Toolbox for Waterborne 2K Polyurethane Coating Systems

Bayhydrol® Bayhydur® Desmodur®

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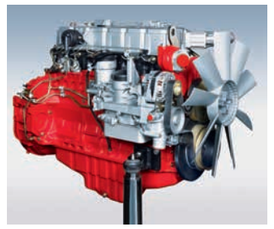
Edition: 2015 · Order-No.: COVw00072989 · Printed in Germany



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INVENTING **VISIONS** FOR YOU

As your leading partner for polyurethane chemistry, we know you are competing in increasingly challenging environments: Your customers are becoming more and more demanding in their expectations for quality, durability, sustainability and aesthetics of products. And they have more choices. For you this means that cost pressure is rising – while innovation cycles are becoming faster and faster.

Helping you to turn this challenge into your competitive advantage is the goal that drives our daily work. We call it: INVENTING FOR YOU. But what exactly are the basic values underlying this promise? What principles enable us to improve your productivity, drive sustainability, ensure reliability and co-create future-proof businesses? First and foremost, we are curious. Because only if we listen closely to you and ask the right questions, we can respond to your individual needs with new, creative and unexpected solutions that make a real difference to you. That's why inventing for us always starts with thinking about your unmet business challenges. It requires an indepth understanding of your needs along the whole value chain. To make sure: What we invent stands the test of time. Living up to this aspiration requires more than competencies – it calls for a corporate culture of being courageous. A culture that is defined and lived by dedicated people who cooperate to push the boundaries of invention founded on knowledge and experience. Our courage permeates our entire business – from partnerships to business models. This is also reflected in our colorful business philosophy. We appreciate partnerships that go beyond traditional black-and-white ways of acting and thinking. An attitude of openness that invites you to co-create new things – rather enabling you than just providing. We are optimistic and resourceful in finding solutions that inspire our customers and partners.

This set of fundamental values adds up to an unrivaled performance orientation to constantly strive for the better, be it through big or small changes. A true sense of business regardless of function. And a deep commitment to delivering our promise everyday. Anywhere. Again and again.

INVENTING FOR YOU.

Building blocks for supply security, efficiency and sustainability

Solutions to enhance your process efficiency
Nowadays, the quality demands made on industrial processes are very high. But at the same time there is a clear need to cut costs. Both goals can be achieved by increasing process efficiency. The complexity of the processes involved in manufacturing coatings offers us various opportunities to enhance process efficiency. Significant process-optimizing and cost-cutting gains are possible, for example through faster curing and shorter process times. At Covestro we have a wide range of solutions designed to enhance your process efficiency. Why not take advantage of our know-how? These solutions will be good for your bottom line.

Outstanding quality and supply security – worldwide
Covestro, the world's leading manufacturer of aliphatic and aromatic isocyanates, offers an extensive range of raw materials and services for coatings manufacturers. This allows the very latest technology to be used extremely effectively for a variety of applications. Thanks to its unique setup and worldwide network of state-of-the-art production sites, R&D facilities and customer technical centers, industry-leading supply chain setup, global orientation and local stocks, extremely large product portfolio, highest health, safety and environmental (HSE) standards, as well as tailored supply chain flexibility with short lead times, Covestro offers the industry unrivaled supply security and assured quality.

High-performance coatings – enabled by nature
Sustainability drives innovation at Covestro. We are committed to optimizing our manufacturing processes, reducing the impact of logistics, and enabling sustainability along the value chains. Renewable feedstocks offer opportunities for developing more sustainable building blocks for coatings and adhesives – with significant potential for reducing the carbon footprint of end products while also reducing our overall dependence on fossil-based resources. But to make more sustainable solutions not just possible but also economically feasible, the performance of all our feedstocks needs to satisfy high industry standards. To this end, we are evaluating the use of renewable raw materials and will enlarge our product portfolio with new bio-based and mid- to long-term cost-competitive products, provided the raw materials become commercially available. In all these efforts we are committed to focusing on products that perform at least as well as established products but are at the same time more sustainable.

Cutting-edge technology from the world market leader

An unparalleled success story

Polyurethane is widely used as a binder in the worldwide paint and coating industry. As the inventor of and driving force behind polyurethane chemistry, Covestro has been a major contributor to this success story.

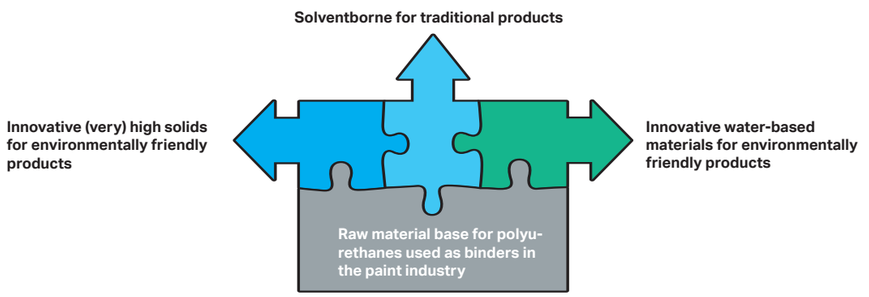


Fig. 1: Polyurethanes from Covestro provide a holistic technology platform for any application or need, especially when it comes to creating added value in the paint and varnish industry.

This is certainly true for 2K polyurethane (PU) coatings, as their impressive data and many success stories in a wide variety of applications prove. Since solventborne 2K PU coatings were introduced, around 1960, they have become the dominant coating technology wherever quality and efficiency are the main drivers. Outstanding examples include the protective coatings of planes, trains, trucks, buses, and passenger cars (in manufacturing and refinishing processes), as well as high-performance coatings for industrial applications, corrosion protection, and high-quality wooden and plastic surfaces. This success story is based on a unique combination of properties ranging from high efficiency during application (high solids content and fast drying even at ambient temperatures) to excellent film appearance, scratch resistance, and high resistance to water, solvents, chemicals and weathering.

Nowadays, the lower solvent content attainable with PU technology has added to this list of advantages. And that is a particularly important point when looking at future business opportunities.

Environmentally friendly technology working for you

The world is changing. Environmentally friendly technology has become an imperative of corporate responsibility and a milestone on the road to future sustainability. Not only do an increasing number of our customers share this view; analysts, investors, and the general public also

Fig. 2: The environmentally friendly product value-added chain from a paint industry perspective

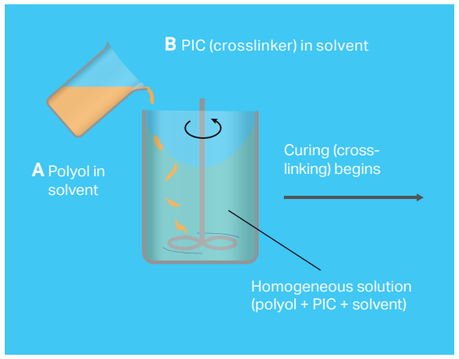


Fig. 3: Solventborne PU paints (DD coatings) in homogeneous phase have been the industry standard up to this point.

Application

expect to see assertive action from the industry. Not least as a result of pressure from the public and the media, environmentally friendly technology has become a mega-trend in the global marketplace. What began as an eco-trend is now mainstream. The market for environmentally friendly products is ramping up rapidly and relentlessly. Covestro recognized this trend very early on. Now, the demand for high-grade, eco-friendly products that can be produced and applied efficiently is reinforcing this trend and increasing the incentive for us to develop and market suitable solutions.

Sophisticated eco-friendly platform

Our water-based PU coating systems are a sophisticated eco-friendly technology platform our customers can build on to gain a significant competitive advantage. This PU platform is not only unique but also one of the most advanced in the world. As a supplement to established solventborne PU systems, we offer customers a range of waterborne PU raw materials that are technically equal or even superior to solventborne raw materials and thus offer the optimal solution for any painting or coating application.

