

# Polyurea spray coatings

## The technology and latest developments

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### **Abstract**

Polyurea spray coatings technology is one of the new developments of the last 20 years. This technology combines fast curing, even at very low temperatures, and water insensitivity with exceptional mechanical properties, chemical resistance and durability. The development of new raw materials and improved spray equipment has made it possible to overcome the initial problems of this technology such as substrate wetting, intercoat adhesion and surface finish quality.

The latest development programs are focussing on the extension of the application fields through the introduction of MDI-prepolymers combining low viscosity with low NCO-content, resulting in slower reactivity and/or higher flexibility. Alternatively, prepolymers with higher NCO-content produce coatings with superior hardness.

This paper details the technology, eradicates the misconceptions and provides an update on the latest developments in the field of raw materials, formulation and application performance for polyurea spray.

### **0- Introduction**

Polyurea spray coatings technology is a recent development in the polyurethane coatings industry. The polyurethane chemistry is about 60 years old. Since the 1970s elastomeric urethane coatings have been available. The polyurea elastomer technology was introduced some 10 years later. Two main application areas are Reaction Injection Moulding (RIM) and sprayable coatings.

Polyurea coatings combine extreme application properties such as rapid cure, even at temperatures well below 0°C, and insensitivity to humidity, to exceptional physical properties such as high hardness, flexibility, tear strength, tensile strength, chemical and water resistance. The result is good weathering and abrasion resistance. The systems are 100 percent-solids, making them compliant with the strictest VOC regulations. Due to its specific curing profile and exceptional film properties, the polyurea spray coating technique developed into various areas, including corrosion protection, containment, membranes, linings and caulks.

## 1- Definition

The term 'polyurea' has been wrongly used in the past. The urethane coatings chemistry can be divided into three sub segments: i/ polyurethane coatings, ii/ polyurea coatings, and iii/ hybrid polyurethane/polyurea coatings, all linked to different isocyanate reactions (Figure 1). Each of these segments deals with systems, which can be aromatic, aliphatic, or a blend of both aromatic and aliphatic. Pigments, fillers, solvents and/or additives can be introduced to all of them.

i/ A purely **polyurethane** coating is the result of a reaction between an isocyanate component and a resin blend made with only hydroxyl-containing resins. The final coating film will contain no intentional urea groups. A polyurethane system will most probably contain one or more catalysts.

ii/ A **polyurea** coating is the result of a one-step reaction between an isocyanate component and a resin blend component. The isocyanate can be monomer based, a prepolymer, a polymer or a blend. For the prepolymer, amine- and/or hydroxyl-terminated resins can be used. On the other hand, the resin blend should only contain amine-terminated resins and/or chain extenders and not any hydroxyl reactive polymer components. All the polyurea coatings mentioned in the paper comply with this requirement.

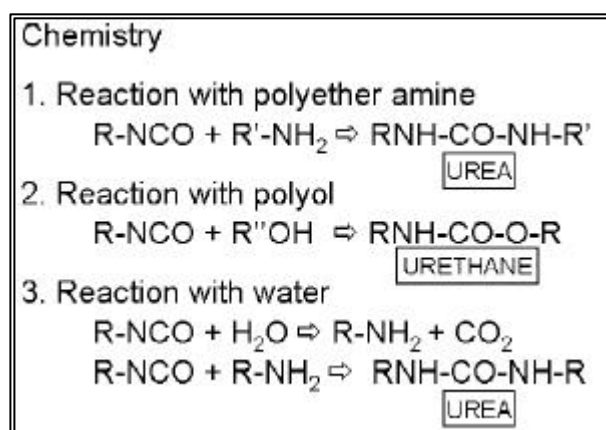


Figure 1: Isocyanate reactions.

iii/ A **polyurethane / polyurea hybrid** coating has a composition which is a combination of the above-mentioned two coating systems. The isocyanate component can be the same as for the "pure" polyurea systems. The resin blend is a blend of amine-terminated and hydroxyl-terminated polymer resins and/or chain extenders. The resin blend may also contain additives, or non-primary components. To bring the reactivity of the hydroxyl-containing resins to the same level of reactivity as the amine-terminated resins, the addition of one or more catalysts is necessary.

