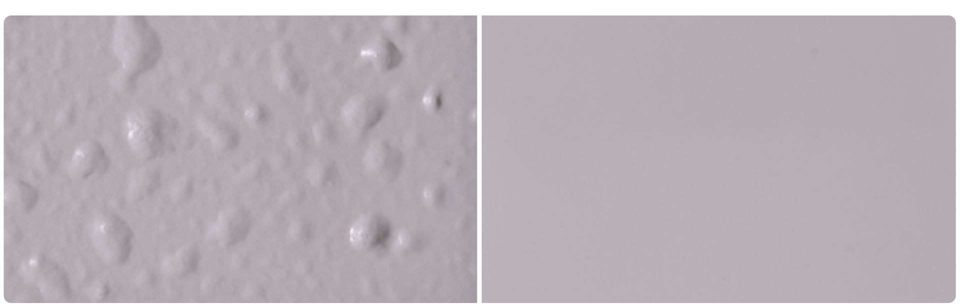


CaO fine, dry Various CaO pastes BYK additive

G. 27

Prevention of surface defects in a gelled PVC plastisol with 0.5 % H_2O

Without additive **With BYK additive**



G. 28

Additive recommendations

Product	
BYK-2616	is recommended for use in all PVC plastisols with exception of chemically foamed plastisols

T. 04

Foam stabilizers for mechanical foams

Why use mechanical foams?

Mechanical foams have a lower gelling temperature compared to chemically-blown PVC foams and provide good sound insulation and rebound elasticity (thick coatings). When used as an impregnation coat, a mechanically frothed PVC plastisol can offer economic advantages, such as less paste at same impregnation and a reduced chance of moisture blistering.

Key differences between silicone-based and silicone-free foam stabilizers

One factor in determining whether to use a silicone or silicone-free surfactant is the choice of plasticizers. The silicone-free surfactant produces a foam with smaller cells than those produced by a silicone stabilizer. In comparison to silicone surfactants, a silicone-free surfactant needs a heat stabilizer to achieve the same foam whiteness (T. 05).

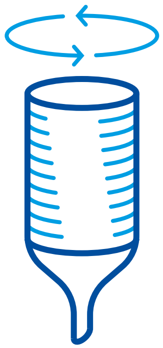
Differences between BYK-8020 and BYK-8070

Effect	Silicone stabilizer BYK-8020	Silicone-free stabilizer BYK-8070
Foam stability	Large, uniform stable cells	Small, uniform stable cells
Foam color	Snow white	White, heat stabilizer required
Water absorption	Hydrophobic	Hydrophilic

T. 05

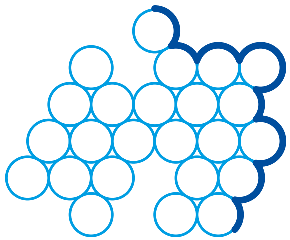
Mechanism of mechanical foams

Air entrapment



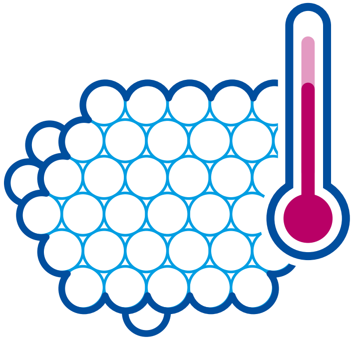
With the use of special mixing equipment, air is entrapped in the PVC plastisol.

Separation and stabilization of air by a foam stabilizer



After air entrapment, the air is separated and stabilized by a foam stabilizer

Fusing at 150 °C–175 °C



After achieving the desired foam density, the plastisol is fused.

G. 29

Both silicone and silicone-free mechanical foam stabilizers produce a uniform cell structure. During processing, the synergism with rheology additives at low dosages of around 0.1–0.4 phr can enhance the froth stability of the mechanical foam without affecting the foam's froth density (G. 30).

Silicone-based foam stabilizers are hydrophobic in nature. Thus, a mechanical foam made with these additives will repel water. In contrast, a foam produced with a hydrophilic foam stabilizer will absorb water (G. 31).