Good by any comparison

In 2K PU systems, a polymer with active OH groups (polyol), referred to as component A, is crosslinked with a polyisocyanate (PIC), referred to as component B. With conventional systems, which were the industry standard in the past, the raw materials are dissolved in a solvent for further processing. The crosslinking reaction takes place in a homogeneous phase (Fig. 3), which has the disadvantage that volatile organic compounds (VOC) evaporate during drying. Needless to say, this is not an acceptable feature of environmentally friendly products, which gives waterborne coatings a huge advantage. If you want environmentally friendly raw materials, our waterborne 2K PU technology platform is your system of choice.

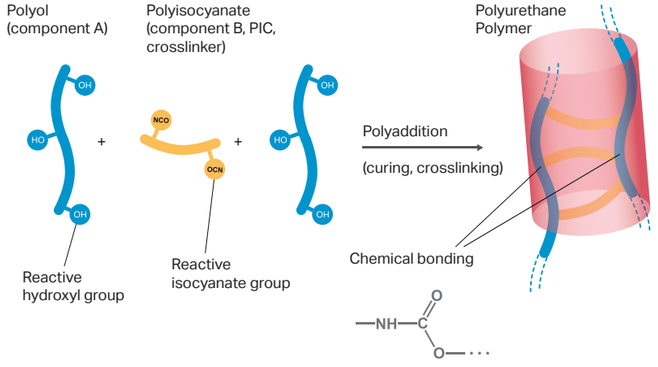


Fig. 4: Proven 2K cross-linking reaction for polyurethane

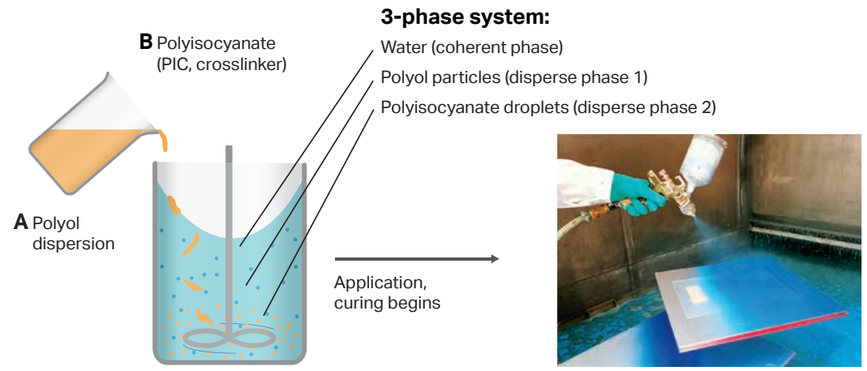


Fig. 5: Waterborne 2K PU systems use a 3-phase system.

How a waterborne 2K PU system works

Actually, it is quite simple. During preparation of the mix, the components are not dissolved in a solvent. Instead, the polyol (A-side) is applied as an aqueous dispersion (Fig. 5). A conventional polyisocyanate (the B-side needed for crosslinking) is hydrophobic and does not mix spontaneously with the aqueous polyol dispersion.

A discovery and its implications

As soon as people hear the term isocyanate, they associate the word water with hydrolysis and the formation of polyurethane foam. For a long time, no one knew that water could be used in place of organic solvents. A team at Covestro discovered that polyisocyanates form a thin protective polyurea membrane at the interface with water (Fig. 6). This acts as a barrier protecting the polyisocyanate underneath it from continued hydrolysis and inactivation. From that point on, it was clear that even in an aqueous environment reactive isocyanate groups were available for the crosslinking reaction. With this groundbreaking discovery Covestro laid the foundation for its waterborne 2K technology platform, which since then has been continuously improved and refined to become one of the world's leading technologies. Above all, it has paved the way for successful eco-friendly products. All this happened at just the right time to meet the growing demand for such products.

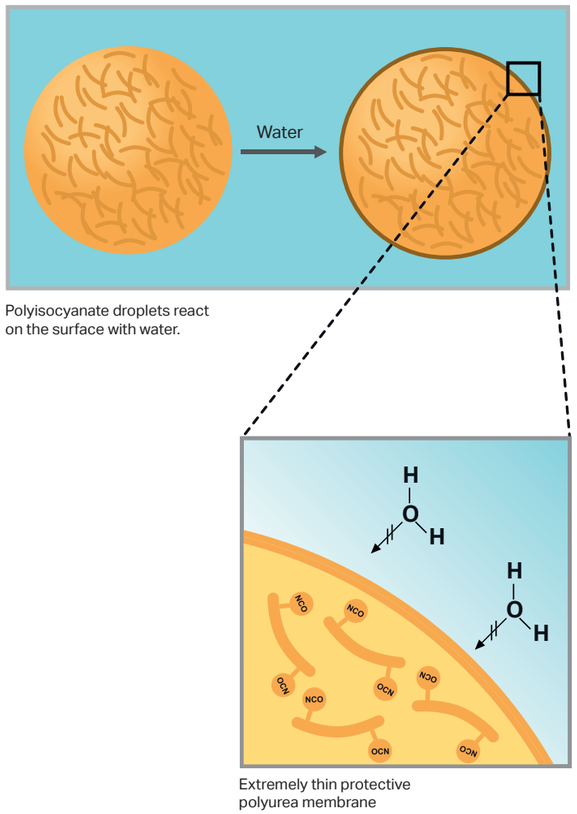


Fig. 6: Polyisocyanates remain stable in water after a protective membrane forms.

To create a reactive polyol and PIC system that is crosslinked in the wet film of paint, the user first has to emulsify the hydrophobic PIC in the polyol dispersion. The finer the emulsion droplets, the better the coating (Fig. 7, 8). Simplifying the emulsion process also makes things easier for the user in the practical application.

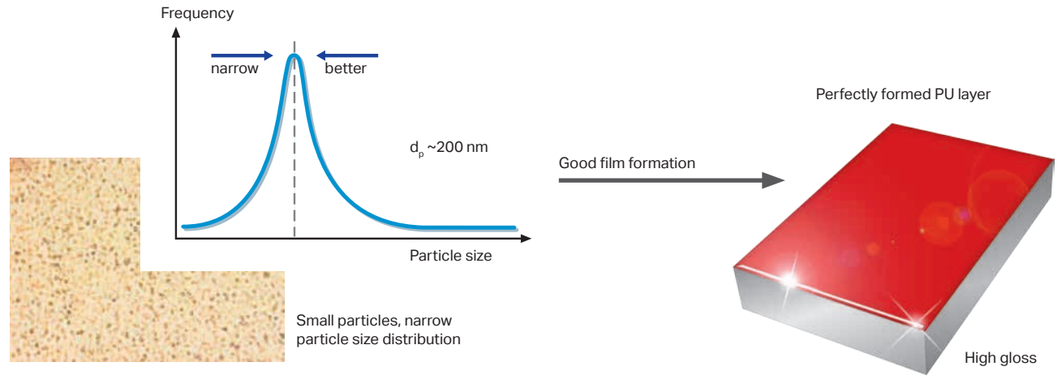


Fig. 7: PIC-in-polyol emulsion containing fine droplets, formulated with a waterborne 2K PU system from Covestro.