The **water**/isocyanate reaction also produces urea-groups at the end of the process. However, this reaction should not be considered a polyurea reaction since the mechanism is a two-step process, which is controlled by the much slower isocyanate/water reaction, and produces carbon dioxide.

## 2- The polyurethane landscape

The choice between the different polyurethane (PU) technologies is based upon different parameters (Figure 2). Polyurethane presents the best compromise between cost and quality, but is limited by the application performance. The polyurethane system is susceptible to blistering when the substrate contains more than 5% humidity. This is due to the competition between hydroxyl-polyols and water for the reaction with an isocyanate group. Humidity content of the environment and the application temperature are limiting factors for polyurethanes and other chemically reacting systems.

Hybrid systems already have a larger scope of application conditions, but the presence of catalysts in hybrids makes them more sensitive to humidity than “pure” polyurea systems. Moreover, because the catalysed polyol/isocyanate reaction behaves differently from the amine/isocyanate reaction to changing application temperatures, the system becomes less robust.

Polyurea can be used in extreme conditions. When it is used on substrates almost saturated with water, polyurea will not provoke blistering nor will blistering occur when the air contains high amounts of humidity. Even at very low temperatures (as low as minus 20°C) the polyurea coating will still cure. Polyurea coatings combine high flexibility with hardness. They are the most suitable coatings when the following is required:

- high curing speed,
- application under high humidity and/or at low temperatures,
- extreme abrasion resistance,
- impermeable membranes,
- high thickness build up,
- chemical resistance.

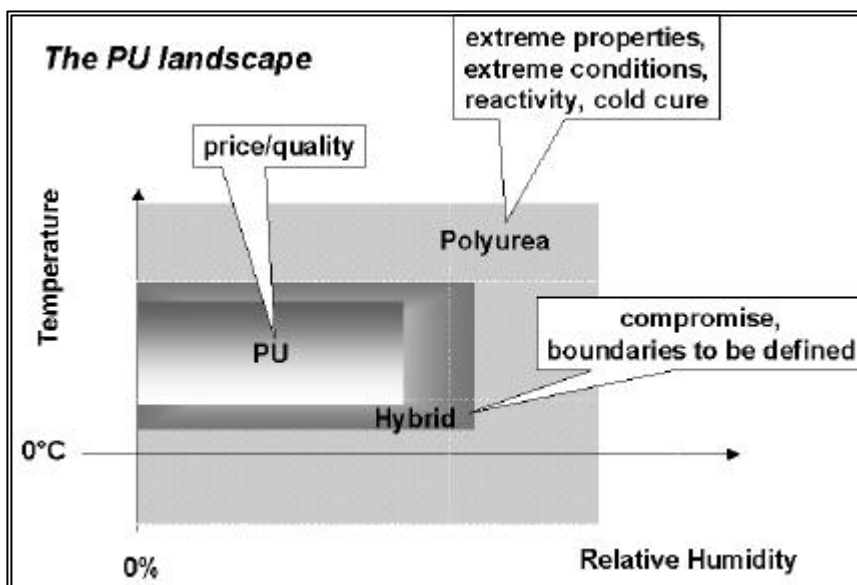


Figure 2: Applicability of the different PU chemistries

### 3- The Applications for Polyurea Coatings

To be able to define the right applications, a good understanding of the properties of polyurea spray coatings is needed. Table 1 provides a general overview of the physical and chemical properties that can be expected of polyurea spray products. Polyurea systems are known to be very tough. They combine high elasticity with high surface hardness, resulting in very good abrasion resistance.