Additive recommendations

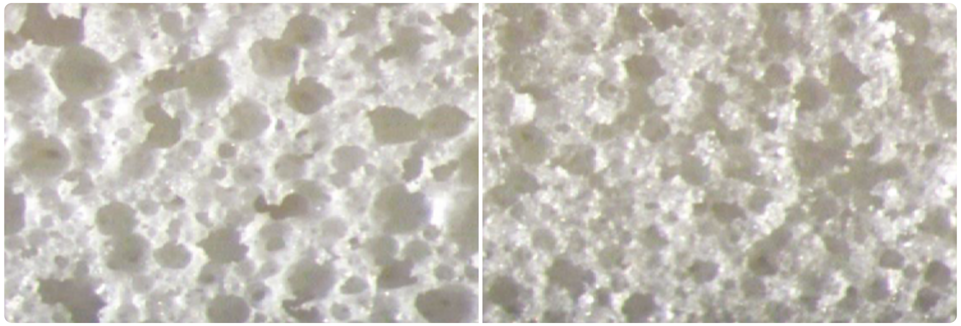
Product	Hydrophilic foams	Hydrophobic foams	Reduction of density	Low emission	Low fogging
BYK-8020		●	●	●	●
BYK-8070	●		●	●	●

● Recommended

T. 06

Cross section of mechanical foams

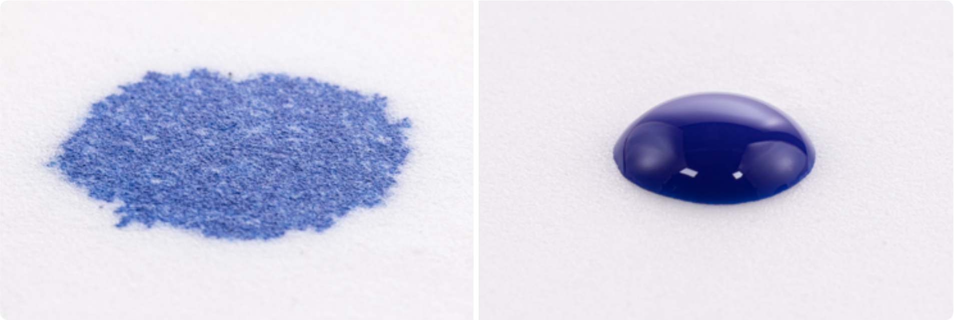
With silicone foam stabilizer / **With silicone-free foam stabilizer**



G. 30

Water absorption test

Water droplet on PVC plastisol with hydrophilic foam stabilizer / **Water droplet on PVC plastisol with hydrophobic foam stabilizer**



G. 31

Processing additives

Why use processing additives?

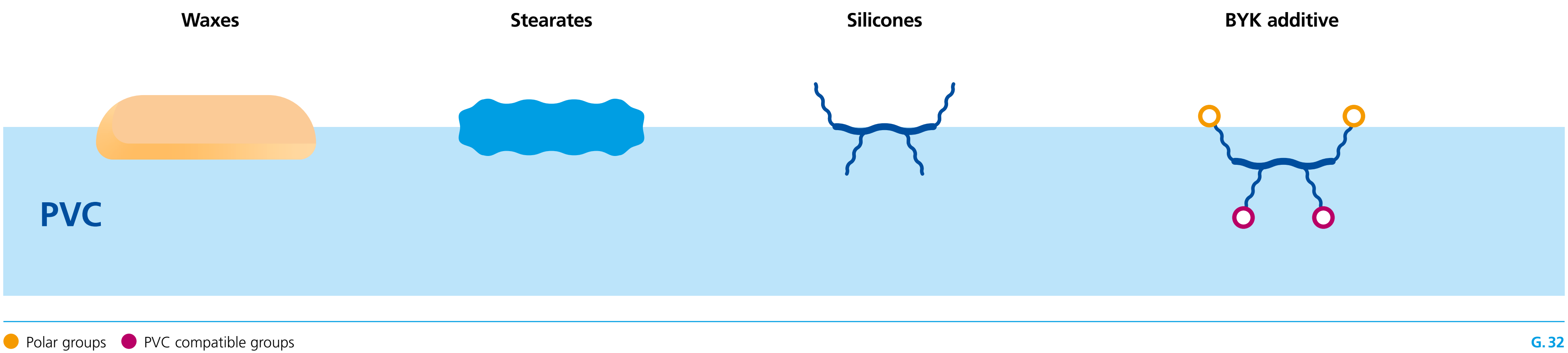
Processing additives improve and influence the processing of PVC plastisol applications.