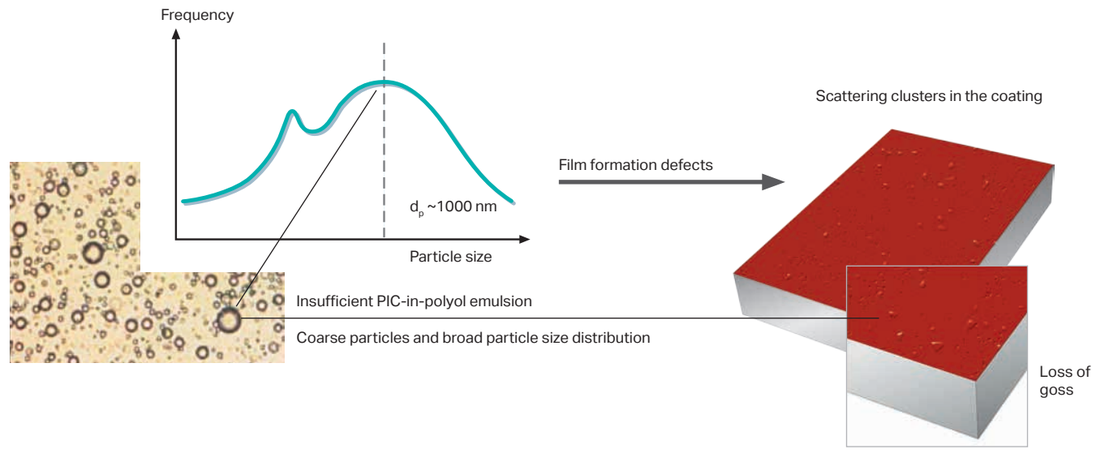
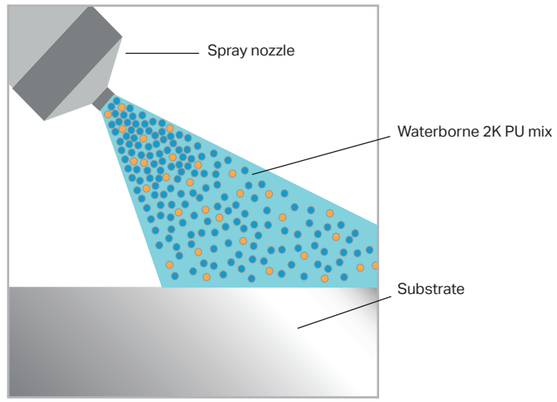


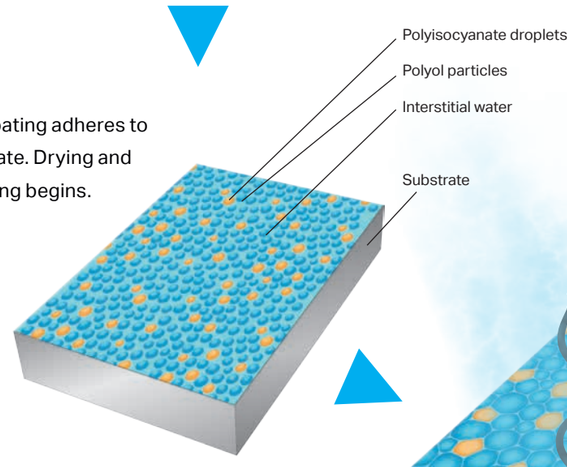
Fig. 8: PIC-in-polyol emulsion containing coarse, non-uniform droplets, formulated with a no-name waterborne 2K PU system

Formation of a waterborne 2K PU coating

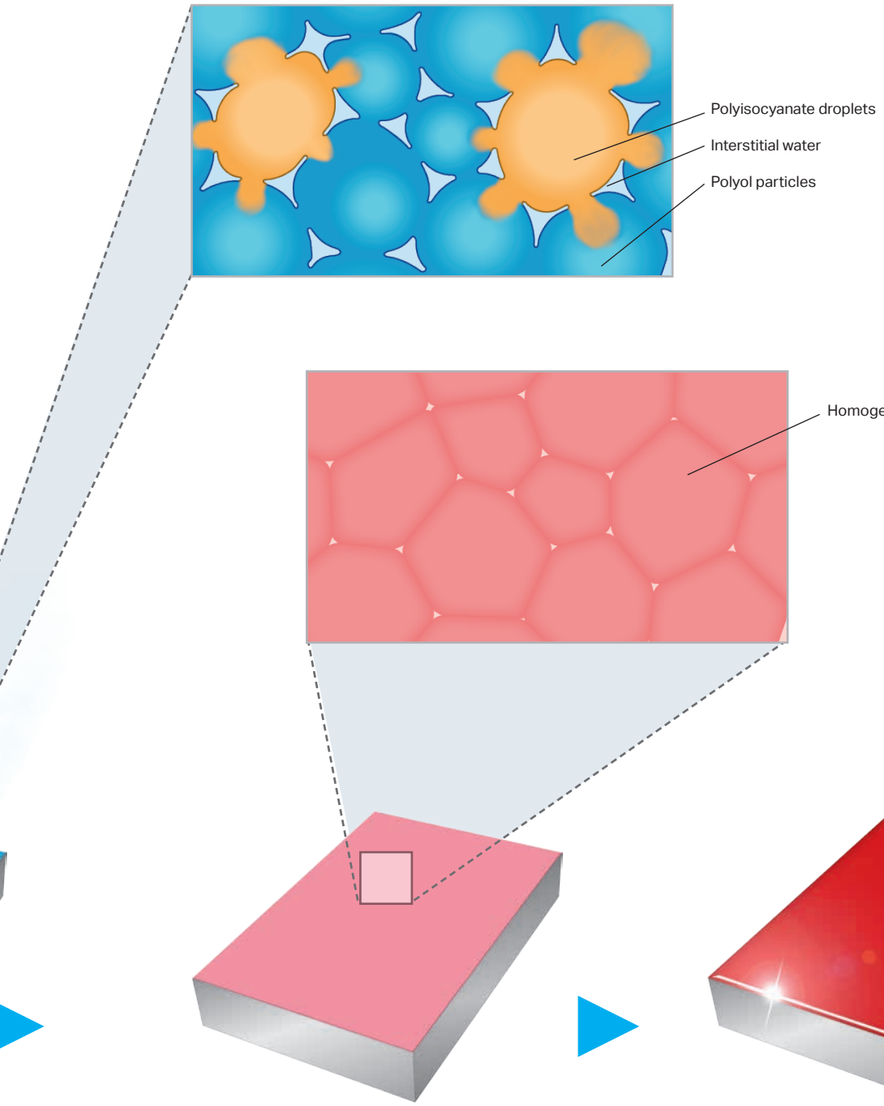
1. The waterborne 2K PU mix, the PIC-in-polyol emulsion, is sprayed on.



2. The wet coating adheres to the substrate. Drying and cross-linking begins.



3. Polyol particles and polyisocyanate droplets coalesce and react. The film begins to form. Interstitial water evaporates.



4. A touch-dry film forms. Physical drying is complete, and chemical hardening is well underway.

5. Curing is complete. The result is a top-quality paint coating.

Why it’s worth switching to waterborne technology

If your formulations are based on our waterborne crosslinking technology, you kill two birds with one stone. For one thing, you only need small amounts of solvents or none at all (low- or zero-VOC formulations). You can also offer coating solutions that meet the increasing demand for environmentally friendly products that are excellent in every respect. After all, polyurethane coatings made from our waterborne 2K systems convincingly prove that the quality of environmentally friendly technology is equal or even superior to conventional solutions. And your customers enjoy the benefits of significantly higher added value.

Proven solutions

There are many good reasons for switching to our extensive eco-friendly technology platform as a source of raw materials for your coatings. The range of proven solutions covers every imaginable substrate and application field, including automotive, wood, industrial goods, construction, and textiles.

Key benefits

Our environmentally friendly technology platform opens the door to ecologically credible and economically profitable products for a whole variety of market segments.

Fig. 9: An impressive variety of waterborne polyurethane systems from Covestro already have a proven track record and an established position in a wide range of applications.

2K PU waterborne – main markets & applications

Plastic industrial + automotive

General industrial

Transportation ACE

Wood

Paper & print

Flooring

Our toolbox for your waterborne 2K PU formulations

We have developed an extensive toolkit for waterborne 2K formulations to help you get faster and more consistent results.

- **A wealth of inspiration:** An outstanding product portfolio of polyisocyanates, polyols and state-of-the-art model formulations as a suggested starting point for your own innovative low- and zero-VOC products.
- **Precision instruments:** Sophisticated tools that give you the flexibility to adjust formulation parameters and manipulate the properties of the PU coating so that you get just the result you want.
- **In-depth support:** Professional paint-engineering support from waterborne paint specialists at our application centers around the world or from specialists near you.
- **Impressive solutions:** Formulations with a proven track record that make it easy for your customers to properly formulate the PU systems you provide, and achieve consistent results.