Table1: Typical physical properties of polyurea and their specifications

Property	Unit	Specification	Results
<b>Reactivity</b>			
<b>Gel time</b>	seconds	Manual	1 - 20
<b>Tack free time</b>	seconds	Manual	3 - 120
<b>Physical Properties</b>			
<b>Shore A</b>	-	DIN 53505	60 – 100
<b>Shore D</b>	-	DIN 53505	25 – 75
<b>Tensile</b>	N/mm <sup>2</sup>	DIN 53504	10 - 30
<b>Elongation</b>	%	DIN 53504	20 - 800
<b>Angle Tear</b>	N/mm	DIN 53515	50 - 125
<b>Trouser Tear</b>	N/mm	DIN 53507	20 - 60
<b>Abrasion</b>	mg	ASTM D 4060-90	150 - 500
<b>Cold Impact Resistance</b>	kJ/m <sup>2</sup>	ISO 180	50 – 100 at -20°C

The market development started in the US, followed by Asia, with a very strong growth during the second half of the 1990s. In a first stage, polyurea was used as a protective layer over polyurethane insulation foam for roofing applications. In Europe, the polyurea spray coatings market only started to develop in the last few years.

The broad window of application conditions, with a high tolerance for humidity, both from the environment and from the substrate, and temperature, makes polyurea a very suitable coating for concrete in construction applications like roof repair, containment liners, membranes, car park decks, bridges and offshore. The high abrasion resistance leads to its application in liners for truck, bulk transport wagons, freight ships and conveyor belts. Table 2 represents an overview of the application fields where polyurea is chosen based on one or more of the unique application and/or film properties.

Table 2: Polyurea application fields

- |  |
|--|
| <ul style="list-style-type: none"> <li>• Roof Coatings</li> <li>• Flat Roof Repair</li> <li>• Pipe Protection</li> <li>• Inner pipe repair</li> <li>• Secondary containment</li> <li>• Tank coatings</li> <li>• Truck bed liners</li> <li>• Freight ship liners</li> <li>• Bulk transport wagon liners</li> <li>• Conveyer belts</li> <li>• Car park decks</li> <li>• Bridges</li> <li>• Offshore</li> </ul> |
|--|

## 4- Raw materials

A polyurea spray coating formulation consists of five different elements:

1. isocyanate component;
2. (reactive) diluent;
3. polyetheramines;
4. chain extenders;
5. additives and pigments.

### 4.1- On the isocyanate side:

#### 1. Isocyanate

Since the most commonly used isocyanate is diphenylmethane diisocyanate (MDI), this paper focuses on MDI-based products. Aliphatic systems can be used where UV-stability is an issue.

Standard polyurea spray coatings use MDI-prepolymers with a NCO-content of 15% to 16%. In this NCO-range, a good compromise between viscosity of the material and the reactivity of the system is obtained. Lower NCO-prepolymers have a higher viscosity, but give higher elasticity and slower reactivity. Higher NCO-prepolymers are lower in viscosity, which is good for an effective mix of the two components. However, they become much more reactive, with the risk of building up more internal stress. Higher NCO-prepolymers will be used if higher surface hardness is needed. More details about the new generation of products can be found in the chapter on the latest developments. Table 3 provides an overview of the main properties of the MDI-prepolymers used for polyurea spray coatings in Europe.

Table 3: Properties of the MDI-prepolymers used in Europe for Polyurea Spray Coatings

	% NCO	2',4-MDI content	Viscosity, Typical value at 20°C, mPa.s
Iso 1	10.2	Low	2830
Iso 2	15.0	Low	750
Iso 3	15.5	High	850
Iso 4	15.0	High	1750
Iso 5	20.5	Low	1490
Iso 6	19.0	Low	1660

#### 2. Diluent

Propylene carbonate is a reactive diluent for polyurea. Propylene carbonate has a high flash point, low toxicity and should not be considered as a volatile organic compound (VOC)

The main advantages of using propylene carbonate are:

- improved shelf life of the isocyanate-prepolymer;
- a compatibiliser for the mixing of the two components in the mixing chamber of the spray gun;
- a viscosity reducer for isocyanate-prepolymers;
- improved levelling of the applied film.

Propylene carbonate reacts with an amine to give a carbamate structure containing a secondary hydroxyl group. Because of the quick reaction between isocyanate and amine, the secondary hydroxyl does not get a chance to react with an isocyanate group. The propylene carbonate molecule should, therefore, be considered as a mono-functional molecule (Figure 4).