BYK additive in comparison to commonly used products

Product	Silicones, waxes, stearates	BYK additive
During processing	• Incompatible with PVC • Risk of migration, plate out • Good release properties	• More compatible with PVC • No plate out • Excellent release properties
Foam cell structure after processing	• No influence on open cell structure, indentation recovery, or foam breathability	• More open cells resulting in better indentation recovery and increased air permeability

T. 07

Comparison of mechanism



G. 32

Benefits of processing additives

Improving release properties with BYK's processing additives

By using BYK's processing additives, improved release properties of a re-gelled or gelled plastisol from a drum, more turns or uses of release paper, and better flat screen or mold release can be obtained even with low dosages, e.g. 0.5 %.

The two main benefits of BYK's processing additives are:

1. **Improving the release properties**
   - From metal parts (e.g. gelling drum)
   - From release paper
   - From flat screens and molds
2. **Influencing the cell structure of chemically blown foams**
   - To improve the indentation recovery
   - To increase air permeability

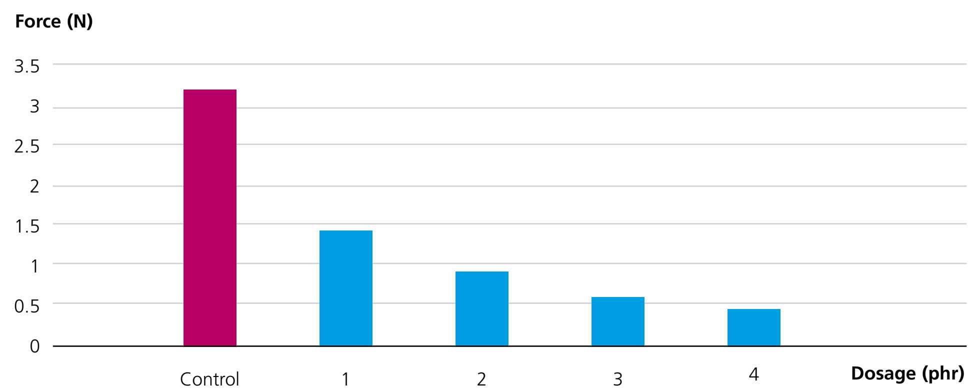
Additionally, the additives don't show negative influences on intercoat adhesion and are available silicone-, stearate-, and wax-free.

Improving the release, e.g. from metal surfaces

Without additive **With BYK additive**

G. 33

Improved release from paper



● Without additive ● With BYK additive

G. 34

Influencing the cell structure of chemical blown foams

Processing additives can also be used to achieve an open cell structure resulting in improved indentation recovery and air permeability. Additionally, an increased water absorption can be achieved. However, it should be noted that only certain PVC types are suitable for open cell foams, and this open cell structure can only be achieved when formulation ingredients and process parameters are balanced to each other.

Additive recommendations

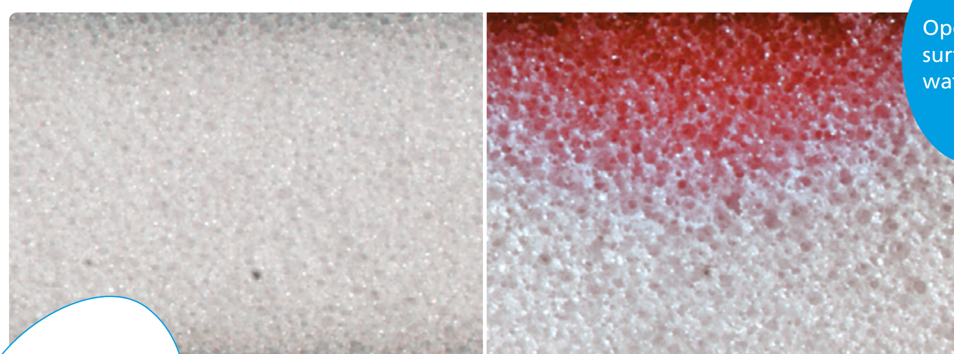
Product	Gelling drum	Release paper	Conveyor belts	Molds	Low emission	Low fogging
BYK-P 4100	●	●	●	●	●	●

● Recommended

T.08

Cross section of a chemical foam formulation

Without additive **With BYK additive**



G.35

Additives to increase electrical conductivity

Why use additives to increase conductivity?