Our PU systems toolkit is part of our holistic, user-centric strategy designed to help our partners and customers.

- Rapid development and introduction of waterborne 2K PU systems
- Fast and dependable road to development of environmentally friendly products to meet market demands
- Quick and painless transition from solvent-borne to waterborne 2K coating products and targeted optimization of existing formulations

How you benefit

Our toolbox gives you a sound framework for designing and quickly producing your innovative products. Visit our website at www.coatings.covestro.com or get in touch with your local engineering contact.

TECHNICAL SERVICE & CUSTOMER CENTERS IN ALL REGIONS

All over the world, we have application development centers for coatings' and adhesives' raw materials.

Superior crosslinking tools: Desmodur® | Bayhydur®

When many groups contribute, success is a more likely outcome. Our polyisocyanates are famous for their excellent functionality since, on average, our polyisocyanate molecules have more NCO groups available for crosslinking (up to five). This means our polyisocyanates have excellent crosslinking properties and are very economical.

Desmodur® – a durability tool in a class of its own

In general, polyisocyanate with thinner consistency are easier to emulsify (Fig 10). With this in mind, our polymer designers have lowered the viscosity of our familiar Desmodur® products (Fig. 11). Our highly popular polyisocyanate crosslinkers fit perfectly into our waterborne 2K PU systems, and their suitability for emulsification in polyol dispersions is simply outstanding. This is true both for HDI-based polyisocyanates, e.g. Desmodur® N 3600 (Fig. 12), and for the asymmetrical Desmodur® N 3900 HDI trimer (Fig. 13), which was created through a stroke of genius by our synthesis research team (Fig. 13). The low-viscosity Desmodur® versions substantially reduce the need to add solvents during formulation of waterborne 2K polyurethanes.

How you benefit:

- Efficient crosslinking
- Very easy to work with to produce high-grade 2K PU coatings

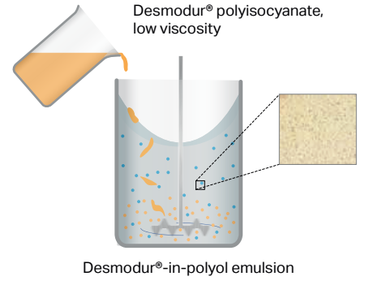


Fig. 10: Low-viscosity Desmodur® polyisocyanates are extremely well suited to emulsification in polyols. The Desmodur® -in-polyol emulsion contains fine, uniform droplets (microscopic view).

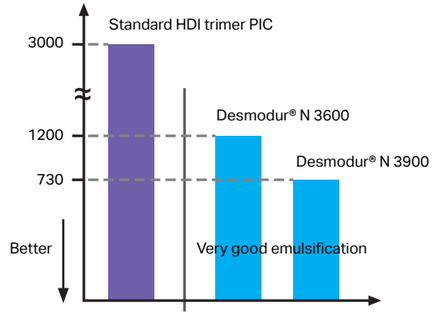


Fig. 11: Designed to facilitate emulsification, Desmodur® polyisocyanates have extremely low viscosity compared to standard HDI trimer polyisocyanates, making them ideal for waterborne 2K formulations.

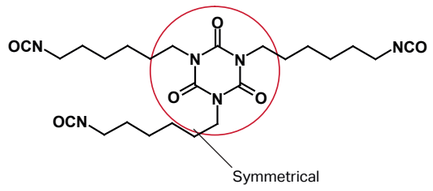


Fig. 12: Idealized chemical structure of HDI-based Desmodur® N 3600: This workhorse for waterborne 2K coatings is highly functional and has low viscosity.

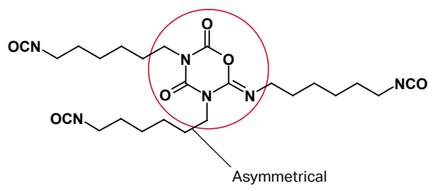


Fig. 13: Idealized chemical structure of Desmodur® N 3900: This highly functional asymmetrical trimer has extremely low viscosity and sets the new benchmark for environmentally friendly 2K PU coatings.

Bayhydur® – the easy-to-mix tool in a class of its own

Since convenience sells, we looked for a solution that makes it as easy as possible for users to mix waterborne 2K PU coatings. The result of our efforts, the easy-to-mix Bayhydur® polyisocyanate, is very impressive. So what makes this solution so good? During formulation of waterborne 2K PU coatings, two components are mixed that do not really go well together at low shear. To ensure that polyol and PIC come together for crosslinking, the lipophilic PIC has to be emulsified in the aqueous polyol dispersion. An emulsifier is needed to act as an intermediary between the two immiscible phases. Of course, you could take the easy route and simply add an external emulsifier to the PIC and offer this mixture as a ready-to-use single-pot crosslinker. Emulsification does take place, but the risks are significant and can be very unpleasant for the user. Since the emulsifier added is not bonded to a PIC, it cannot be anchored in the PU network of the coating. As it is still a foreign substance, it can work itself free after a short time and, for example, form clusters (Fig. 14). The emulsifier can migrate to the coating-substrate boundary or to the surface of the coating where it impairs key properties such as hardness, adhesion, and resistance to water. This is not something any user wants.

Bayhydur® eliminates the problems associated with stray emulsifiers. The scientists who developed this unique waterborne crosslinking technology incorporated the emulsifying function into the PIC molecules. Covalent bonds hold them firmly in place (Fig. 15) and straighten up at the boundary to deliver perfect emulsification of the hydrophilic PIC, in some cases spontaneously without any intensive stirring (Fig. 16).

In other words, Bayhydur® polyisocyanates with emulsifier functionality are directly involved in the crosslinking process and completely integrated into the PU network of the coating. As a result, they are firmly anchored and homogeneously distributed (Fig. 17). Our aqueous crosslinking technology makes yet another essential contribution to the quality of PU coatings.

How you benefit:

- Exceptionally stable and durable coatings
- No unpleasant surprises for users

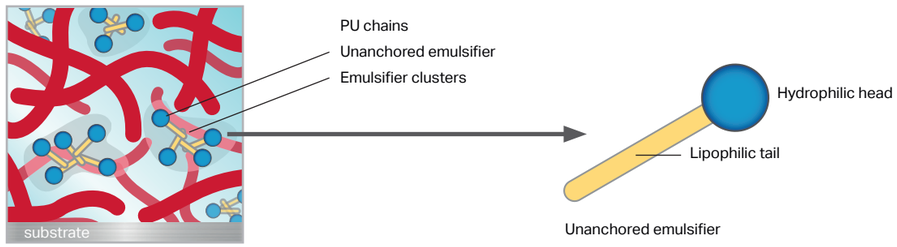


Fig. 14: Emulsifier clusters and film defects can form in formulations which have free emulsifiers.

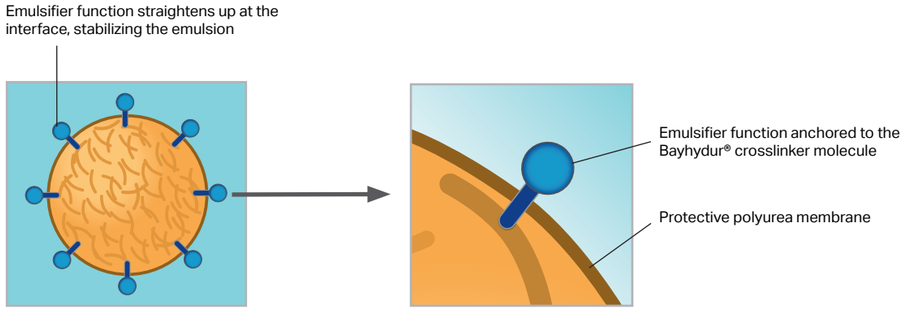


Fig. 15: With Bayhydur® products, the emulsifying functions are attached to the polyisocyanate with covalent bonds. They straighten up at the interface, facilitating the formation and stabilization of the emulsion.