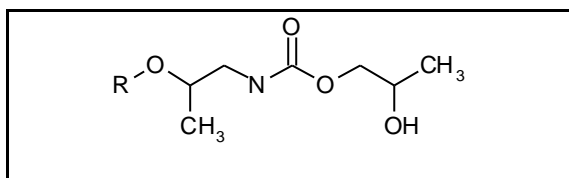


Figure 4: Carbamate Structure

In applications where contact with water cannot be avoided, the use of propylene carbonate should also be limited since propylene carbonate is completely miscible with water and unreacted propylene carbonate could be extracted, increasing the water permeability of the film.

Other solvents or viscosity reducers can be used if they are compatible with the isocyanate component. They may be considered as a VOC. However, they will increase the shrinkage effect.

#### 4.2- On the resin blend or amine blend side:

The amine blend used in polyurea spray coatings is a mixture of polyetheramines and chain extenders.

##### 1. Polyetheramines

The main component of the resin blend is a mixture of amine terminated ethylene oxide and/or propylene oxide polyether with molecular weights varying from 200 to 5000 g/mole. The primary amine groups provide a very fast and reliable reaction with the NCO-groups of the isocyanate component. Table 4 represents the properties of the polyetheramines commonly used in polyurea.

Table 4: Polyetheramines

	Molecular Weight	Functionality	Viscosity, Typical value at 25°C, mPa.s
Amine 1	5000	3	820
Amine 2	2000	2	250
Amine 3	400	3	70
Amine 4	400	2	21
Amine 5	200	2	9

## 2. Chain extenders

Diethyl-toluenediamine or DETDA is the standard chain extender used in aromatic polyurea spray coatings. DETDA contributes to the hard block and improves the heat resistance of the cured film. It is the most reactive amine in the resin blend but, because of the phase separation during the curing, it controls the reaction mechanism and makes it possible to spray a polyurea film.

Other chain extenders like dimethylthio-toluenediamine (DMTDA), N,N'-di(sec.butyl)-amino-biphenyl methane (DBMDA) or 4,4'-methylenebis-(3-chloro, 2,6-diethyl)-aniline (MCDEA) slow down the reaction significantly. Table 5 lists various chain extenders and their characteristics.

Table 5: Chain extenders

	Molecular Weight	Functionality	Viscosity, Typical value, mPa.s
Chain Extender 1	178	2	280 at 20°C
Chain Extender 2	214	2	691 at 20°C
Chain Extender 3	310	2	8 at 38°C
Chain Extender 4	379	2	Solid at 20°C

Slowing down the reaction also means that the competition with the water reaction becomes more important and precautions need to be taken.

## 3. Additives

Depending on the application, additives, pigments and/or fillers are introduced to the formulation. The addition of pigment and/or fillers is limited because the viscosity of the two components at the application temperature has to be kept under control. Higher amounts of fillers and reinforcement fillers can be added to the system as a third component.

## 5- Product application specifics

The most important element of handling polyurea coatings is the mixing. Good mixing will be obtained in a suitable mixing module by impingement with mechanical purge. Operational pressure and temperature of the products will also help to optimise the mixing efficiency.

Because of the high cure speed of polyurea and the short mixing time, the products are mixed by impingement at high pressure. Certainly for field applications, it is preferable to formulate the products on a fixed 1:1 volume-mixing ratio. The pressure used in the field will vary between 150 and 250 bar. The viscosity of the products at application temperature ideally needs to be lower than 100 mPa.s and the viscosity of the two components needs to be of the same level. Figure 5 shows the viscosity of the MDI-prepolymers at different temperatures. The properties of these prepolymers can be found in table 3.

The viscosity of the resin blend at 25°C is of approximately 900 mPa.s, dropping below 100 mPa.s at application temperature.

Experiments have proven that polyurea films produced at 65°C, 70°C and 80°C have different properties and that these improve with increasing temperature. The new spray equipment allows different temperature settings for the two components, ensuring an optimum mixing in the spray head.