In many application areas, such as ATEX (ATmosphere EXplosible), electronic, or medical areas, it is important to create antistatic layers, e.g. on floorings, functional textiles or conveyor belts, to avoid explosions or static charging. This can be achieved by using additives that increase electrical conductivity or decrease resistivity to values in the antistatic range.

Benefits of BYK's additive to increase conductivity

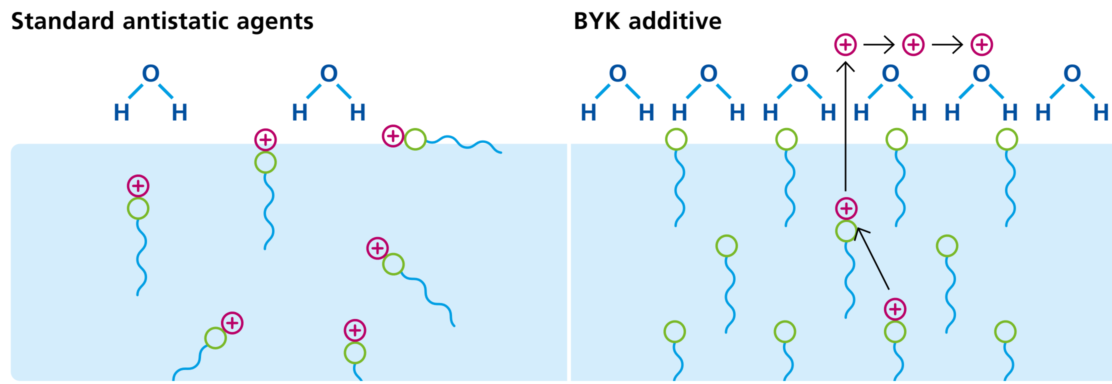
BYK's additive to increase conductivity is a non-ionic antistatic agent with a well-balanced and optimized amphiphilic structure that leads to the formation of a hygroscopic layer of the additive on the PVC surface. This results in the arrangement of water molecules into a thin continuous film of water and the creation of a conductive path to dissipate electrostatic charges.

Additive recommendations

Product	Filled	Surface resistivity	Volume resistivity
BYK-5128	●	●	●

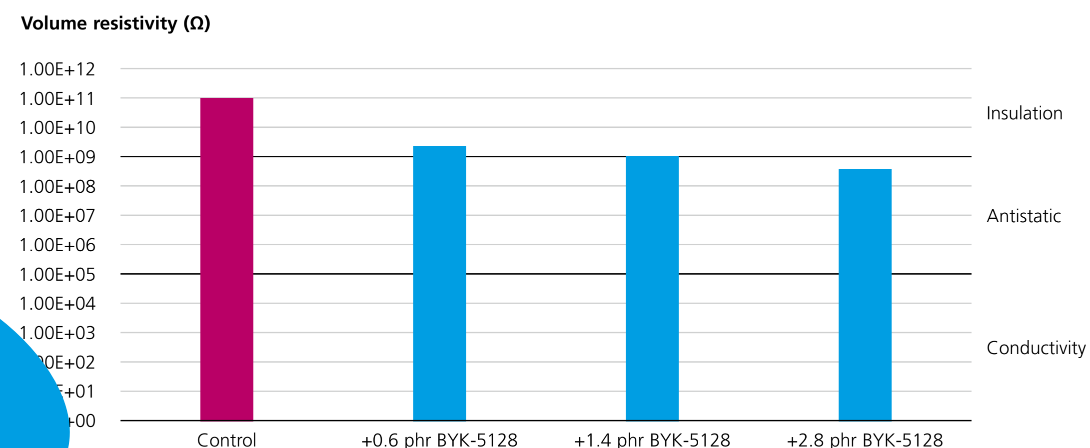
● Recommended T. 09

Working mechanism of antistatic agents



G. 36

Volume resistivity in a calendered flooring formulation after 28 days



Test formulation:
100 phr S-PVC
40 phr Plasticizer
2 phr Stabilizer
2 phr ESO
50 phr $CaCO_3$

G. 37

Additives to increase the surface energy after gelling

Why use additives to increase the surface energy?