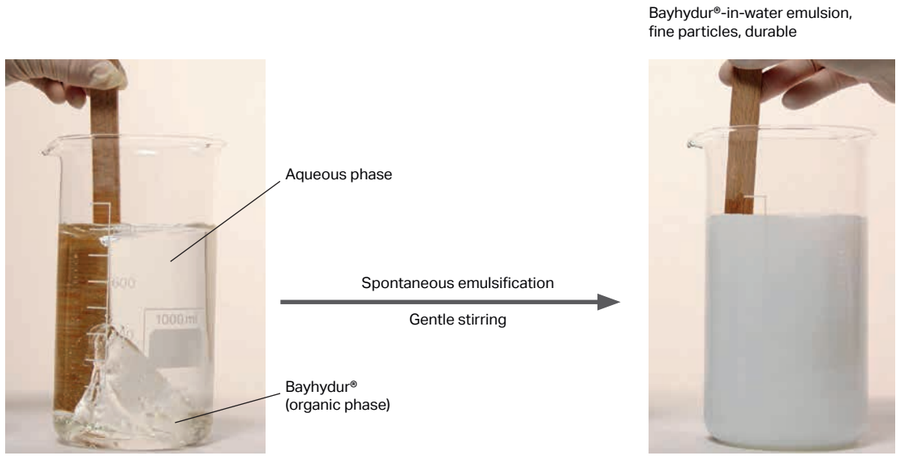


Fig. 16: When lightly stirred, Bayhydur® polyisocyanates emulsify spontaneously in the aqueous phase making it very easy to blend them into polyol dispersions without elaborate equipment i.e. using a wooden rod at construction sites.

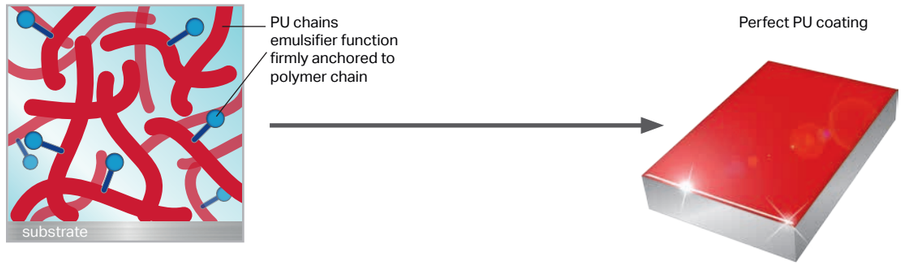


Fig. 17: The emulsifier functions are firmly anchored into the polymer network in coatings produced using Bayhydur®. The result is perfect, highly durable PU coatings.

Soft/hard tools for added flexibility during formulation

A flexible response to the preferences of your customer base and users is a key success factor for any PU coatings manufacturer. That is why you need tools that give you added flexibility. Such application-oriented tools coatings help manufacturers to achieve unique, professional results with 2K PU coating formulations.

In 2K PU systems the properties of the polyisocyanates used in the formulation can be manipulated to control a number of coating parameters that affect mechanical and tactile properties, drying characteristics, and durability. HDI polyisocyanates are the typical solution for highly durable, tenacious or flexible PU coatings. The "bulky" IPDI versions, on the other hand, accentuate hardness in a PU paint system (Fig. 18).

Our polymer designers have succeeded in transferring the ability to vary the PU properties to waterborne systems by combining the easy-to-mix tools mentioned above with the hard/soft tools. The results are very impressive. The extensive range of HDI- and IPDI-based polyisocyanates now available can be readily emulsified in polyol dispersions. More importantly, these polyisocyanates coatings help manufacturers define and regulate the properties of their products.

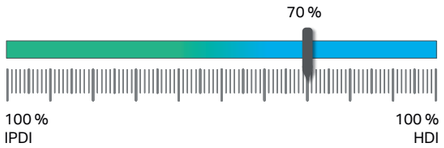
This environmentally friendly technology platform includes groundbreaking IPDI polyisocyanates, e.g. low-viscosity Desmodur® XP 2565 and the emulsifier-modified versions Bayhydur® 401-70 and XP 2759. These products, which have to be combined with the familiar HDI versions, provide an elegant path to environmentally friendly formulations, simple handling, fast drying, and high application efficiency.

How you benefit:

- More freedom in waterborne 2K PU formulations
- Coating properties variable over a wide range with greater precision than ever before
- Precise fulfillment of the needs of a specific application

IPDI Types	HDI Types
Hard and ductile coatings	For tough and elastic coatings
Slower crosslinking reaction	Fast crosslinking reaction
Higher early strength	Cures at low temperatures possible
Excellent chemical resistances (after curing at higher temperatures)	High resistance to chemicals at low curing temperatures
Longer pot life	Shorter pot life
High popping limit	Excellent scratch resistance
High weather resistance	Lightfast
Very fast physical drying	

Fig. 18: Our polyisocyanates offer an exceptional amount of flexibility to modify coating properties.



Easy-to-Mix / Soft-Hard

Product group	IPDI-based	HDI-based
Low viscosity Desmodur®	✓	✓
Bayhydur®	✓	✓

Fig. 19: We offer a combination of soft/hard and easy-to-mix tools to support optimal formulation of waterborne 2K PU coatings.

Bayhydrol® – the world-class polyol tool for waterborne 2K PU applications

Thanks to our holistic approach to polymer design, paint and coating manufacturers can choose the best combination of raw materials for their waterborne 2K formulations. So in addition to polyisocyanate chemistry, we have also worked intensively on binders (polyols) to produce the Bayhydrol® range of waterborne dispersions (Fig. 20) that are perfectly tailored to our polyisocyanate crosslinkers. Our binder toolbox for waterborne 2K PU coatings includes the OH-functional Bayhydrol® A range of polyacrylate dispersions and the Bayhydrol® U range of polyurethane dispersions. Both have been specially optimized for aqueous crosslinking applications. These Bayhydrol® polyols are primarily responsible for the mechanical and chemical properties of the coating film.

The Bayhydrol® UH series of high-molecular weight but non-OH-functional PU dispersions are the ideal mixing partners, as they can be used to control important paint properties, e.g. drying, adhesion, and the mechanical characteristics of the film.

Bayhydrol® dispersions are supplied as clear or opaque liquids that can be thinned with water. Isolated polyol droplets, which are finely distributed and swim around in the aqueous phase, are present in the dispersions (Fig. 21). Like charges on the surface of the polyol droplets ensure that they repel each other and do not clump together to form aggregates.

All of our fine polyol dispersions have a defined, narrow particle size distribution. They remain stable during storage (within their given shelf life) and are not susceptible to creaming or sedimentation. This is essential to achieve perfect coating results in combination with our polyisocyanates, particularly with regard to the key features of coating quality, i.e. the sheen and durability of the film.

Polyols with a high molecular weight are the solution of choice for quickly producing the final properties of the coating film. This requirement can be easily met with our Bayhydrol® UH dispersions – without a rapid increase in viscosity. Despite the high molecular weight of the polymer in the polyol droplets, our dispersions have a very welcome low viscosity thanks to their particle size distribution, and are also easy to process.

How you benefit:

- One of the world's most advanced polyol families
- Tailored for waterborne 2K PU formulations

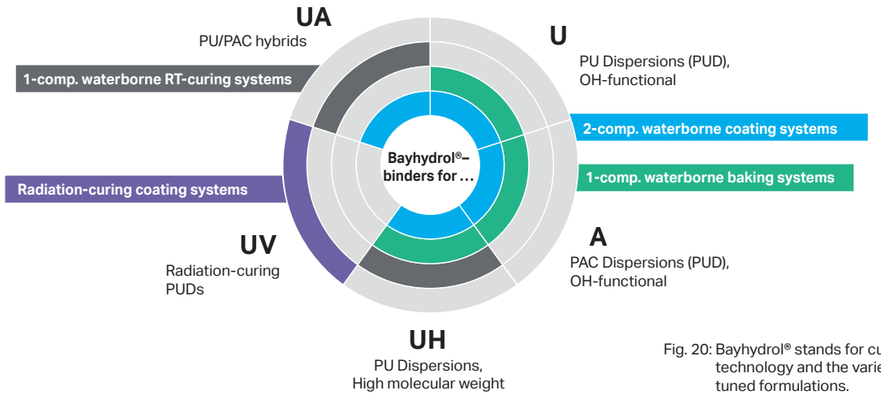


Fig. 20: Bayhydrol® stands for cutting-edge polyol dispersion technology and the variety you need for your finely tuned formulations.