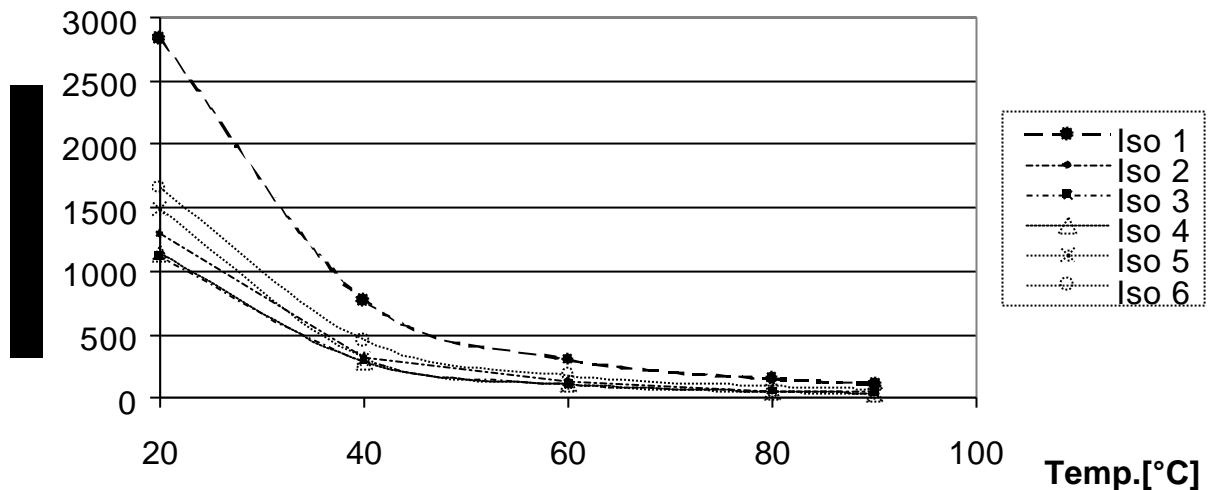


Figure 5: Effect of temperature on the viscosity of the isocyanates

The spraying equipment has improved significantly. New features are:

- the separate temperature setting for both components;
- easier variable ratio settings;
- easy output control;
- easy monitoring of application parameters.

The index of a polyurea system is typically kept at a slight over-index of the isocyanate in the range of 1.05-1.10. As the isocyanate-group reacts to humidity, the excess isocyanate compensates for the 'loss' of isocyanate-groups during storage and/or application. The film properties for 1:1 volume ratio sprayed system were measured for an index variation between 0.90 and 1.15. The test results indicate that the film performs best at an index of 1.05 and higher. Below an index of 1.05 the results can vary significantly and become unpredictable, even for an index shift of 0.2.



## **6- Misconception/past problems**

The application of polyurea has known some problems during the initial start up phase, which are at the origin of the misconception still existing about polyurea technology. These problems can be attributed partly to the lack of experience at the time of the introduction of this technology, partly to the lack of adequate application equipment, and partly to the fact that this new technology could not be applied in the same way as the existing coating systems.

When polyurea was first presented, the initial misunderstanding started, as it simply looked almost too easy to apply: Polyurea is very fast, the coating can be put in service immediately after the application and the final properties of the coating are obtained only a few hours afterwards; it is not water or temperature sensitive, and is easy to formulate and produce. Below is a list of common concerns resulting from unsuccessful trials and their solutions:

### **1. The system is too fast, intercoat adhesion is therefore bad.**

The first systems on the market were indeed very fast with a gel time of maximum 2 seconds. Lab tests with times between coats of several weeks have shown that intercoat adhesion is very good, also with these very fast systems. When problems occur with intercoat adhesion, most of the time they can be related back to problems with the raw materials, the manufacturing of the systems or the spray equipment. Spray equipment problems or a disturbance of the feeding of one or both components towards the mixing module can cause poor mixing. Adapting the machine settings of the spray can solve this.