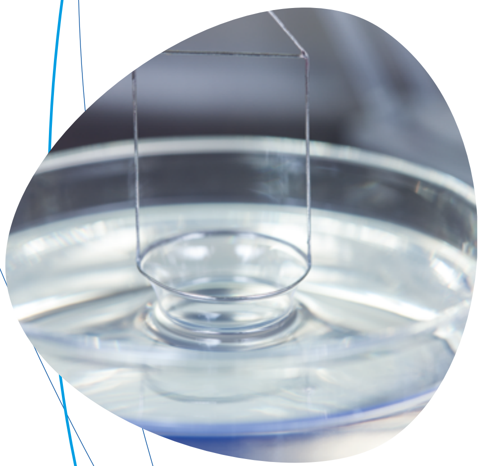
The wetting of a surface with a liquid depends on the surface tension of the liquid, but also of the substrate to be coated. Generally, the surface tension of the coating should be lower than or equal to the surface energy of the substrate in order to achieve a good wetting. Poor wetting, i.e. a crawling or beading of the coating, will occur if the surface tension of the coating is higher than the surface energy of the substrate. Substrates with a generally lower surface energy or contaminated surfaces (oil residue, release agent) are therefore difficult to wet.

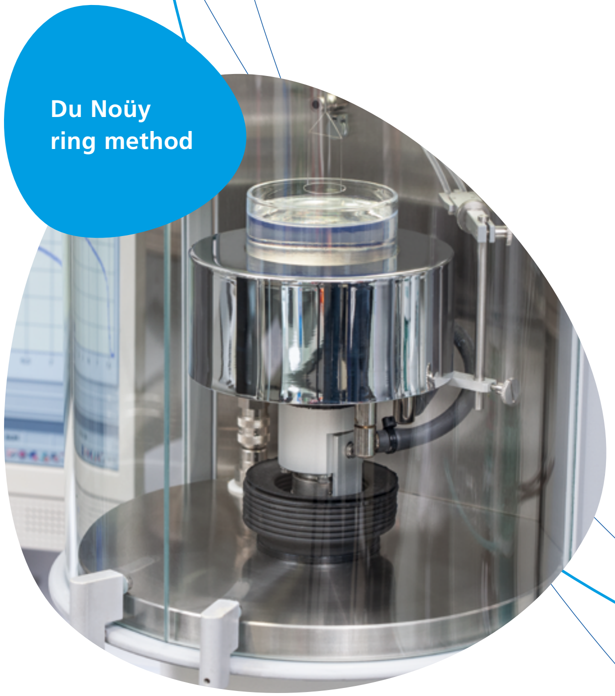
Generally, a higher polarity goes along with a higher surface tension. Especially on low-polar PVC substrates, coating or printing with highly polar aqueous ink systems can therefore be challenging, as the high water content leads to a higher surface tension of the coating. Therefore, additives that increase the surface energy of PVC plastisols after gelling are needed to achieve a substrate that can be coated properly.

Test methods

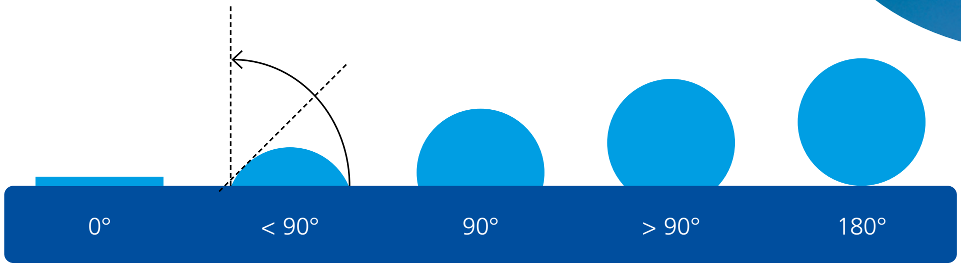
Free surface energy
The free surface energy of solids can be determined by contact angle measurements where defined liquids are applied on solid surfaces. The free surface energy is then calculated using different models (e.g. WORK, Wu).