Core-shell technology – the ideal coalescence and film-formation tool

Our Bayhydrol® range of polyols are no ordinary dispersions. They are complex binders that have been specially optimized for the waterborne 2K PUs (Fig. 22). During production of the dispersion, our polymer designers first synthesize a (normally harder) core and then cover it with a functional shell (core-shell technology). The core is the "nerve" of the polymer microstructure in the final PU coating and largely determines the durability of the paintwork. We match the composition of the monomers to create a core that is just right for the particular application. The same is true of the surrounding shell. The functional design is tailored to ensure that the shell offers a polyisocyanate droplet the optimal opportunity to dock and initiate the crosslinking process. The shell on Bayhydrol® polyols also plays the role of a co-solvent, promoting film formation and facilitating the homogeneous reaction of the components during curing to guarantee outstanding film performance.

How you benefit:

- Minimum amount of co-solvent required
- Very effective solution for reducing solvent emissions during application
- Opens the door to environmentally friendly VOC-reduced products

Fig. 21: Bayhydrol® dispersions and the schematic structure of a Bayhydrol® particle

Fig. 22: Core-shell technology: schematic drawing showing the structure and surface of a Bayhydrol® particle

Internal activation – the environmentally friendly function for quick drying and long pot life

Internal activation, an extremely important additional function of selected Covestro polyols, addresses a specific problem. The fact is that it takes time for the OH groups in the polyol to react with the NCO groups in the polyisocyanate crosslinker. Sometimes it takes too much time, and that can be a real disadvantage for users who need short drying times to achieve high productivity during paint application. The standard solution is to add dibutyl tin dilaurate (DBTL) or other external catalysts to speed up crosslinking/drying, but this has the major disadvantage of significantly reducing pot life. As a result, users often do not have enough time to properly prepare and apply their 2K PU mix. The coating film may show signs of streaking, reduced gloss, or other defects. Moreover, there are concerns about the environmental impact of organic tin compounds.

This is not the case with internally activated Bayhydrol® polyols. Eco-friendly activation centers are virtually built right into the Bayhydrol® A particles (Fig. 23). This activation system is a classic example of environmentally friendly technology, and compared to conventional catalysts offers the advantage that the pot life is not affected – despite the paint drying faster.

Thanks to these Bayhydrol® products customers can mix their 2K PU coatings in large batches and use them over for as long as they have been used to with conventional products (Fig. 24).

How you benefit:

- Outstanding environmentally friendly technology
- Fast drying
- Long pot life

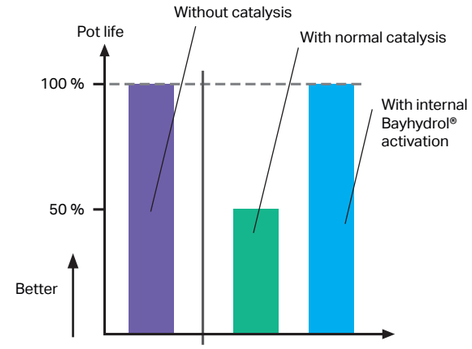


Fig. 24: In contrast to standard catalysis, special Bayhydrol® polyols with internal activation ensure long pot life.

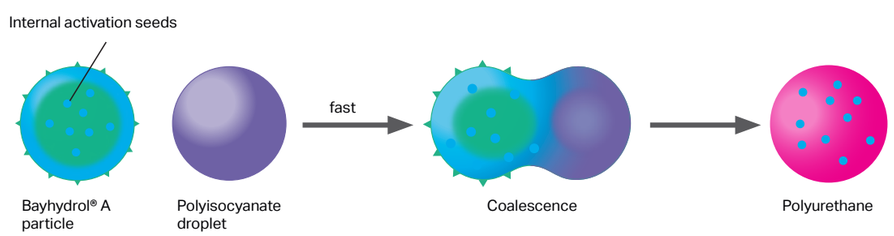


Fig. 23: Internal activation from Covestro, eco-friendly design and a milestone in fast-drying waterborne 2K coatings

The anti-scratch tool for self-healing coatings

We set another environmentally friendly benchmark by developing waterborne 2K polyurethane systems with virtually unparalleled self-healing capabilities to repair scratches in coatings caused by mechanical damage.
Urethane-modified polyester polyols from the Bayhydrol® U range have a very high number of hydrogen bonds that are cleaved when the coating is scratched. However, this damage is reversible. Thanks to sufficient mobility in our polyurethane coatings and partially charged groups, the hydrogen bonds reform and the scratches repair themselves (Fig. 25, 26).

How you benefit:

- Self-healing anti-scratch coatings based on waterborne 2K polyurethanes
- Feature highly appreciated by end users, e.g. car owners

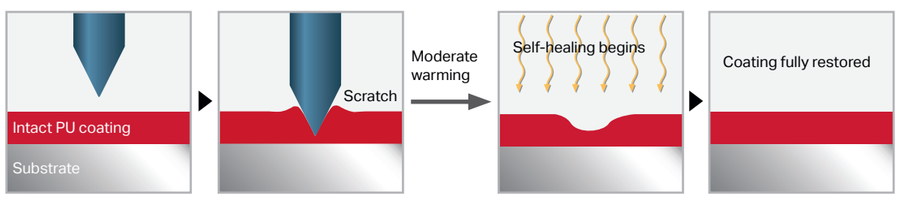


Fig. 26: Schematic diagram showing self-healing of polyurethane coatings

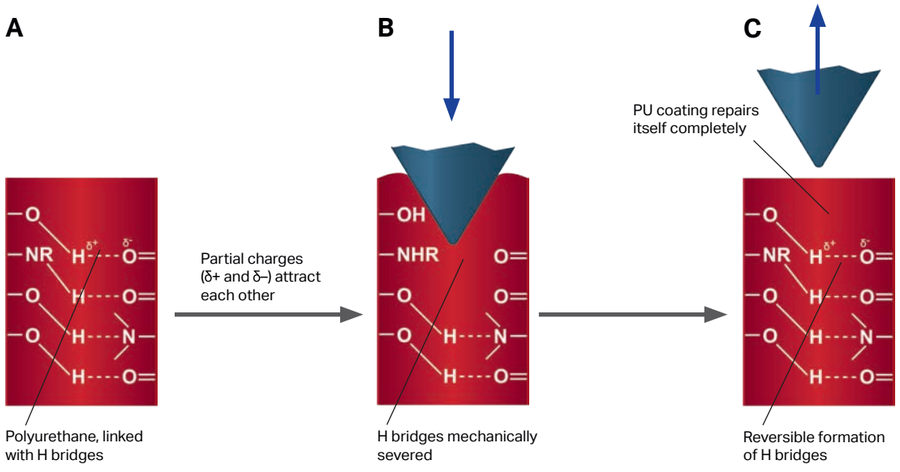


Fig. 26: Molecular-level view of damage and self-repair in polyurethane coatings (schematic). Hydrogen bonds (A) in the PU coating are cleaved as a result of mechanical damage (B). The process is reversible. The bonds reform, repairing the coating (C).

Outstanding productivity tools

Productivity and application reliability are the benefits we prioritize when focusing on the entire applications' spectrum of our waterborne 2K PU systems. Forced drying at high temperature is a major issue since it can lead to surface defects such as pinholes and cratering. Our application centers understand the complex relationship between the composition of the formulation and the elimination of coating defects when the coating is force-dried. For us all this is not just theory. Our expertise is based on practical experience. That means we can provide specific advice to our customers and users on how to formulate coatings using Bayhydrol® polyols so to achieve exactly the desired coating results.