### **2. Surface quality is very poor.**

Due to the high reactivity of the systems, the surface quality of the sprayed film was initially very poor. The fine-tuning of the spraying equipment was a first improvement for solving that problem. The use of non-VOC, reactive diluents and the development of new MDI-prepolymers with higher 2,4'-isomer content resulted in perfect surface quality without compromising on working time.

### **3. Too fast build up of layer thickness.**

The initial applications of polyurea spray coatings resulted in high layer thickness. Further development of the spray equipment provided access to applications where only a few hundred microns were needed. Industrial applications looking for 100 to 150 microns will be available in the near future.

### **4. Substrate wetting is very poor.**

Again, this was a problem linked to the development phase of polyurea with the use of extremely fast spray systems. Development programs focusing on adhesion on concrete, with polyurea systems presenting gel times of 3 to 4 seconds, resulted in cohesive adhesion failure in the concrete. In practice, to limit the risks under variable field conditions, a multilayer system is applied, made of a primer and a topcoat.

## **5. Cost of the system (raw material cost versus project cost and product life cycle).**

“Pure” polyurea systems are more expensive, when considering the raw materials cost alone, but can be applied in areas where any other systems will fail. While estimating the capital for a project, polyurea is even more competitive, when both the processing time and the waiting period are included, before putting the coated substrate back in service.

## **6. Equipment investment.**

The initial investment in equipment is rather costly. As highlighted above, the success of the project is very equipment and applicator dependent and we believe that the high entry barrier can only guarantee quality services from specialised and skilled operators.

## **7. Experienced applicators.**

The experience and motivation of well-trained applicator teams is as important as the spray equipment, the choice of raw materials, the adequate personal protective equipment and the formulation of a suitable system.

# **7- Latest developments**

## **1. Influence of the functionality of the system.**

Polyurea coatings are known for their chemical resistance and toughness. For some application areas like primary containment and inside oil-pipe coatings, a high chemical resistance is needed. A way to improve chemical resistance is by increasing the crosslink density. The following conclusion results from one of our experimental programs:

### **With increasing functionality of the polyurea system:**

- the viscosity of prepolymer increases and the mixing becomes less efficient;
- the gel and tack free time decreases and the surface quality becomes very poor. At prepolymer functionalities above 2.5 the systems cannot be processed anymore;
- the physical properties improve until a functionality of about 2.5 is reached; above 2.5, the physical properties decrease with the increasing functionality of the polyurea system;
- The flexibility of the system decreases;
- The abrasion resistance decreases;
- The chemical resistance decreases.

The expected improvements of physical and chemical resistance properties are not obtained because of the loss of crosslink efficiency with increasing functionality of the polyurea system. In a typical formulation with a gel time of 2 to 4 seconds, a functionality of 2.2 or below should be taken.

Table 6: Film properties as a function of the functionality of the system

<b>System</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
Functionality of the MDI isocyanate	2.0	2.2	2.4	2.6	2.8	2.0	2.2	2.4	2.6	2.8
Functionality of the resin blend	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1
Gel time (seconds)	4	3	4	2	3	4	4	2	<1	<1
Tack free Time (seconds)	7	8	9	6	5	5	8	5	2	2
Surface quality	+	+	+	+/-	-	+	+	+/-	-	-
Tear (N/mm)	50.5	50.0	37.5	43.7	41.1	47.6	39.6	32.9	29.8	34.5
Tensile (N/mm <sup>2</sup> )	14.6	15.2	10.5	12.5	11.5	13.5	15.0	9.3	7.9	8.9
Elongation (%)	315	225	192	136	110	285	182	150	91	68
Shore A	93	97	95	95	97	92	95	96	95	94
Shore D	44	51	45	49	50	46	48	45	45	45

## 2. 2,4'-isomer content of the prepolymer.

The higher sterical hindrance of the 2,4'-isomer has an effect on the reaction time. The longer gel time and open time result in:

- less critical application conditions setting;
- better substrate wetting;
- superior adhesion on a variety of substrates;
- improved levelling behaviour resulting in a better surface quality, and
- enhanced physical properties (Table 7).