Static surface tension
The static surface tension can be measured using the Du Noüy ring method. A platinum-iridium ring is drawn out of the liquid while, at the same time, the maximum force caused by the tension of the liquid lamella during the movement of the ring is measured.





Contact angle measurement



G.38

Benefits of additives to increase the surface energy after gelling

Using BYK's additive increases the surface energy and the polarity of PVC plastisols after gelling without influencing the surface tension of the liquid plastisol, leading to improved wetting of the gelled plastisol by subsequent layers, such as printing inks, as well as an enhanced adhesion and very good leveling of the subsequent layers. It also improves the leveling of the system in which it is used.

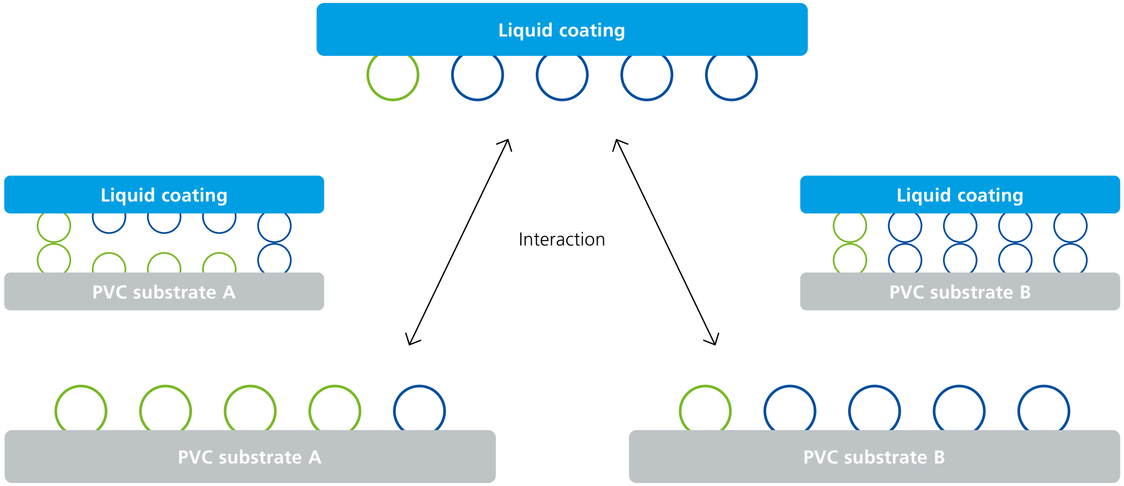
Additive recommendations

Product	Transparent	Foamed	Filled
BYK-3560	●	●	●

● Recommended

T. 10

Wetting behavior depending on the surface energy

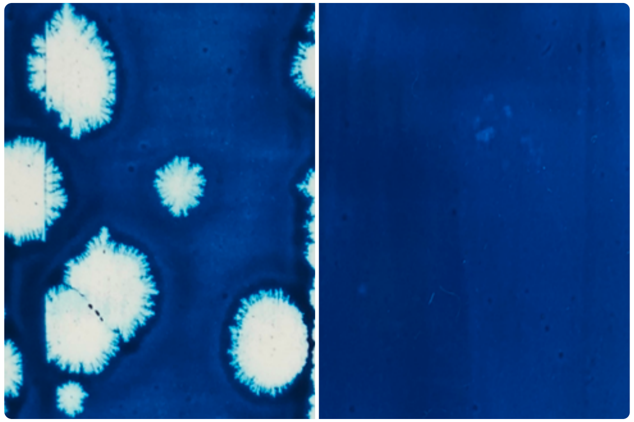


● Disperse parts ● Polar parts

G. 39

Improved wetting of low-polar PVC substrates

Without additive **With BYK additive**



G. 40

BYK

BYK-Chemie GmbH
Abelstraße 45
46483 Wesel
Germany
Tel +49 281 670-0
Fax +49 281 65735

info@byk.com
www.byk.com

A member of ALTANA