We also provide useful tips to customers, e.g. on which defoamers and co-solvents to use and how to balance the ratio of hydrophilic and hydrophobic polyisocyanates to ensure a perfect visual appearance with high popping limits and minimal cratering when drying occurs at room temperature or if the coating is force-dried. Covestro offers coatings' manufacturers and their customers the benefits of high productivity and outstanding coating results, which is good news for everyone involved.

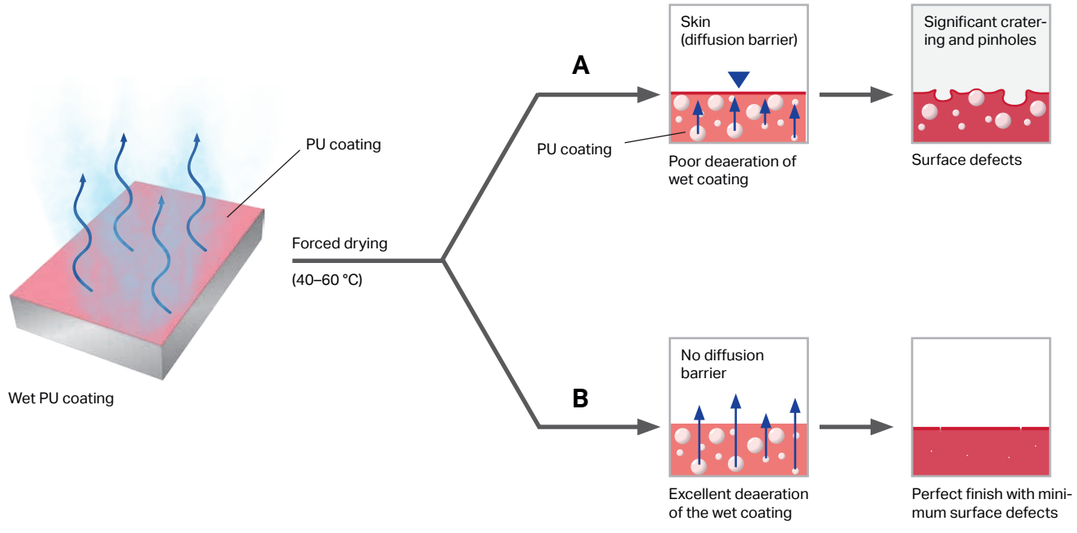


Fig. 27: Forced drying and finish quality
(A) Suboptimal formulation leads to surface defects caused by a diffusion barrier
(B) Waterborne crosslinking technology from Covestro produces excellent finish quality

Bayhydrol® A – the best tool for durable, fast-drying coatings

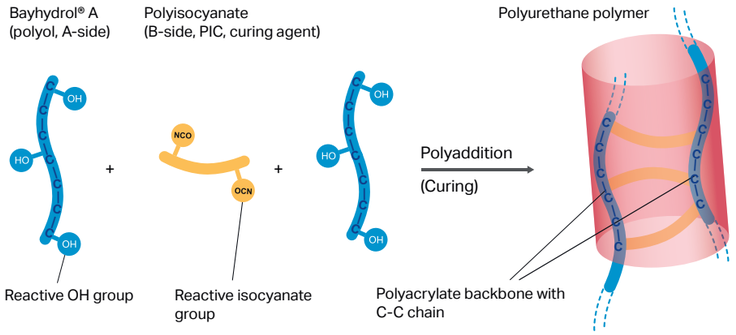


Fig. 28: Diagram showing crosslinking of Bayhydrol® A with a polyisocyanate

Bayhydrol® A polyacrylate (PAC) secondary dispersions are highly compatible with our Desmodur® and Bayhydur® polyisocyanate crosslinkers. These coating systems offer virtually unbeatable handling features and durability. They can also be combined with the high molecular weight Bayhydrol® A polyacrylate primary dispersions which provide accelerated physical drying performance. In combination with polyisocyanate crosslinkers, Bayhydrol® A polyacrylates play a vital role since the specific strengths of Bayhydrol® A come into play as a "durability network" forms in the crosslinked coating (Fig. 28). Due to the chemical properties of its unsaponifiable C-C chain, for example, it has excellent resistance to everything that comes into contact with a coating during its lifecycle. The network formed by Bayhydrol® A polyacrylates and our polyisocyanate hardeners is highly resistant to acids, alkaline solutions, solvents, food, and cleaning agents (Fig. 29). So it comes as no surprise that our raw materials are now included in many formulations specifically designed for extra durability, e.g. the anti-graffiti paint used for trains and buses. These coatings are so durable that even the most stubborn graffiti can be removed without trace. Our raw materials are usually involved when coatings for the transportation and logistics markets pass certification tests carried out by large transportation or rail companies.

How you benefit:

- Durability network formed by Bayhydrol® A in PU coatings
- Fast-drying application process

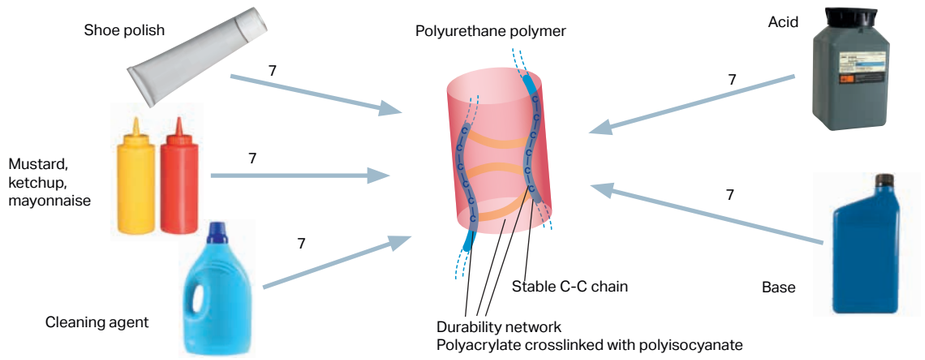


Fig. 29: Crosslinked polyurethanes made of Bayhydrol® A and polyisocyanate are extremely resistant to any type of attack.

Bayhydrol® U – the ideal tool for harmonious formulations

The sophisticated structure of Bayhydrol® U binders also makes them highly useful members of the polyol family. Our polymer designers combine polyesters or polycarbonates with special polyisocyanates to produce urethane-modified polyesters or polycarbonates that offer a number of advantages during formulation. They still have enough OH groups for subsequent crosslinking but contain no reactive NCO groups. They are easy to work with and give the coating top-class mechanical and visual properties. What more could you want? The special polyesters in Bayhydrol® U are designed for high compatibility and harmonize extremely well with other coating constituents, such as inorganic and organic pigments, fillers, etc. The forces they generate with these substances are either polar (H bridge) or disperse (van der Waals), and very balanced.

Bayhydrol® U binders ensure that the pigments and other solids in a formulation are very effectively wetted, encapsulated, and permanently integrated into the polymer network (Fig. 30). The good pigment wetting Bayhydrol® U delivers is evident in the extremely high durability and excellent gloss of the coating.

How you benefit:

- Highly versatile mediators in complex coating formulations
- Extremely durable and high-gloss coatings

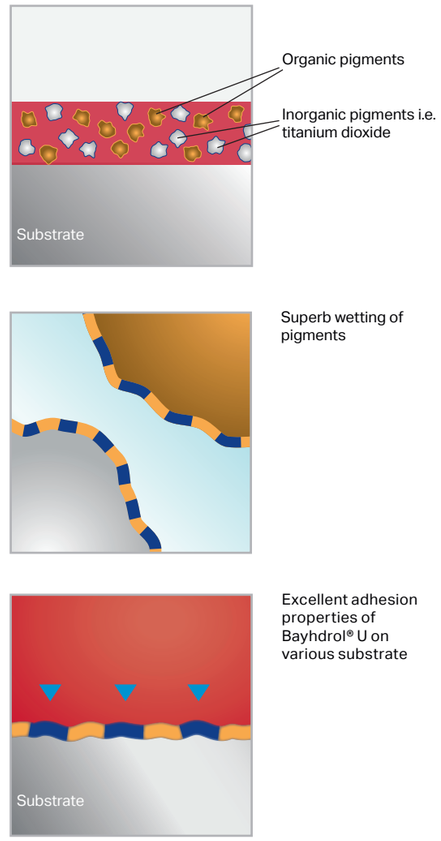


Fig. 30: Bayhydrol® U guarantees outstanding wetting of pigments in waterborne 2K PU systems.