Table 7: Influence of the 2,4'-content

System	11	12	13	14	15*
2,4' content of the MDI	25	30	40	50	50
Gel time (seconds)	3	4	5	6	6
Tack free Time (seconds)	6	6	7	8	8
Surface quality	-	+/-	+/-	+	+
Tear (N/mm)	9.2	9.3	8.2	7.4	10.3
Tensile (N/mm <sup>2</sup> )	95	85	62	63	81
Shore A	97	99	97	93	96
Shore D	54	55	52	52	53

\* Slightly higher functionality

### 3. Fast property development.

Polyurea coatings are mainly used in applications where fast curing is needed. When used as a corrosion protection on pipes, storage of high volumes of coated pipes is difficult and, because of the weight, the coating needs to be fully cured before being transported. Polyurea used for pier protection needs to be fully cured before high tide.

A polyurea coating builds up high internal stress during the initial phase of the curing due to the high reactivity. The stress has a negative influence on the development of the physical properties of the freshly applied polyurea film. By modifying the MDI-prepolymer, it is possible to improve the relaxation of the coating and thereby reduce the waiting period before the applied coating can be put in service. The improved relaxation results in:

- less stress build up;
- no deformation;
- improved adhesion, and
- faster physical properties development.

For this study the cold impact resistance was tested, along with standard physical properties (table 8a). Cold impact testing within the hour after application proved to be a very reliable measurement of property development as a function of time. The goal was to develop the properties faster without compromising the end properties as shown in table 8b.

Table 8a: Cold impact resistance at -20°C (kJ/m<sup>2</sup>)

Time in days*	System		
	16	17	18
0	1.3	1.9	6.4
1	10.2	22.7	52.7
4	16.8	65.9	60.5
7	15.7	63.7	59.9
14	76.0	68.6	61.1

\* Time between application and testing

Table 8b: Physical Properties after 14 days

	System		
	16	17	18
Aspect	+/-	+	+
Cold impact resistance at -20°C (kJ/m <sup>2</sup> )	76.0	68.6	61.1
Tear (N/mm)	61.0	59.0	59.0
Tensile (N/mm <sup>2</sup> )	20.0	19.1	19.0
Elongation (%)	401	373	383
Taber abrasion, H18, 1kg, 1000 cycles (mg weight loss)	299	420	270

#### 4. Flexibility and/or hardness.

Standard polyurea spray coatings are formulated with a MDI-prepolymer of approx. 15% NCO on one side and a blend of Polyetheramines and DETDA on the other side. For field applications, it is preferable to stick to an index of about 1.05-1.10 for product consistency and a 1:1 volume-mixing ratio for practical reasons. However, these limitations always result in film properties with comparable physical properties. Slight modifications could be made by adding secondary or sterically hindered diamines, or by introducing additives like fillers, diluents or plasticizer.

Polyurea coatings combine surface hardness with flexibility and hence result in tough coatings with good abrasion resistance. This combination of properties is the result of the soft block-hard block balance in the system (table 9).

Higher elasticity values up to 1000% can be obtained by lowering the hard block content. This can be done by:

- using lower NCO-containing prepolymers;
- changing the mixing ratio.

The use of lower NCO-prepolymers is limited by the viscosity increase. The mixing ratio variations will be limited by the mixing efficiency decrease at extreme ratios.

Harder coatings can be formulated in line with the physical property modifications for more flexibility. With higher NCO-prepolymers, additional hardblock can be built in, resulting in a higher surface hardness. Those high NCO-prepolymers are lower in viscosity, improving the mixing.

However, the higher reactivity results in:

- higher internal stress, making those systems very brittle during the first 24 hours after the application;
- shorter gel times resulting in a limited flow and possibly a poorer surface finish.

Table 9: High flexibility/ high hardness systems

<b>System</b>	<b>19</b>	<b>20</b>	<b>Reference</b>	<b>21*</b>	<b>22</b>
MDI Isocyanate	Iso 1	Iso 1	Iso 2	Iso 5	Iso 6
Gel time (seconds)	7	13	3	9	1
Tack free time (seconds)	21	37	5	22	2
Surface quality	+	+	+	+	-
Tensile (N/mm <sup>2</sup> )	11.7	9.3	20.6	21.3	26.3
Tear (N/mm)	53	41	63	113	124
Elongation (%)	615	750	393	273	241
Shore A	78	69	95	99	97
Shore D	26	20	46	67	66
Taber abrasion, H18, 1kg, 1000 cycles (mg weight loss)	386	430	356	226	139

\* Slow formulation for improved flow

## 5. Primers.

The polyurea technology provides the opportunity to produce durable and high-performance coating films very rapidly, even in difficult conditions. However, experienced applicators have reported encountering undesirable side effects varying from pinholes even to delamination. In practice, the risks of failure can be limited by the use of a system consisting of a suitable primer/sealer combined with a polyurea coating.

A general study was performed with an acrylic emulsion, a high solids epoxy, an emulsifiable MDI and a two component PU system on dry and wet concrete, steel, plywood and fiber cement board. Table 10 presents an overview of the obtained results.

Table 10: Adhesion on different primers (N/mm<sup>2</sup>)

	<b>No primer</b>	<b>Acrylic</b>	<b>Epoxy</b>	<b>Emulsifiable MDI</b>	<b>2-Component Polyurethane</b>
<b>Dry Concrete</b>	2.1	2.6/3.4*	3.4/3.4	4.1/4.0	3.8/4.3
<b>Wet Concrete</b>	4.0	2.2/2.9	1.4/0.1	1.7/1.7	1.6/1.9
<b>Steel</b>	6.9	7.4/6.9	6.9/7.4	5.5/5.5	6.9/7.6
<b>Plywood</b>	3.3	2.8/2.9	3.2/3.3	2.9/2.8	4.3/5.7
<b>Fiber Cement Board</b>	1.9	1.2/1.0	1.5/1.2	1.4/2.1	1.7/1.4

\* Time between primer application and polyurea spraying 2hours/24 hours

The following conclusions can be made:

- on dry concrete all primers generated improved adhesion results;
- on wet concrete the primers produced inferior adhesion results with the acrylic emulsion performing better than the other primers;
- on steel the adhesion values with or without primer are of the same order of magnitude (cohesive failure of the epoxy adhesive between polyurea film and the pull-off adhesive test's dolly);
- also on plywood the adhesion with or without primer is similar;
- on fiber cement board all primers, except for the emulsifiable MDI, perform less effectively.

## 6. Adhesion on concrete.

The influence of temperature and humidity content on the adhesion performance on concrete is summed up in table 11. The following conclusions can be made:

- for all systems applied at 23°C, a cohesive substrate failure is observed;
- without primer, the adhesion is insufficient at 8°C. A primer is recommended;
- at 8°C epoxy primer 1 performs better than epoxy primer 2.

Table 11: Adhesion on concrete (N/mm<sup>2</sup>)

	Dry		Wet	
	8° C	23° C	8° C	23° C
<b>No primer</b>	0.75	> 4.45*	1.30	> 4.45
<b>Epoxy primer 1</b>	> 4.45	> 4.45	> 4.45	> 4.45
<b>Epoxy primer 2</b>	2.70	> 4.45	1.75	> 4.45

\* cohesive failure of the concrete

## 8- Conclusions

Polyurea holds a unique position in the coatings industry as well as in the polyurethane coatings industry. The new developments both for the raw material and the application equipment have enlarged the application portfolio considerably. The important advantages of polyurea spray coatings are their reactivity, water insensitivity, low temperature curing and their unique physical and chemical properties.

Despite its raw material cost, higher than for most other systems, polyurea can still be the most cost-effective system available at present for consequent and specific projects.

Polyurea coatings will not replace all other systems, but have their place in high growth niche coatings markets. If one or more of the unique performance properties are met, polyurea can be the best or even the only suitable solution available depending on end-properties required or application conditions.

The ultimate success of a polyurea system for a project will always be dependent on the involvement of the four key players, namely the raw material supplier, the equipment manufacturer, the systems house and the applicator.

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