Bayhydrol® U – the unbeatably flexible formulation tool

The reaction of Bayhydrol® U with the polyisocyanates in waterborne 2K systems produces something that is particularly appreciated in the world of coatings – a polyurethane film with special properties. Depending on the formulation, the solution can deliver a huge range of mechanical, tactile, and visual properties on a substrate surface. Anything is possible – from hard as bone to soft, from smooth and firm to super-soft touch, and from matt to high gloss with a wet look and fascinating highly reflective depth (Fig. 31).

Bayhydrol® U is a genuinely universal and flexible tool. One of the factors behind this unique versatility is the access our polymer designers have to the world's largest range of isocyanate products. Almost at will, they can modify and optimize basic polymers, such as polyesters and polycarbonates, by adding urethane functions to deliver exactly the coating features users want.

How you benefit:

Bayhydrol® U opens the door to an enormous variety of options for designing the desired features of waterborne PU systems. Of course, the issue of chemical and especially hydrolytic resistance arises in pure polyester dispersions. Ester groups, including those that form in polymer chains, undoubtedly tend to get hydrolyzed and saponify quite readily when attacked by acids or bases (Fig. 32). This applies both to the polyester dispersion supplied in aqueous form and to the coating when exposed to acid rain or other hydrolytic attack. However, Bayhydrol® U is an intelligent and effective answer to this potential problem.

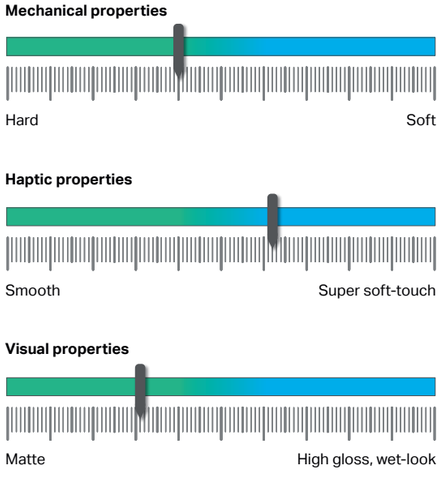


Fig. 31: Bayhydrol® U – a new world of freedom to formulate specific coating features

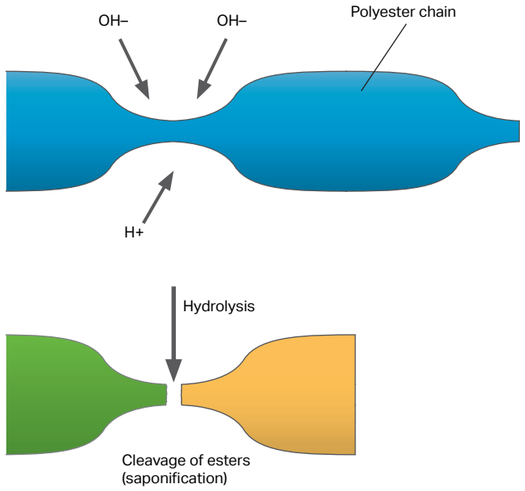


Fig. 32: Normal polyesters have a weakness that makes them vulnerable to attack by water in the presence of acids or alkalis.

Bayhydrol® U – the best tool to protect against hydrolysis

The basic problem with polyester dispersions is the polar emulsifying functions needed to stabilize the dispersion. Their polarity causes them to attract water as if by magic. They help the water molecules reach the groups in the polyester chain that are susceptible to attack by water, thus hydrolyzing the ester.

Bayhydrol® U uses the core-shell technology described before to effectively protect the polyester groups susceptible to hydrolytic attack. The polar emulsifier functions in the shell stand up like bristles in the direction of the water phase. Underneath, stable urethane chains prevent further water ingression into the core. This double hydrolysis barrier ensures optimal stabilization of the polyester polyurethane polyols in the dispersion and provides effective protection against hydrolytic attack. This is a somewhat complex solution, but it is very effective (Fig. 33, 34).

Our developers have taken a similar approach in adding a protective barrier for the polyester chains in the Bayhydrol® A polyester-polyacrylate hybrid-dispersions. In this case, hydrolytically stable polyacrylate chains in the shell of the dispersion particles protect the polyester chains in the interior, keeping them intact until the time comes.

How you benefit:

- Polyester stabilization ensured in the formulation and final coating
- Sophisticated protection system

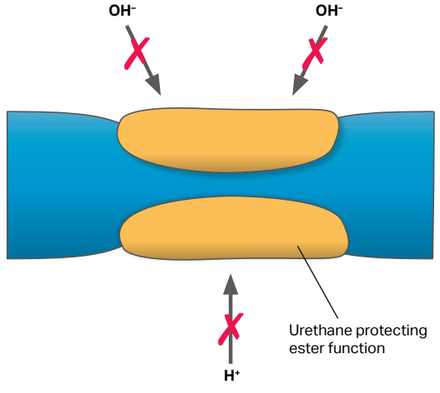


Fig. 33: Urethane groups in the Bayhydrol® U urethane-modified polyesters protect the vulnerable ester bond from hydrolytic attack.

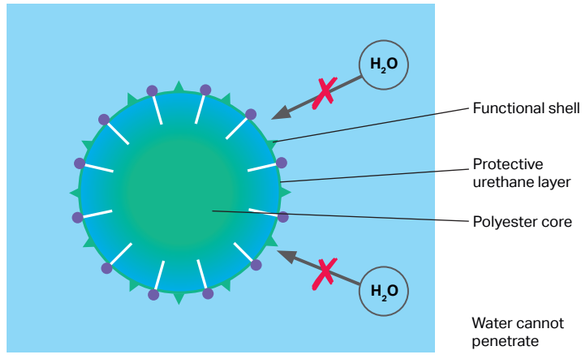


Fig. 34: Bayhydrol® U, the urethane-modified polyester polyol that can withstand hydrolytic attacks.

Waterborne 2K PU technology: VOC-compliant, superior and sustainable

Our environmentally friendly technology platform makes your technical and commercial success possible!

Our waterborne 2K PU raw materials are technically the equivalent of solventborne systems – and in many cases actually superior. The new generation of Bayhydrol®, Desmodur® and Bayhydur® products are efficient and fast in application and curing. And they enable the formulation of low-VOC coatings with excellent mechanical and chemical resistance properties.

Areas of application include:

- General industry
- Transportation and ACE (agricultural, construction and earthmoving equipment)
- Automotive and industrial plastics
- Wood
- Paper and printing
- Flooring

The products we develop offer you the following benefits:

- Eco-friendly
- Superior quality and performance
- Highly efficient coating processes

Abbreviations used in this brochure:

CAS:	Coatings Adhesives Specialties (Covestro Business Unit Polycarbonates)
DIS:	Dispersions
2K:	2-component
PU:	Polyurethane
PIC:	Polyisocyanate
VOC:	Volatile Organic Compounds

Fast-lane access to polyurethane innovations

At Covestro innovation is in our DNA. Ever since Otto Bayer discovered polyurethanes in 1937, we have been driving polyurethane innovations in coatings and adhesives as well as in other application areas. As our partner you enjoy fast-lane access to polyurethane innovations, and can help us in developing the next generation of polyurethanes to meet the industry's upcoming challenges and needs. What can we offer you?

- Powerful know-how on both established and new polyisocyanates, as well as on new polyurethane hybrid technologies.
- The prospect of new application technologies to enable efficient processes.
- More sustainable, biomass- or CO_2-based materials that do not sacrifice high performance.

Join us to shape the future!